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LESSONS IN PHARMACY

BY

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DEAN OF NORTHWESTERN UNIVERSITY SCHOOL OF PHARMACY

A COURSE OF STUDY FOR HOME STUDENTS

CHICAGO
INTERSTATE SCHOOL OF CORRESPONDENCE

AFFILIATED WITH NORTHWESTERN UNIVERSITY, EVANSTON—CHICAGO

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PUBLISHER'S NOTE

A Correspondence Course in Pharmacy was written expressly for the home student who wishes to prepare for the examinations given by state boards of pharmacy or for more extended courses in technical schools, such as the School of Pharmacy of Northwestern University.

Dr. Oscar Oldberg, the author of the course, was born in Sweden in 1846 and educated in the Gymnasium at Gefle. He became a licensed practitioner in pharmacy, and since coming to the United States has risen rapidly into prominence. Since the establishment of its School of Pharmacy by Northwestern University in 1886, he has been professor of pharmacy in that institution and dean of its faculty. During this time he has been an editor of pharmaceutical journals and is the author of a number of text-books on pharmacy, chemistry, metrology and related subjects. In 1880 he became a member of the committee of revision of the United States Pharmacopoeia, and has been in active connection with the committee ever since.

Not only have Doctor Oldberg's training and experience fitted him to write a course of study which could be followed by students at home, but he has himself had wide experience in directing students under similar conditions. Accordingly, this course may be relied upon to be as simple as conditions warrant, and so practical that no well prepared student need fear his ability to carry it through.

The papers of the student will be corrected by teachers experienced in correspondence work who have been selected by the School under the approval of Doctor Oldberg. The papers written by the students, bearing the careful criticisms and suggestions of the teachers, will be returned in all cases to the former, accompanied by extended and accurate printed answers, which will enable the student to compare his own work with the perfect standard.

INTERSTATE SCHOOL OF CORRESPONDENCE.

Chicago, April, 1906.

A CORRESPONDENCE COURSE IN PHARMACY.

LESSON ONE.

To the Student:

Read this introductory letter carefully before you begin your study.

This course is the result of long years of classroom experience, in which the author and his students were in daily conversation. To adapt this instruction to the needs of the home student has been a pleasing task that, it is hoped, has been successfully accomplished.

Though a large number of different subjects are treated in the course, it is a unit. All the parts are closely related and are integral portions of pharmacy. The course is divided into chapters, and the chapters into paragraphs numbered consecutively from the first lesson to the last. The entire work is thus easily available for cross reference. The chapters are grouped into lessons of approximately equal length and difficulty. The early lessons are simple and consist largely of definitions and general principles. Later lessons may be more difficult, but it is thought that the logical arrangement and the gradual development of your knowledge will enable you to handle the more technical subjects with ease.

Only the first two lessons are sent you at this time. When you have mastered the first lesson, write your recitation paper and mail it to us in the manner and form described in the *Student's Guide* which was sent you with this lesson. Then, without waiting for returns from us, proceed at once upon the study of your second lesson. More explicit directions are given in the *Student's Guide.* If this plan is followed intelligently you will always have work on hand and will not be delayed by the passage of your papers through the mails.

Your papers will be read with care by an expert instructor. His suggestions, directions and criticisms will be plainly marked in red ink on your recitation paper and returned to you for further consideration.

When the course has been completed in a satisfactory manner, your diploma will be sent to you and at the same time you will be given the entire course handsomely bound. This you will always find a valuable reference work.

If, in the preparation of all your lessons, you work as directed, you will find when you complete your course that you are thoroughly versed in the subjects taught. We wish you to obtain the greatest possible benefit and are sure that you can do so only by observing the following general directions:

1. Be regular, systematic and persistent in your work. Select some stated time for your daily study and let nothing interfere with it.

2. If possible, devote at least a full hour to study each day. While you can accomplish something in less time, yet you will find that your thought will be much clearer if you can work continuously for at least that period.

3. The best plan is to begin by reading the first chapter through to the end. This gives you a general idea of what you are expected to learn. Then proceed to more careful study. Do not memorize the definitions, but get the thought so thoroughly that you can make a definition for yourself.

4. You will meet many new words and not a few that are difficult. Use whatever reference books are at hand. The *International Dictionary* contains most of the words used in the course, but some of them are so technical that they are not to be found there. However, the number of words not to be found in the *Dictionary* is so small that you can afford to look for everything of whose meaning and pronunciation you are not certain. Encyclopedia articles on all the subjects mentioned are helpful, especially those of the more recent publications. It is always worth your while to watch for articles on topics kindred to your lesson in newspapers and magazines. The habit of looking for such things will always be valuable to you.

5. Study broadly. Try to see all sides of every subject. Have ideas of your own and do not follow slavishly the words of your text.

6. Put *yourself* into your work. Spend the last part of every study hour in carefully thinking over what you have done. Close your book and try to recall all that you have read. If you persist in this exercise you will be surprised at the increase in your power to hold what you have read.

7. Take time to do your work well. Be patient and thorough,

and then be satisfied with small progress at first. As you get further into the subject you will learn more rapidly.

8. These general directions are worth following throughout the course, and from time to time, as you need it, specific advice will be given.

9. Do not hesitate to write us on any subject connected with the course which puzzles you. Your letters will always be answered promptly and with pleasure by us. Address, always,

Interstate School of Correspondence,
378–388 Wabash Avenue, Chicago, Ill.

I

Introductory

1. **Medicines** are substances employed to relieve, counteract, remove or prevent disease or pain, or to defend or promote health.

2. **Poisons** are substances which, when taken into the body in small quantities, are liable to do serious or fatal injury.

The meaning of the term poison cannot be sharply defined, because some substances may be beneficial or wholesome under certain conditions, or when used in relatively small amounts, but decidedly hurtful or even fatal to life under other conditions or in greater quantities.

3. Since it is evident that disease and pain are associated with abnormal states of the parts of the body and their functions, substances that greatly affect those parts and functions are employed as medicines.

The most valuable medicines accordingly include substances which are poisons when abused or ignorantly used, and it is mainly for this reason that all civilized nations prohibit the practice of medicine by persons not possessing a thorough knowledge of the human body and the disorders to which it is subject, and of the nature and effects of medicines. For the same reason, also, the laws of all civilized countries forbid the practice of pharmacy by persons not specially trained for the safe performance of its duties.

4. **Pharmacy** (from Greek *pharmakon*, medicine) is the scientific-technical business of selecting, preparing and dispensing medicines.

The selection of medicinal substances requires the ability to identify them and to determine their quality, purity and strength. Properly to prepare and dispense medicines requires an intimate knowledge of their composition and properties and of the laws of chemistry and pharmacy, together with ample practical experience and skill.

5. **Materia Pharmaceutica.** The materials out of which medicines are made are derived from the mineral, the vegetable and the animal kingdom. They include not only substances of decided medicinal activity, but many materials which are valuable chiefly because they are quite without any medicinal effect of their own.

Hydrocyanic acid, strychnine, morphine and numerous other deadly poisons are medicines of great value; but water, sugar, lard, wax, starch, gelatin, and other things used as diluents or solvents, or to give body and form to the preparations into whose composition they enter, are also important *pharmaceutical materials.*

6. **Crude Drugs** are medicines, and other pharmaceutical materials consisting of unchanged or but little altered or prepared natural products, such as minerals, roots and other plant organs, gums, resins, etc. But the "crude drugs" also include many products manufactured on a large scale for various industrial purposes, such as lime, the commercial or raw chemicals, catechu, tar, alcohol, etc.

7. **The Inorganic or Mineral Drugs** are comparatively few. Among them are chalk, marble, lime, alum, copperas, blue vitriol, litharge, sugar of lead, sulphur, black sulphide

of antimony, black oxide of manganese, mercury, zinc, iron, bismuth, borax, saltpeter, the commercial impure acids and alkalies.

When these crude inorganic substances have been purified or converted into preparations suitable for immediate medicinal use, they are no longer called *drugs*, but *chemicals* and *pharmaceutical preparations*.

8. **The Vegetable Drugs** are numerous and the most important of all crude drugs. They include not only whole plants and parts or organs of plants, as herbs, leaves, flowering tops, twigs, roots, underground stems, barks, fruits and seeds, but also plant exudations such as gums, resins, gum-resins, oleoresins, and such manufactured products as opium, catechu, kino, aloes, starch, sugar, olive oil, castor oil, linseed oil, oil of turpentine, cottonseed oil, and many other commercial commodities.

About two or three hundred plant drugs are important enough to be described in pharmacopœias.

9. **Animal Drugs** were formerly more common than now. Those at present employed include cantharis (Spanish fly), musk, castor, ox-gall, cod-liver oil, lard, suet, wax and honey.

Pepsin, pancreatin, dried animal glands, and extracts prepared from animal organs, glands and tissues, are manufactured products which may be more properly called pharmaceutical preparations, although the pharmacist who dispenses these medicines is rarely the preparer of them.

Not a score of animal drugs are medicinally important.

10. **Medicinal Chemicals** are unmixed single substances of definite chemical structure, such as single elements and chemical compounds in a pure state. Familiar examples are sulphur, iodine, calomel, quinine, carbolic acid, chloroform, potassium bromide, chloride of iron, glycerin, cream of tartar, Epsom salt, nitrate of silver.

Simple water-solutions of chemical compounds are frequently called chemicals.

11. **Inorganic Chemicals** are those prepared from materials derived from the mineral kingdom. They are for the most part compounds of potassium, sodium, lithium, calcium, magnesium, aluminum, iron, silver, gold, copper, lead, zinc, bismuth and other metals, and the compounds formed by the non-metallic elements, chlorine, bromine, iodine, sulphur, phosphorus, arsenic and antimony with one another, and with oxygen and hydrogen.

About three hundred inorganic chemicals are sufficiently important to be mentioned in the pharmacopœias.

12. **Organic Chemicals** are those prepared from materials derived from plants or animals, or from coal oil and coal tar, and from artificially produced hydrocarbons (compounds of carbon and hydrogen) and their derivatives. The organic chemicals are composed chiefly of the elements carbon, hydrogen and oxygen, and frequently nitrogen.

About sixty or seventy organic chemical substances are mentioned in the pharmacopœias.

13. But many chemicals are of such composition that they belong to both inorganic and organic chemistry. Such are, for instance, the salts formed by organic acids with the inorganic bases, and by the inorganic acids with organic bases.

Tartaric acid is obtained from grapes and citric acid from lemons; they are, therefore, organic acids. These organic acids form salts (called tartrates and citrates) with several of the metals, as potassium, sodium, magnesium, iron, etc.

Sulphuric, nitric and phosphoric acids are inorganic acids; but they form salts with quinine, morphine, strychnine and other organic bases derived from plants.

14. Pharmaceutical or Medicinal Preparations are substances prepared either by *manufacturing pharmacists* or by *dispensing pharmacists* expressly for medicinal uses.

Distinction must be made between *stock preparations* which are rarely finished medicines, and *finished medicines* which are rarely kept in stock.

Stock preparations are generally made by such time-consuming methods that they cannot be prepared for the occasion whenever they are wanted but must be made in advance of the demand for them. But the stock preparations may or may not be medicines ready for immediate administration or application. Many of them are simply materials which require further treatment by the dispensing pharmacist in order to convert them into convenient and effective forms for medicinal uses, or they are combined or mixed with other substances to subserve the requirements of individual cases. Other stock preparations are finished medicines prescribed by physicians and dispensed by pharmacists without modification.

Stock preparations may be prepared either by manufacturers or by dispensing pharmacists; but they are chiefly made by manufacturers.

By way of illustration, we may say that manufacturing pharmacists make such preparations as extracts and fluid extracts of vegetable drugs. They supply these and other stock preparations to the dispensing pharmacists, who use them as materials for preparing finished medicines ordered by physicians. Extracts, fluid extracts, oleoresins, tinctures and many other classes of pharmaceutical preparations are rarely used without modification, dilution, or other treatment, or without combination with other materials.

A dispensing pharmacist may make the stock preparations he uses, and a manufacturer may manufacture pills and other preparations which are finished medicines ready for immediate use. But only the dispensing pharmacist expressly licensed to practice pharmacy is permitted to compound and dispense medicines upon physicians' prescriptions.

15. Galenical Preparations are pharmaceutical preparations prepared by methods which do not result in chemical alterations of the ingredients employed. The transformations of one or more substances into one or more other substances are chemical alterations; but mere mechanical mixtures, solutions and extracts contain no new substances formed out of the original substances employed as materials.

The pharmaceutical *solutions* are water solutions, alcoholic solutions, and solutions made with mixtures of alcohol and water, or with other solvents.

The *extracts* are either liquid or solid, and the solvent or menstruum employed to make an extract may be water, alcohol, wine, diluted acetic acid, or some other liquid. The extracts include infusions, decoctions, tinctures, wines, vinegars, fluid extracts, solid extracts and oleoresins.

The *mixtures* include not only those made out of liquids, but also mixtures of solids and liquids together, and out of solid substances only. Numerous liquid mixtures are used, and of the dry or solid mixtures we may mention compound powders, pills, troches, ointments, etc.

But there are also Galenical preparations not readily classified because they are partly solutions, partly mixtures and partly extracts, or belong to more than one class.

Galenical preparations are so named after Galen, because the preparations made and used by that physician and teacher did not include any chemicals or any substances prepared by intelligent chemical processes, since chemistry was unknown in his time.

About three hundred Galenical preparations are important pharmacopœical medicines.

16. Chemical Pharmaceutical Preparations are those produced by chemical means. Whenever the materials employed in making the preparations are transformed into new substances, the product is a chemical preparation, and the process of preparing it is a chemical process. The principal materials employed in making the preparation called solution of acetate of ammonium are acetic acid and ammonium carbonate. But the product contains no ammonium carbonate whatever and very little acetic acid; it contains instead a compound called ammonium acetate, which was produced out of the acetic acid and ammonium carbonate. Solution of acetate of ammonium is, therefore, a chemical preparation.

All salts, acids, and other chemicals are chemical preparations; but there are many chemical pharmaceutical preparations which are of indefinite composition, or which are mixtures of several substances, and hence are not true chemical compounds, as, for instance, tincture of chloride of iron, syrup of ferrous iodide, "effervescent salts," etc.

17. Extemporaneous Preparations are those not kept in stock but prepared for the occasion whenever required. They include such products as would deteriorate or decompose in a comparatively short time, as well as medicines specially ordered to be prepared in accordance with magistral formulas or prescriptions written by physicians to meet the requirements of individual cases.

A magistral formula (from *magister*, master) is a formula or recipe written by one who is authorized or competent to compose prescriptions.

18. Pharmacology is that branch of the study of medicine which treats of the *materia medica*, or medicinal substances, and of their sources, commercial history, preparations, effects, uses and doses.

More recently the term pharmacology has been employed in a more restricted sense or to signify the study of pharmaco-dynamics.

19. **Pharmacography** is that branch of the study of medicine which treats of the natural origin, appearance, structure and other means of identification of organic drugs.

Pharmacognosy is the knowledge of pharmacography.

The study of pharmacography necessarily demands a good knowledge of the organs, tissues and microscopical structure of plants.

20. **Pharmaco-dynamics** is the action of drugs or medicines, or the study of the quality, quantity and direction of their effects.

21. **Pharmacopœias** are books compiled by recognized national authorities establishing the titles, definitions, descriptions, tests, formulas, and standards of quality, purity and strength of the medicinal substances employed by licensed physicians and surgeons.

Every civilized country has a national pharmacopœia of its own, or uses but one pharmacopœia, even if that be the pharmacopœia produced by some other country.

22. **The Official** medicinal preparations, processes, titles, definitions and descriptions of any country are those contained in the pharmacopœia of that country.

23. **An Officine** is the workshop or place of business of a dispensing pharmacist. In America the drugstore constitutes or contains the officine; but the precise location of the drugstore is not specifically fixed by law. In nearly all the countries of Europe the *locale* of the apothecary's shop or officine is fixed by the government and cannot be changed except by its express permission. The permission to remove an apothecary's shop from one location to another is given in those countries only in cases where the change is found to be warranted and not contrary to the wel-

fare of the community served by that officine, and in each case the authorized new location is specifically placed on record. In those countries, therefore, not only the pharmacist or druggist is registered and licensed, but every officine or pharmacy or drugstore or apothecary's shop is also registered and licensed, and that independently of the temporary owner or manager.

24. **Officinal Drugs**, chemicals and preparations are those commonly found in an officine or pharmacy.

An officinal medicine is often unofficial, and an official medicine is not necessarily officinal.

25. **A Pharmacist** is a specially trained scientific-technical expert competent safely to prepare and dispense medicines.

II

Pharmaceutical Education and the Legal Regulation of the Practice of Pharmacy

26. **Pharmacy Laws** exist in all civilized countries. They are public health laws, enacted for the sole purpose of protecting the people against the grave dangers to health and life which necessarily attend upon ignorance, incompetence, negligence and irresponsibility in the business of supplying medicines for the sick, and upon unrestrained traffic in poisons.

The physician would be powerless without medicines. The welfare of the community, therefore, demands that necessary medicines shall be promptly procurable. Hence it is made the duty of designated public servants to be at all times ready to prepare and dispense commonly employed and specially important remedies without unnecessary delay. These public servants are the pharmacists. They are necessarily given the exclusive right to practice pharmacy, and that right is expressly forbidden to all others. Thus the exclusive privilege of the pharmacist to practice his profession imposes upon him the obligation to perform faithfully his functions. He must not only qualify himself to perform his duties intelligently and safely, but must fulfill his obligations by actually rendering the services assigned to him. In most countries he is, therefore, required to make oath, before his license to practice becomes effective, that he will faithfully perform his duties to the community, uninfluenced by fear or favor, loss or gain, and his work is at all times subject to that supervision which must be exercised by the government to insure to the people the benefits for which the pharmacy laws and regulations exist. As not only the pharmacists and their assistants but the pharmacies or drugstores, too, are registered, the pharmacies are inspected annually or oftener by a special inspector, just as banks are inspected.

England and America are the only countries in which this is not done.

27. All well-made pharmacy laws take cognizance of three distinct classes of persons necessarily engaged in the performance of the pharmaceutical work of the drugstores, or pharmacies: Managers, clerks and apprentices.

The respective qualifications, duties, privileges and responsibilities of each of these three classes of pharmaceutical workers are sharply defined and prescribed in all countries where the practice of pharmacy has reached its highest present development and where it has been regulated by law for centuries. In America, however, many of the State pharmacy laws make no distinction between them, and in only two States (New York and Illinois) does the law contain the specific requirement that all apprentices must satisfy the Board of Pharmacy that they possess sufficient preliminary general education to be fit to learn pharmacy and to undertake the study of chemistry and the other subjects which are necessary to intelligent pharmacy, and upon which all candidates for registration as pharmacists or assistant pharmacists are therefore examined. Yet, of all the requirements of sound pharmaceutical legislation, the most important is good general education. All pharmacy laws, in America as well as everywhere else, do, of course, demand of all persons who desire to be registered as pharmacists or assistant pharmacists, that they must be competent to perform their duties intelligently and safely and they cannot be competent if their education is deficient, but a definite standard of preliminary general education is a fundamental necessity, and therefore of far greater importance than any other feature of the law.

28. **Managers** of pharmacies, whether they are the owners or not, are responsible for their own acts as such and also for the acts of any persons in their employ who are not legally qualified to perform the duties assigned them. Managers are also responsible for the character of the medicines, or materials employed in the preparation of medicines, dispensed by themselves and others in the pharmacies under their charge. They must accordingly possess the technical training necessary to enable them intelligently to examine, identify, test or prepare the medicinal substances requiring it.

29. **Clerks** in pharmacies who do any pharmaceutical work, whether they be Registered Pharmacists or Registered Assistant Pharmacists, are not responsible for the identity, quality, purity, strength or condition of the medicines they dispense, or the materials they are required to use in preparing and dispensing medicines, except so far as they may dispense medicinal substances which they themselves know to be spurious or to deviate from recognized standards

of purity, quality or strength. But they, and not their employers, are responsible for the correctness of their own work, if they are registered or licensed.

30. Apprentices are not permitted to do any technical pharmaceutical work nor to dispense any medicine except under the direct supervision of the Registered Pharmacists and Registered Assistant Pharmacists by whom they are employed or who are their preceptors. They are necessarily permitted to *assist* in the daily technical work in order that they may learn the art and, in time, become qualified to succeed their preceptors or practice pharmacy on their own responsibility. They are responsible for any unlawful act performed by them, and for any act of theirs not authorized by their employers or preceptors. But they are not accountable for any act performed by them under the direction of their employers or preceptors unless such act is one prohibited by law.

31. Three kinds of training are each and all absolutely necessary to fit any person for the intelligent and safe practice of pharmacy. They are: 1, Good *general education;* 2, good *special education* in botany, chemistry, pharmacognosy and pharmacy; and 3, good *shop training* in the actual performance of pharmaceutical work in the pharmacy.

32. The occupation of the pharmacist is truly a scientific-technical profession worthy of the highest ambition. The best education obtainable in our universities and colleges cannot be regarded as too high for the practice of scientific pharmacy, for it but serves to arm the pharmacist for greater usefulness and achievements. Practicing pharmacists with doctor's degrees in philosophy or medicine are not rare in Europe. In past times a large proportion of the most renowned chemists of the world were pharmacists. The practice of pharmacy offers limitless opportunities for scientific research to all who are competent to do such work.

The drug business as ordinarily conducted in England and America is not pharmacy. But pharmacy is still practiced in many of the best drugstores, and it will survive and be in time entirely divorced from the mercantile business which has so debauched it and nearly crushed it out.

Legitimate pharmacy will prevail because it is necessary to civilization.

The ordinary drug business requires large capital. Large rent, expensive furniture, a varied and heavy stock of merchandise, the wages of the salesmen, and the small profits due to excessive competition, not only with other drugstores but with groceries, dry-goods stores, candy shops, ice-cream parlors, cigar stores, stationery stores, paint stores, department stores and many other retail shops, render it necessary that the volume of trade shall be very great before the merchant-druggist can hope to make his business pay. But if he is a shrewd, careful and industrious merchant he succeeds as a merchant whether he be a pharmacist or not. His drug department is largely made up of quack nostrums and proprietary products. The prescription department is frequently an insignificant fraction of his establishment and sometimes wholly absent. Legitimate professional pharmacy cannot be expected to flourish amid such surroundings.

Scientific-technical pharmacy is something altogether different. Thirty years ago pure scientific pharmacy, free from extraneous merchandising, was almost unknown in America. Yet the drugstore of thirty years ago did far more real pharmaceutical work and less miscellaneous merchandising than the average drugstore of to-day. But hundreds of pharmacists are at last discovering that true professional pharmacy completely divorced from mere trading is both practicable and profitable in every sense.

They find that they can succeed better without dealing in quack nostrums, cigars, soda water, ice cream, perfumery, stationery, rubber goods, toilet articles, books, paints, oils, glass, chewing gum, and other articles foreign to pharmacy. They devote themselves wholly to the preparation and dispensing of medicines on physicians' prescriptions, and to such other technical work as they may be called upon to do, such as urine analysis, etc. To do this business successfully requires perhaps less than one-fifth the capital necessary to make the ordinary drug business pay. The current expenses of purely pharmaceutical practice are small, because a couple of rooms upstairs at a small rent will be found sufficient. The monthly bills for "goods" are insignificant, because nearly all the goods bought are the materials necessary to dispense prescriptions. The scientifically trained technical experts who practice professional pharmacy are not merely selling merchandise, but rendering professional services. But to succeed well in such practice of pharmacy as this, the pharmacist must, of course, possess the education necessary to command confidence and respect as a truly professional man.

33. No person should enter upon the career of pharmacy without full recognition of its responsibilities and the courage and conscience requisite to meet those responsibilities efficiently and honorably. Human suffering and loss of life are involved. A few illustrations will suffice to emphasize this.

We have already pointed out that some of the most valuable remedies known to the physician are deadly poisons. Such remedies are often employed in heroic doses, as large as the patient can bear, when no other course gives any promise of saving life. If in such a case the medicine dispensed is much above or much below the prescribed standard of strength, the patient's life will probably be sacrificed either from an overdose, or for want of a sufficient dose to produce the desired result. Diluted hydrocyanic acid is such a remedy. It should be of two per `cent strength. But it is often found to be of less than one per cent strength, and is sometimes found in the market of three or four per cent strength. It is the pharmacist's duty to test it, to know its actual strength, and to govern himself accordingly.

Extract of Calabar bean is a deadly poison. Heroic doses of it are sometimes administered as a last resort to save life in cases of lockjaw. But the preparation is made in two different ways. Made with strong alcohol it is four times as poisonous as when made with diluted alcohol. It is the duty of the pharmacist to know what kind to dispense, to examine the manufactured product so as to determine which kind it is, and to be governed by the facts.

Digitalis is an extremely valuable drug and numerous sufferers have been relieved by it. But it is very sensitive and rendered valueless by age or want of care in its preservation. It is the pharmacist's duty to have as fresh digitalis as the season permits, to preserve it as carefully as possible, and to notify the physician if unable to furnish a drug which he knows to be in proper condition.

Unless the pharmacist possesses that education which enables him to know his duty, and will faithfully perform that duty as he sees it, he fails to carry out his part of the contract between him and the people, by virtue of which he acquired the right to practice his profession.

Test Questions

To the Student:

Before you begin to answer these Test Questions, read those parts of the *Student's Guide* which relate especially to the preparation of the recitation paper. Be sure that your paper corresponds in form to that prescribed in the *Student's Guide.* By so doing you will aid your instructors materially and save yourself the possibility of delay.

Study the question thoroughly before you begin to write your answer and then as far as possible put your own thoughts into your own words. Never use the language of the text-book unless you are specifically requested to do so.

Execute your papers as neatly as possible and arrange the leaves in proper order, as directed in the *Student's Guide.* Be particular in language, spelling, capitals and punctuation, for in all these respects your instructor will mark your paper. This is done not for the purpose of making your work more difficult, but because every pharmacist should be able to write intelligently and correctly.

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1. Why are pharmacists and no others permitted to sell poisons?

2. A certain medicinal preparation is composed of alcohol, water, sugar, strychnine, quinine and iron. Which of these substances belong to the *materia medica* and which to the *materia pharmaceutica?*

3. Which of the following substances are inorganic and which are organic: Paper, clay, water, wood ashes, snow, diamond, amber, coal oil, soap, rubber?

4. What special technical work belongs exclusively to the pharmacist?

5. What is meant by Galenical preparations?

6. What is the difference between an officinal drug and an official one?

7. What are the main objects of pharmacy laws?

8. What are the respective public responsibilities of proprietors, clerks and apprentices in the retail drug business under the pharmacy laws?

9. Why is a good working knowledge of analytical chemistry necessary to the pharmacist for his own protection as well as for the protection of his customers?

10. Why is a knowledge of botany and microscopy necessary in pharmacy?

LESSON TWO

To the Student:

Your last lesson was composed largely of definitions and of introductory statements concerning the position and responsibility of the pharmacist. With this second lesson you begin the study of the important principles upon which all pharmaceutical operations are based. You are now dealing with physics and chemistry.

While your text contains all that is essential on these subjects, yet your understanding will be more complete if you can find the time to read other authorities. If you have a high school text-book in physics such as that of Carhart & Chute, or one in chemistry such as Remsen's or Oldberg's, it will be very profitable for you to read in each what is said on the topics mentioned in this lesson. If you have previously studied physics and chemistry in the high school or elsewhere, review such portions of those branches as are alluded to here. While the great merit of this course is that it contains those things which are essential to a pharmacist, yet a broader knowledge is always an advantage to the person who has time to secure it.

Do not be content with learning what this book says. Constantly apply the knowledge you gain. Keep watch for illustrations of the principles that are given here. Think while at work of what you have learned and you will find these principles continually reappearing. No experiments are here called for, and you will not be required to report on any. Still, no better practice can be had by an aspiring young pharmacist than what he can get out of his endeavors to demonstrate the truth of statements made to him or to apply in his daily work the definitions and principles he learns. Oftentimes you may find statements that do not appear credible to you, or whose real meaning does not seem apparent at once. If, however, you try to find applications of the law or proofs of its verity, you will succeed easily. In this lesson, for instance, you are told, "The quantity of matter in the universe is constant; it cannot be increased or diminished." How is that? Does not fire destroy wood and lessen the quantity of matter? Certainly not. Ashes, water and gases form and the wood becomes something else, but no matter is really destroyed. Study to understand, not merely to remember

In the lesson you will find mentioned many elements or substances with which you are familiar, and doubtless many others previously unknown to you. In the latter case, fix the names in your mind, and in your reading of newspapers and magazines watch for anything that relates to them. You will be surprised to see how frequently you will find these articles mentioned. Your study has already broadened your field of interest.

But the essential thing for you is to get the pharmacist's view and the pharmacist's knowledge. This you will obtain by mastering just what is contained in the chapters that compose the lesson.

III

About Matter and Energy

34. All medicines consist of matter.

The human body and all its parts and contents are also made up of matter.

35. All things and phenomena perceptible to our bodily senses are either matter or changes in matter.

36. Physical Bodies are the things of nature which consist of matter.

Earth, air and water, as well as the bodies of all plants and animals, are composed of matter.

37. Matter is that which occupies space and is affected by gravitation and subject to motion.

38. Whatever occupies space is matter; and whatever does not occupy space is not matter.

Each individual particle of matter, however small or large, occupies its own space to the exclusion of every other individual particle of matter.

This property of matter is called its **impenetrability.**

39. The **volume** of a body is the space occupied by it.

40. All physical bodies in the universe are apparently attracted to and by each other, and this apparent mutual attraction which operates between all bodies in nature is called **gravitation.**

The power with which bodies of matter mutually attract each other is in direct ratio to their masses and in inverse proportion to the squares of their distances from each other.

41. **Weight** is the measure of the force by which the earth attracts toward its center other bodies of lesser mass.

Weight manifests itself by the power required to lift any body of matter from a lower to a higher position, and by the pressure exerted by an uplifted body upon any support which prevents it from falling.

42. Whatever has weight or is affected by gravitation is matter; and whatever has no weight cannot be matter.

43. The **mass** of any physical body is the actual quantity of matter contained in it, irrespective of the space it occupies and irrespective of its weight.

Two or more bodies may have the same mass and yet occupy widely different extents of space; or they may have equal volumes although their respective masses vary greatly.

The relative *masses* of different bodies may be approximately measured by weight. But the mass of any particular body is a positive magnitude unaffected by its relations to other bodies or by any form of energy, whereas the *weight* of any material body varies according to its distance from the earth's center.

44. The relation of the mass of a body to its volume is called its **density.**

Of two bodies having the same volume, that having the greater mass has, therefore, also the greater density.

A cubic inch of iron weighs more than a cubic inch of water because the density of iron is greater than that of water.

Of two bodies having the same mass but of different volumes, that having the smaller volume possesses, therefore, the greater density.

Whenever any two bodies have the same density their relative volumes correspond to their relative masses; therefore, if their masses are equal their volumes are also equal.

45. One of the general properties of matter is **inertia.**

By inertia is meant the inability of matter to move without the impulse called energy, and its inability of its own accord to stop its own motion when once started.

Matter is accordingly altogether passive.

46. **Motion** is a change of place or position.

The idea of motion is inseparable from the idea of that which is moved, and that which is moved is matter.

All matter is in motion.

47. **Energy** is the power which acts upon, and in, and through matter, causing or preventing changes in its position, form, condition and properties.

Gravitation is not caused by matter, but it is one of the effects of energy upon matter.

48. Energy is **indestructible.**

The quantity of energy in the universe is constant. It cannot be added to nor diminished.

49. All of man's knowledge concerning energy must be derived from his observation of its effects upon matter. Hence man cannot know what energy *is*, but only what it *does*.

50. Since all the knowledge we may acquire concerning energy must ever be based upon what we learn of its manifestations in the world of matter, and since these manifestations are infinitely varied, they must be classified for

purposes of study and comparison according to our observation and conception of their nature.

Various **forms of energy** are, therefore, recognized.

Gravitation, cohesion, adhesion, heat, light, electricity, and chemical energy are different *forms of energy*.

But any form of energy can be converted into any other form of energy; and whenever energy in one form disappears, its exact equivalent in another form takes its place. From this it may be seen that there is but one universal energy, and that its quantity is unchanged although its modes of manifestation are various, according to the kind and condition of the matter upon which it acts.

51. Matter and energy are inseparable in the sense that all matter is actuated by or endowed with energy, and that energy is known only through matter. Yet, matter is not energy and energy is not matter; one cannot produce the other, nor can one be converted into the other.

52. Matter, like energy, is **indestructible** in the sense that it cannot be annihilated.

The quantity of matter in the universe is constant. It cannot be increased nor diminished.

Nearly all kinds of matter may be converted into other kinds of matter by various means; but whenever matter is changed as to its kind, or chemical structure, its mass remains nevertheless unchanged.

53. The various different forms of energy and motion may be communicated or transmitted from one particle or body of matter to another.

54. **Work** is the application of energy resulting in changes in the position or motion of matter.

Work is always the result of energy and all energy has the power to perform work.

Potential energy is *stored-up energy*—energy not performing work but capable of performing work when released or when the causes which prevent it from doing work are removed. It is energy prevented from performing work by an equal quantity of energy operating in opposition to it.

Kinetic energy is *energy of motion* or energy in the act of performing work. A cannon ball fired at high velocity acquires the power of overcoming great resistance. This power is its kinetic energy.

55. Energy does not act in the same manner upon all kinds of matter. All matter offers more or less resistance to the action of energy, and the amount of resistance offered by matter is according to its kind. Moreover, different individual kinds of matter appear to possess the property of qualifying the operation of energy through them. Thus one form of energy may be changed into another form of energy according to the kind of matter upon or through which it acts; as heat into mechanical action in the steam engine, and mechanical action into light and heat as in the production of electric light. In fact, different kinds of matter are recognized according to their behavior in respect to energy, for **the specific properties of any individual kind of matter are its relations to energy.**

56. From the observed respective attitudes and behavior of bodies of matter toward each other when acted upon by different forms of energy, it is evident that one form of energy may act in direct opposition to another form of energy. Energy may cause certain particles of matter to be apparently attracted by and to each other, while it causes certain other particles of matter apparently to repel each other.

Energy, therefore, manifests itself in two opposite modes—*attraction* and *repulsion.*

Attraction and repulsion co-exist.

IV

The Divisibility and Composition of Matter

57. The wonderful divisibility of matter is exemplified by numerous phenomena, such as the property of various kinds of colored substances to impart their color to enormous quantities of water or other solvents, the property of odorous substances to perfume the air, and that of the most minute quantities of various substances to reveal their presence by chemical tests.

58. Countless **kinds of matter** exist. Numerous kinds are known, and substances before unknown are being discovered or produced in practically endless variety.

59. All kinds of matter may be classified into: 1, *elemental matter*, and 2, *compound matter*.

60. Elemental matter is matter which cannot by any known means be decomposed or separated into other kinds of matter, nor produced by combining together any other kinds of matter.

One kind of elemental matter cannot be transmuted into any other kind of elemental matter.

61. About eighty distinct kinds of elemental matter are believed to be now known (1904). There are strong reasons for believing that still other kinds of elemental matter are in existence which may yet be discovered. At the same time it is not impossible that one or more of the kinds of matter now recognized as elemental may be found to be decomposable or compound matter.

It is also believed to be possible that some substances now regarded as distinct individual kinds of elemental matter may be found to be simply different forms of but one kind of matter. Finally, it is believed possible, if not probable, that all matter is one, and that the different kinds of elemental matter called the chemical **elements** are but the various forms which the one matter assumes under different conditions. But the oneness of matter, should it be demonstrated to be a fact, will not do away with the conception of the distinct kinds of simple matter now called elements, but will only modify it.

62. About three-fourths of the known elements are the so-called **metals.**

Iron, copper, lead, tin, zinc, nickel, gold, silver, platinum, aluminum and mercury are familiar examples of metals or *metallic elements.*

63. About one-fourth of the known elements are called **non-metallic elements,** or **not-metals.**

Sulphur, carbon, phosphorus, chlorine, bromine, iodine, oxygen, nitrogen, hydrogen, and silicon are non-metallic elements.

64. All matter consists of indivisible and therefore undecomposable particles called **atoms.**

An atom is consequently the smallest particle of any element that can enter into the formation of any kind of compound matter.

There are, of course, as many distinct elements as there are different kinds of atoms, and no more.

65. About one-half of the distinct kinds of atoms or distinct elements now believed to be known are of rare occurrence in nature. Of the more widely distributed elements occurring in large quantities, oxygen and silicon are the most abundant.

66. Very few of the elements exist in nature uncombined with other elements.

But oxygen, nitrogen, carbon, sulphur, silver, and copper occur both combined and uncombined with other elements; and gold, platinum, argon, krypton, and some other elements occur in nature only in their free or uncombined state.

67. Under ordinary conditions atoms rarely exist singly or detached from other atoms. They are found almost invariably united in groups of two or more. This union of atoms into groups is governed by fixed laws.

Some recently discovered gaseous elements, including argon and krypton, contained in the atmosphere, consist of particles which are evidently single atoms. At very high temperatures the vapors of the elements called chlorine, bromine, iodine, mercury, cadmium and zinc also consist of monatomic particles.

68. Molecules are the smallest particles into which any particular kind of matter can be divided without losing the specific properties which determine its individuality. A molecule of starch is the smallest particle in which that substance can exist as starch. When the molecule is broken up, the starch is separated into its elemental substances.

Molecules may consist of one or two or more atoms, and molecules containing more than one atom may consist of atoms of but one kind, or of atoms of different kinds.

Molecules consisting of single atoms (monatomic molecules) must necessarily be elements.

69. Elemental molecules are molecules consisting of but one kind of atoms.

The eighty chemical elements, or the several kinds of elemental matter, consist of elemental molecules.

70. Compound matter is matter composed of two or more elements united together into one or more kinds of atomic groups held together in certain definite proportions. Compound matter can accordingly be decomposed into two or more other kinds of matter, and can be, either directly or indirectly, composed out of, or produced by combining together, two or more other kinds of matter.

71. Each distinct or individual kind of compound matter is called a **chemical compound.**

Among the familiar examples of chemical compounds are water, common salt, sugar, alum, borax, quartz, lime, washing soda, baking soda, cream of tartar, green vitriol, blue vitriol, flint, chalk, iron rust, alcohol, glycerin, quinine, carbonic acid gas, camphor, ether, chloroform, and oxides, acids and salts of all kinds.

72. **Compound molecules** are molecules composed of more than one kind of atoms, or of two or more elements, held together in definite proportions in accordance with the laws of atomic combining value, called *valence*.

All the innumerable different kinds of matter in the world are made up of the relatively extremely small number of chemical elements.

73. All atoms of any one kind have the same mass and in all respects the same properties.

74. All molecules of any one kind have the same mass, the same composition and structure, and in all respects the same properties under the same conditions.

75. Atoms and molecules are so minute that they cannot singly be rendered visible by any known means.

It has been stated that it takes 8,000,000,000 molecules of water to make a particle of sufficient size to be seen by the aid of one of the best modern microscopes.

76. The *relative masses* of different kinds *of atoms*, called their **atomic weights**, are known; but their absolute weights are unknown.

77. The *relative masses of molecules*, called their **molecular weights**, are the sums of the masses of their component atoms.

78. Comparatively few chemical compounds exist in nature in a pure condition or unmixed with other kinds of matter. Nearly all pure or unmixed chemical compounds are produced or separated from other substances by man's labor.

79. The innumerable varieties of matter found in nature are generally **mixtures** of two or more, and usually very

many, different kinds of chemical compounds in varying proportions.

Earths, soils, wood, flesh, bone, oils, fats, milk, cheese, resins, and many other substances having the appearance of uniform composition, are nevertheless, chemically considered, mixtures or mixed substances because they are made up of several kinds of molecules not held together by chemical energy nor combined in definite proportions.

80. A **chemically homogeneous substance** consists exclusively of individual particles of identical specific properties or of but one distinct kind of matter.

All chemically homogeneous substances are also physically homogeneous.

81. **Physically homogeneous substances** are substances of uniform appearance and whose least discernible particles all have the same composition and properties. Such substances *may* consist of but one kind of matter, elemental or compound; but they are in the vast majority of cases mixtures, chemically considered.

Benzine, volatile oils, fixed oils, alloys, solutions, air, the yolk of an egg, wines, and numerous other substances which appear to be of perfect sameness throughout their whole mass are nevertheless mixed substances or mixtures of different kinds of matter, or consist, each, of different kinds of molecules.

82. The **physical properties** of matter are those properties which can be observed or discovered by means not involving any alteration in its composition or structure.

The physical properties of any substance belong to any number of its particles taken together. They are properties perceptible to our physical senses unaided by chemical agencies, and include external form, color, odor, taste, specific weight, hardness, malleability, ductility, brittleness, elasticity, tenacity, adhesiveness, melting point, boiling point, solubilities, etc. But while the physical properties of matter may be determined or observed without any reference to chemistry, they nevertheless depend primarily upon the composition and structure of the molecules, or, in other words, upon the component elements and the arrangement of the component atoms.

83. The **chemical properties** of matter are those directly and exclusively dependent upon and relating to conditions within each individual molecule, and discoverable only by chemical means. They include the intensity, quality, and quantity of the chemical energy actuating the component atoms, and the masses, chemical behavior and relative stability of the molecules.

84. No two different kinds of matter have exactly the same properties in every particular.

85. Under the same conditions, any one distinct kind of matter has invariably the same properties in every particular.

86. **Allotropy.** Certain elemental substances occur in different forms, with different properties. This is called allotropy, and the different forms assumed by the element are called its *allotropic modifications.*

Carbon, sulphur, phosphorus, and several other elements occur in various allotropic modifications. Diamond, the black lead or graphite of our lead pencils, and charcoal are all one element—carbon. Sulphur occurs in at least four distinct modifications which differ in consistence, color, solubility and other particulars. Phosphorus is either a waxy, white substance which is self-inflammable in the air and very poisonous, or a red powder which is neither self-inflammable nor poisonous.

The causes of allotropy are not understood. It is probably due to differences in the number of atoms contained in their molecules or to differences in the relative grouping of those atoms, or to differences in the arrangement of the molecules with reference to one another.

Test Questions

To the Student:

Consult the *Student's Guide* again. Be sure that the form of your paper is right. Do not consult your text-book while you are answering the questions. Be independent and self-reliant if you really mean to become a skillful pharmacist. Keep your paper neat and well arranged. Be particular with your writing. No profession requires greater accuracy than pharmacy, and accuracy can be made a habit.

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1. What is the difference between volume and mass?

2. Which has the greater mass, an ounce of cotton or an ounce of lead?

3. What is the difference between gravitation and weight?

4. What is the difference between mass and weight?

5. How do we know that energy exists?

6. How are different individual kinds of matter distinguished from one another?

7. Give an illustration of the extreme divisibility of matter.

8. Into how many distinct kinds of atoms can all the substances on the globe be split up, so far as now known?

9. About how many different kinds of metals are known?

10. About how many different chemical elements are known to occur in comparatively common kinds of matter?

11. Name some elements that exist in nature in an elemental condition.

12. Name some elements known to exist in nature in an atomic condition.

13. What is the difference between an atom and a molecule?

14. What is the weight of an atom in grains?

15. What is the difference between a physical mixture and a chemical mixture?

16. Do all atoms have the same weight and the same volume without reference to their kind?

17. How many different kinds of molecules can be contained in one chemical compound?

18. Are any molecules divisible? If so, how? Are any molecules indivisible?

19. In what particulars may any two molecules of the same kind differ from each other in their physical properties?

20. How is energy produced?

LESSON THREE

To the Student:

In your previous lesson you learned of the different kinds of matter and the general properties of matter. In this lesson your attention is called to a number of phenomena of matter generally known as *changes.* You are already familiar with many of these, but probably recognize some of them under a different name from that given in the text. In your study you should try to find an application of and an illustration for each principle and each new term presented. As far as you are able to do this, you can feel certain that you understand the subject.

V

The Important Forms of Energy and Motion Which Affect the Condition of Matter

87. All the individual particles of matter of which any physical body consists are mutually attracted to and by one another.

This attraction is called **cohesion** when it operates between molecules all of which are of the same kind, having the same mass and identical specific properties.

It is called **adhesion** when the individual molecules attracted by and held to each other are of two or more kinds.

Cohesion and adhesion are generally referred to as forms of *molecular attraction*, cohesion operating between like molecules, while adhesion operates between unlike molecules. But the like individual particles of chemically homogeneous substances held together by cohesion are not always true single molecules; they may consist of two or more molecules of one or more kinds, as will be explained later on. Moreover, while it is true that adhesion operates between definite individual particles of matter of different kinds, it also operates between pieces each consisting of numerous millions of such particles, as when two pieces of wood are held strongly by and to an intervening layer of glue. Finally, it is evident that both cohesion and adhesion are together operative in all bodies of mixed matter.

88. Matter occurs in three different **states of cohesion**, or *states of aggregation:* 1, the *solid;* 2, the *liquid;* and 3, the *gaseous* state.

But some solids approach the liquid form, some liquids are so thick as to be nearly solid; some substances are *semi-fluids* and others are described as *semi-solids.* Some liquids are so *volatile* that under ordinary conditions of temperature and pressure they easily assume the aeriform or gaseous state.

Numerous kinds of matter can assume any one of the three states of cohesion according to circumstances. But many substances are known only as solids; others only in the liquid state; while others exist in two of the states of cohesion.

All gases and vapors can probably be condensed into liquids and solids by strong enough pressure at a sufficiently low temperature; but not all solids can be converted into liquids, and not all liquids can be converted into gases, without decomposition.

89. Cohesion (and adhesion), unless overcome by other forces, sufficiently resist changes of the relative positions of the aggregated particles of **solid bodies** to enable these to retain their shape without external support. Thus cohesion (and adhesion) impart hardness, tenacity, and other related properties to solids. But the greater solidity of many solids is clearly due in part to their physical structure or the mechanical effects of the formation of the aggregated particles into crystals, fibrous tissues, etc.

90. A **liquid** is a substance of such feeble cohesion that it has no definite shape of its own, but assumes a conformation determined by the containing vessel. Without the support of such a vessel the liquid, impelled by its weight, spreads outward and downward unless its *flow* is arrested by obstacles.

Liquids may be *viscid*, like castor oil, tar, honey, glycerin, or thick mucilage; they may be *mobile*, like chloroform or ether; they may be *heavy*, like chloroform and sulphuric acid; or *light*, like ether.

91. Gases are substances apparently without cohesion; or substances in which cohesion is nullified by other forces.

The air is a mixture of gases, chiefly nitrogen and oxygen, and gases are, therefore, frequently described as *aeriform*.

92. Distinction is made between gases which can exist as such at ordinary temperatures, and substances which assume the gaseous state only at higher temperatures. The last mentioned are called *vapors*.

93. Liquids and gases are called **fluids**.

94. Heat is a form or mode of molecular motion. The degree of velocity of heat motion is called *temperature*.

To heat a substance or to increase its temperature is to increase the velocity of the heat motion of its molecules.

95. Mechanical motion is the motion of molar matter. Molar motion can cause independent molecular motion. Hence mechanical motion is convertible into heat. Thus friction generates heat. Heat motion is also convertible into mechanical motion, as may be seen from the applications of steam power.

96. Heat motion may cause molecules to separate from one another; and, when its velocity is sufficient, the atoms of which the molecules are composed may also be swung away or separated from one another so that the molecules are disrupted or decomposed into smaller groups of atoms or into single atoms. Heat is, therefore, described as a *repellant* *force.* But the atoms or groups of atoms separated from one another by their heat motion do not mutually repel one another.

97. Atomic motion is the motion of individual atoms composing the molecules, and is distinct from molecular motion. Yet atomic motion or chemical motion is one of the chief causes of molecular motion.

98. Whenever any two or more elements combine with each other to form any chemical compound, heat is generated; and whenever any chemical compound is decomposed into its elements, heat energy is consumed or heat motion is diminished, or the temperature is depressed.

99. The **effects of heat** upon cohesion.

Many solids and all fluids expand measurably in every direction when heated.

Some solids liquefy when heated to a sufficiently high temperature and are then called *fusible* solids. The temperature at which any solid fuses is called its *fusing point* or *melting point.* The melting point of any given substance is a fixed temperature or a *physical constant.* But many solids are infusible.

Some infusible substances remain practically unaltered by the heat; others become converted into vapor without first melting; and still others are decomposed into other substances under the influence of heat.

The freezing point or *congealing point* of any substance is theoretically identical with its melting point; practically it is only approximately so.

Solids and liquids which can be converted into vapors are described as *vaporizable.* If they assume the gaseous state readily or at comparatively low temperatures they are said to be *volatile.* But some solids and liquids are *fixed substances;* their state of cohesion is fixed or unaltered even at very high temperatures while they remain undecomposed.

The temperature at which any solid or liquid rapidly assumes the gaseous state is called its *boiling point*, and the boiling point of any substance is, under like conditions, constant. The *condensation point* of any substance is nearly coincident with its boiling point.

100. The expansion and contraction of solids and liquids under the influence of changes of temperature are not uniform or regular. But gases and vapors expand or contract equally and uniformly. The volume of any gas is increased at the rate of 0.003663 for each degree C. of increased temperature, and it decreases at the same ratio as its temperature falls.

101. The power by which any gas resists compression is called its **vapor tension.**

102. The volume of any gas is inversely proportional to the pressure it sustains. This is called **Mariotte's law.**

The density of any gas is directly proportional to the pressure to which it is subject.

103. Whenever any given substance expands under the influence of heat, the pressure remaining constant, a fixed quantity of heat is required to cause and maintain the expansion; and whenever contraction takes place that heat energy is liberated, or, rather; at once proceeds to do other work.

When a liquid assumes the state of vapor it *absorbs* a fixed quantity of heat, and that heat is liberated whenever the vapor is condensed to the liquid state.

104. The heat required to expand the volume of any body of matter, or to convert a solid into a liquid, or a liquid into vapor, is called **latent heat**, because that heat manifests its presence in no other way. The heat which melts ice cannot at the same time raise its temperature, and the heat which turns water into steam cannot at the same time make that steam hotter. Additional heat energy is necessary to raise the temperature of the water formed by the melted ice, or of the steam formed out of the water, after their formation.

When ice is melted in a vessel placed over a fire, the temperature of the water formed out of the ice remains constant, 0° C. or 32° F., until all of the solid water has been changed to liquid water; afterwards, if the application of heat be continued, the temperature of the water rises to 100° C. or 212° F. and then remains stationary until all of the liquid water has become converted into vapor.

105. The temperature of the water vapor or steam is 100° C., no more and no less. But if the steam be confined in a boiler or in tubes so that it cannot expand, the pressure which opposes the formation and expansion of the vapor raises the boiling point because a greater amount of heat energy is required to overcome that pressure, and if the steam is conducted through iron pipes into a furnace fire the steam passing through the pipes may be heated to the same temperature as the iron. Steam thus heated is called *superheated steam.*

106. Solution is a physically perfectly homogeneous intermixture of two or more substances. It is not known by what kinds of energy the components of a solution are so intimately blended with one another. Both physical and chemical energy must be concerned in the phenomena of solution, for it is now generally admitted that when certain soluble substances are dissolved in a sufficiently large quantity of water the molecules of the dissolved substances are dissociated into their component atoms or groups of atoms, each molecule being divided into two parts called *ions.*

107. Solutions are formed by solids, liquids and gases. Thus a homogeneous mixture of gases, such as air, is a solution; when camphor evaporates into the air, a gaseous solution of camphor in air or of air in camphor vapor may be said to be formed; and when water evaporates, the water vapor and the air form a solution with or in each other. When camphor and chloral, which are both solids, are rubbed together a homogeneous liquid is formed.

108. But the most commonly accepted **definition of solution** is: the liquefaction of any substance by the action upon it of any liquid, the product being a homogeneous liquid consisting of the solvent and the dissolved substance.

This definition recognizes no solution except a liquid solution, and no solvent except a liquid solvent, while the dissolved substance may have been either solid, liquid or gaseous before it was dissolved.

109. Some substances are quite insoluble in all liquids; other substances are soluble in some liquids but insoluble in others; and soluble substances may be freely soluble, moderately soluble, or only sparingly soluble.

Solids are generally, but not always, much more readily soluble in hot than in cold liquids. Gases are more soluble in cold than in hot solvents. The miscibility of liquids, or their solubility in each other, is also affected by temperature.

When solubility is mentioned without naming the solvent, it is always the solubility in *water* that is referred to.

110. The rate of solubility of any given substance in any given solvent is constant under constant conditions. The **coefficient of solubility** of any substance is the number of grams of it soluble in 100 grams of water at 15° C.

111. Water is the most wonderful and useful of all solvents. Other common solvents are alcohol, ether, liquid hydrocarbons (like benzine), fixed oils (like olive oil), volatile oils (like oil of turpentine), and chloroform.

Water-soluble substances are very numerous and include both inorganic and organic substances.

112. Solids and liquids which attract and absorb water from moist air are called **hygroscopic** substances.

Hygroscopic moisture is the amount of absorbed moisture contained in substances exposed to the air.

113. Excessively hygroscopic solids which are freely soluble in water and which, therefore, attract enough water from the air to become liquefied by solution in that water, are **deliquescent.**

Chlorinated lime, compressed yeast, and glycerin are hygroscopic. Caustic potash, zinc chloride, and ferric chloride are deliquescent.

114. The **diffusion of liquids** into one another, or the tendency of any two or more liquids in contact with one another to form a perfect solution of uniform composition whenever they are mutually soluble in one another, is clearly a phenomenon effected by the same cause or causes which produce solution.

The **diffusion of gases** into each other is also solution.

115. **Light** is caused by energy because it can produce motion. It is capable of producing striking changes in matter and sometimes almost instantaneously, as we know from the results of photography.

Light, like heat, frequently causes the decomposition of substances. It is, therefore, necessary to protect from the light all medicines and other valuable substances affected by it.

116. That form or manifestation of energy which is called **electricity** possesses enormous power to effect changes in matter. Its most striking chemical effects are in opposition to chemical attraction, for many substances are decomposed by the electric current.

117. **Chemism** is that mode of energy by which distinct individual kinds of matter are formed or transformed.

Chemism is also called chemical energy, chemical attraction, chemical combining power, chemical affinity, atomic attraction, and atomic energy.

118. The particles of matter which can unite with one another by chemical energy to form distinct individual substances of definite composition and structure may be either atoms or molecules. But the specific properties of chemical compounds formed by the combination of atoms into single molecules are radically different from those of their component atoms, while the specific properties of substances formed when two or more unlike molecules are held to each other, do not, as a rule, differ widely from those of their component molecules.

119. All changes in the composition and structure of molecules are chemical changes and are governed by chemical energy in accordance with chemical laws of nature.

The formation, relative stability, transformation and decomposition of molecules all depend upon chemism, but chemism is decidedly affected by other forms of energy, such as heat, light, electricity, and even cohesion and adhesion.

120. Any and every chemical change is chemical action and reaction.

Among the most familiar examples of chemical action are fire, explosions, fermentation, decay, the action of metals and many other substances upon acids, and the corrosive action of strong lye upon animal and vegetable matter.

Fire, or *combustion*, is chemical action accompanied by the evolution of large quantities of heat and light. This is the chief source of heat available for the use of man. When carbon and oxygen unite, heat and light are both produced, but in many chemical reactions no light is evolved, though heat may be liberated in large quantities. If water be poured upon unslaked lime, chemical action results, and the mixture grows very hot, but no light is seen. The same phenomenon may be noticed when dilute sulphuric acid and ammonia water are mixed. Heat indirectly aids chemical action. Some reactions are begun only in the presence of heat, but after once started the heat generated by the reaction is sufficient to keep up the process. It is necessary to heat wood or coal to a certain point to compel ignition, but once burning, the fire continues as long as coal or wood and oxygen are supplied.

Test Questions

To the Student:

Again consult your *Student's Guide*, so that you will make no mistake as to the form and arrangement of your paper. Before writing this paper, review carefully the paper on Lesson II. That will undoubtedly contain some criticisms and suggestions which will assist you in writing your paper on this lesson. You should aim to make each paper freer from error and in every way stronger than the previous one. Do not consult the text-book while writing.

Be careful with your penmanship. It is especially important that a pharmacist write a neat, legible hand. Your spelling, too, should be accurate. A pharmacist easily might be led into serious mistakes by errors in spelling. The new words of these lessons should be made a part of your vocabulary at once. Where terms are similar be sure to distinguish between them. Accuracy in everything, is the pharmacist's motto.

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1. Define cohesion.
2. What are the effects of adhesion?
3. How may cohesion be overcome?
4. Under what conditions do cohesion and adhesion oppose each other?
5. What is meant by a fluid?
6. What is the difference between gas and vapor?
7. What is the meaning of the word temperature and what causes the difference between a high temperature and a low temperature?
8. Mention several means of producing heat.
9. Mention some of the effects of heat upon matter.

10. What is the boiling point of any liquid?

11. If a certain gas measures 273 volumes at 20° C., how much will it measure at 22° C.?

12. A volume of a certain gas being 1 liter under the pressure of 1 atmosphere, what will be its volume under the pressure of 2 atmospheres?

13. If a given mass of gas occupies 10 cubic centimeters at 0° C., how many cubic centimeters will it occupy at 212° F.?

14. If a given mass of gas occupies 50 volumes under 760 millimeters pressure, how many volumes will it occupy under 756 millimeters pressure?

15. One liter of oxygen at 0° C. and under 760 millimeters pressure weighs 1.43 grams. What is the weight of two liters of oxygen at 16° C. under 750 millimeters pressure?

16. One liter of carbon dioxide at 0° C. under the pressure of one atmosphere weighs 1.9657 grams. What is the volume of 10 kilograms of CO_2 at 8° C. under a pressure of 4 atmospheres?

17. State the law of Mariotte.

18. What is meant by latent heat?

19. How can steam be heated to 200° C.?

20. What form of molecular attraction in a solid must be overcome when that solid is dissolved in a liquid?

21. How would you aid the solution of a gas in a liquid?

22. What is commonly meant by the term solution?

23. Does increased temperature always aid solution?

24. What is the coefficient of solubility of a substance of which 60 grams can be dissolved in 300 grams of water at 15° C.?

25. What are the most common solvents in pharmacy and chemistry?

26. What is the difference between a hygroscopic and a deliquescent substance?

27. What is meant by the expression *diffusion of gases?*

28. Why is it necessary to protect medicinal substances from light?

29. Define chemical energy.

30. Does heat aid or oppose chemical attraction?

31. Is chemical attraction aided or opposed by light and by electricity?

32. Which form of attraction will cause the greater changes in matter, atomic attraction or molecular attraction?

33. What produces combustion?

LESSON FOUR

To the Student:

The last two lessons have been concerned with the elements of physics. We now leave for a time that subject and take up the elements of chemistry. The next few lessons treat of the theory of chemistry and may seem somewhat obscure at first, but if you will read them carefully and weigh each statement, the meaning will doubtless appear to you. If the course of reasoning does not then seem clear, you can wait with the confident expectation that the subject will become clearer in subsequent lessons. Every new subject has a vocabulary and language of its own, which for a time is difficult to the beginner, but by constant use of the terms he becomes familiar with them and is able to reason with greater ease and accuracy.

It is not expected that you will learn the text verbatim, except in the case of certain rules and principles which are italicized to attract your attention. Such, for instance, are the Law of Definite Proportions and Avogadro's Law, both of which you will find stated in the sixth lesson. The table of elements given in Section 122 is not to be committed to memory, though the names, symbols and atomic weights of the principal elements should be familiar. What these are you will learn from the frequency with which they are mentioned in the text. If you find yourself frequently referring to the table for the symbols and atomic weights of any given element, that should be sufficient hint to learn the facts relating to that element.

VI

The Chemical Elements

121. The classification of the elements into *metals* and *non-metals* has been referred to.

But some elements possessing *physical* properties characteristic of the most pronounced metals have *chemical* properties such as strikingly characterize non-metallic elements, and a few elements partake more or less of the properties of both metals and non-metals, physically as well as chemically.

122. The following list includes the known elements (1905), a few of which have been so recently discovered and are so rare and costly that their properties have not yet been thoroughly studied.

All elements are represented by specific symbols derived from their latinic or other names. These symbols are used for the purpose of constructing formulas representing the composition and structure of chemical compounds.

The names of the most important elements contained in common substances, including those of medicinal value, are printed in **heavy-faced** type. The others are comparatively rare or economically unimportant. The names in the second column are in most cases coined words which are not Latin but simply latinic in form.

TABLE OF THE CHEMICAL ELEMENTS WITH THEIR ATOMIC WEIGHTS

※ ※ Elements thus marked are both physically and chemically non-metallic.

※ Elements which exhibit some of the physical properties of metals but which resemble the non-metallic elements in their chemical behavior.

+ Elements which are both physically and chemically metallic in their properties and behavior.

Elements which are not known to enter into any chemical combination are printed in italics.

COMMON NAME.	LATINIC NAME.	SYMBOL.	APPROXIMATE RELATIVE WEIGHT OF THE ATOM. (ATOMIC WEIGHT.)
Aluminum +	Aluminum	Al	27
Antimony ※	Antimony or Stibium	Sb	120
Argon	Argonum	A	39?
Arsenic ※	Arsenum	As	75
Barium +	Barium	Ba	137
Beryllium +	Beryllium	Be	9

TABLE OF THE CHEMICAL ELEMENTS—*Continued.*

COMMON NAME.	LATINIC NAME.	SYMBOL.	APPROXIMATE RELATIVE WEIGHT OF THE ATOM. (ATOMIC WEIGHT.)
BISMUTH +	Bismuthum	Bi	208
BORON ※ ※	Borum	B	11
BROMINE ※ ※	Bromum	Br	80
CADMIUM +	Cadmium	Cd	112
Cæsium +	Cæsium	Cs	133
CALCIUM +	Calcium	Ca	40
CARBON ※ ※	Carboneum	C	12
CERIUM +	Cerium	Ce	140
CHLORINE ※ ※	Chlorum	Cl	35.5
CHROMIUM +	Chromium	Cr	52
COBALT +	Cobaltum	Co	59
Columbium +	Columbium	Cb	94
COPPER +	Cuprum	Cu	63.5
Erbium +	Erbium	Er	166
Fluorine ※ ※	Fluorum	F	19
Gallium +	Gallium	Ga	70
Germanium +	Germanium	Ge	72
GOLD +	Aurum	Au	197
Helium	Helium	He	4
HYDROGEN ※ ※	Hydrogenium	H	1
Indium +	Indium	In	114
IODINE ※ ※	Iodum	I	126.5
IRIDIUM +	Iridium	Ir	193
IRON +	Ferrum	Fe	56
Krypton	Kryptum	Kr	82
Lanthanum +	Lanthanum	La	138
LEAD +	Plumbum	Pb	207
LITHIUM +	Lithium	Li	7
MAGNESIUM +	Magnesium	Mg	24.5
MANGANESE +	Manganum	Mn	55
MERCURY +	Hydrargyrum	Hg	200
Molybdenum +	Molybdenum	Mo	96
Neodymium +	Neodymium	Nd	143
Neon	Neum	Ne	20
NICKEL +	Niccolum	Ni	58.5
NITROGEN ※ ※	Nitrogenium	N	14
Osmium +	Osmium	Os	191
OXYGEN ※ ※	Oxygenium	O	16
Palladium +	Palladium	Pd	106
PHOSPHORUS ※ ※	Phosphorus	P	31
PLATINUM +	Platinum	Pt	195
Pollonium +	Pollonium	Po	?
POTASSIUM +	Potassium or Kalium	K	39
Praseodymium +	Praseodymium	Pr	140.5

TABLE OF THE CHEMICAL ELEMENTS—*Continued.*

Common Name.	Latinic Name.	Symbol.	Approximate Relative Weight of the Atom. (Atomic Weight.)
Radium +	Radium	Ra	227
Rhodium +	Rhodium	Rh	103
Rubidium +	Rubidium	Rb	85.5
Ruthenium +	Ruthenium	Ru	101.5
Samarium +	Samarium	Sm	150
Scandium +	Scandium	Sc	44
Selenium ※ ※	Selenium	Se	79
Silicon ※ ※	Silicium	Si	28.5
Silver +	Argentum	Ag	108
Sodium +	Sodium or Natrium	Na	23
Strontium +	Strontium	Sr	88
Sulphur ※ ※	Sulphur	S	32
Tantalum +	Tantalum	Ta	183
Tellurium ※	Tellurium	Te	127
Terbium +	Terbium	Tb	160
Thallium +	Thallium	Tl	204
Thorium +	Thorium	Th	233
Tin +	Stannum	Sn	118.5
Titanium +	Titanium	Ti	48
Tungsten +	Wolframium	W	184
Uranium +	Uranium	U	240
Vanadium +	Vanadium	V	51.5
Xenon	Xenum	X	128
Ytterbium +	Ytterbium	Yb	173
Yttrium +	Yttrium	Yt	89
Zinc +	Zincum	Zn	65.5
Zirconium +	Zirconium	Zr	90.5

All the elements marked with ※ or with ※ ※ can combine directly with hydrogen. They are chemically non-metallic elements. Elements marked + do not combine directly with hydrogen, although some of them form alloys with it.

Neon, argon, krypton and xenon are gaseous elements recently discovered in the atmosphere; all efforts so far made to cause these elements to enter into chemical combination with any other elements have been unsuccessful.

Oxygen and fluorine combine with hydrogen but not with each other. All elements can be directly united to oxygen except fluorine and the four elements named in the preceding paragraph.

123. State of Cohesion of the Elements. All of the elements enumerated in the preceding table are solids at ordinary temperatures, with the following exceptions: Mercury and bromine are liquids; argon, chlorine, fluorine, helium, krypton, neon, nitrogen, oxygen, xenon and hydrogen are gases.

124. Colors of the Elements. The metals are generally opaque and white with or without a hue of grayish, bluish or reddish; but gold is yellow, barium and calcium are yellowish, copper is reddish. Bismuth displays variegated hues of purplish, while its general color is reddish-white.

Of the non-metallic elements boron is black; carbon is either black, as in coal and graphite, or colorless, as in diamond; iodine is purplish-black; phosphorus is a white waxy substance or a dark red powder; selenium, red or black; silicon, brown or gray; sulphur, pale yellow, amber, dark brown, or nearly milk-white; bromine is a brown-red liquid; hydrogen, oxygen, nitrogen, argon, krypton, neon and xenon are colorless gases; chlorine is a greenish gas; and fluorine greenish-yellow.

125. Luster. All the metals possess a peculiar luster which in many cases can be greatly heightened by polishing.

The only non-metallic elements that have a luster approaching that of metals are iodine in crystals and carbon in the form of graphite. The luster of the diamond is quite different from and far surpasses that of the metals.

126. The non-metallic elements never possess **tenacity, ductility** or **malleability.** Most of the metals exhibit one or the other of those properties.

127. Density. The specific weights of the five metals called lithium, sodium, potassium, rubidium and cæsium range from 0.6 to 1.5; those of the metals called beryllium, magnesium, calcium, strontium and barium from 1.6 to 4; and those of the metals aluminum, scandium, yttrium, titanium and zirconium from 2.5 to 4. The specific weights of all other metals are higher than 5, ranging from 5.5 to 22.42.

The specific weights of all physically non-metallic elements are below 5.

128. Fusibility. All metals are fusible. Of the non-metallic elements one is liquid and ten are gases. Sulphur, selenium, phosphorus and iodine are readily fusible. Carbon, boron and silicon are infusible.

129. Volatility. Of the physically metallic elements only mercury, potassium, sodium, magnesium, zinc, cadmium and arsenic may be readily distilled; and antimony and tellurium can be distilled with a current of hydrogen.

The non-metallic elements that are not gaseous at ordinary temperatures can all be readily vaporized except carbon, boron and silicon.

130. Solubility in common solvents. All metals are absolutely insoluble in water, alcohol, ether, chloroform, glycerin, benzin, carbon disulphide, volatile oils and fixed oils.

Chlorine and iodine are slightly soluble in water; bromine more so. Iodine is soluble in alcohol, glycerin, chloroform, liquid hydrocarbons, carbon disulphide, volatile oils and fixed oils. Phosphorus is soluble in chloroform, ether, absolute alcohol, carbon disulphide and fixed oils. Sulphur dissolves in chloroform, benzine, carbon disulphide, oil of turpentine and fixed oils.

131. Metals are usually good **conductors of heat** and of electricity. The non-metallic elements are very feeble conductors.

132. Chemical behavior of metals and non-metals. The metals form various solutions and alloys with each other. Gold and several other metals dissolve in mercury at ordinary temperatures. Many metals can be dissolved in each other when melted. Sometimes the combinations effected may be crystallizable bodies containing the component metals in definite proportions corresponding to their atomic weights. But these combinations or alloys are decidedly metallic, retaining in a high degree the characteristics of the metals of which they are constituted. Hence it may be concluded that the combinations formed by the metals with each other are not true chemical compounds, but only solutions.

The compounds formed by non-metallic elements with each other or with metals are strikingly different. They are countless, and they rarely resemble in any respect or degree their component elements. Thus the reddish metal copper combines with the colorless gas oxygen, forming a black powder called copper oxide; the brilliant, silver-white, liquid metal mercury combines with the colorless oxygen to form a red, or yellow, or black oxide, and with yellow sulphur to form a red or a black sulphide; sulphur combined with its own weight of oxygen forms a colorless gas of an irritating odor, but with one and one-half times its weight of the gaseous oxygen it forms an odorless white solid; the three colorless gases nitrogen, hydrogen and oxygen form a white solid called ammonium nitrate; and the elements carbon, hydrogen, oxygen and nitrogen form innumerable compounds of a great variety of properties.

Test Questions

It will probably not be necessary for us to call your attention again to the form of your paper. Let it be understood that unless you are specifically directed to change your plan, you are to continue in that which has been prescribed for you. If the questions seem to call for any explanation, you will find that explanation at the beginning of the questions.

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1. About how many metals are known and about how many non-metallic elements?

2. What are the symbols for lead, antimony, mercury, potassium, silver, sodium and tin?

3. What is the difference between a chemically metallic element and a chemically non-metallic element?

4. Mention six elements which at ordinary temperatures are gases.

5. What elements are liquid at ordinary temperatures?

6. Mention the most striking physical properties by which metals differ from non-metallic elements.

7. Do you know of any non-metallic elements having specific weights between 6 and 10?

8. Can you mention some non-metallic elements which are not fusible?

9. Mention some that are not volatile.

10. Are any of the metals soluble in each other, and if so, what are such solutions called?

11. How many of the metals combine chemically with oxygen? How many of them combine with hydrogen?

12. How many of the non-metallic elements combine with oxygen and how many of them with hydrogen?

LESSON FIVE

To the Student:

Considerable attention has been given in this lesson and others that follow to elaborating for you the course of reasoning by which certain laws were established. It is thought that everything has been made sufficiently clear, but it is too much to expect that you will be able to follow the reasoning at first reading. We expect that you will have to go many times over the text, until not only the words become familiar to you in their meaning, but the trend of thought becomes as natural to you as it is to the writer. Do not forget your dictionary or the treatment of corresponding subjects in the school text-books. All will help you to a clearer understanding of the text.

VII

Definite Combining Proportions and the Atomic Hypothesis

133. Proust pointed out that all chemical compounds contain their component elements in fixed and invariable proportions. The following examples illustrate this:

a. 1 gram of hydrogen unites with 16 grams of oxygen to form the compound called hydrogen dioxide, commonly known as peroxide of hydrogen. These proportions cannot be altered. And a mass of 17 grams of hydrogen dioxide always consists of 1 gram of hydrogen and 16 grams of oxygen.

A 2-gram mass of hydrogen unites with a 16-gram mass of oxygen to form the compound called water. And all water, wherever found or however produced, when decomposed yields hydrogen and oxygen in the proportion of 1 part of the first named to 8 parts of the other element.

b. 1 gram of hydrogen unites with 35.5 grams of the element called chlorine to form 36.5 grams of hydrogen chloride, commonly called hydrochloric acid gas.

In the following table are given in grams the combining proportions of several different elements and the product obtained from the combination. Read from left to right, the first and third columns give the names of the elements; the second and fourth, their combining weights; the fifth, the name of the product; and the sixth, the weight of the product. The horizontal lines separate the compounds into related groups:

Element	No. of Grams	Element	No. of Grams	Product	Grams in Product
Nitrogen	14	Hydrogen	3	Hydrogen Nitride (Ammonia)	17
Nitrogen	2x14	Oxygen	16	Hyponitrous oxide	44
Nitrogen	14	Oxygen	16	Mononitrogen monoxide (nitrosyl)	30
Nitrogen	2x14	Oxygen	3x16	Nitrogen trioxide	76
Nitrogen	2x14	Oxygen	2x16	Nitrogen peroxide	60
Nitrogen	2x14	Oxygen	5x16	Nitrogen pentoxide	108
Nitrogen	14	Chlorine	3x35.5	Nitrogen trichloride	120.5
Manganese	55	Chlorine	2x35.5	Manganous chloride	126
Manganese	55	Oxygen	16	Manganous oxide	71
Manganese	2x55	Oxygen	3x16	Manganic oxide	158
Manganese	55	Oxygen	2x16	Manganese dioxide	87
Carbon	12	Oxygen	16	Carbon monoxide (Carbonyl)	28
Carbon	12	Oxygen	2x16	Carbon dioxide	44
Carbon	12	Hydrogen	4x1	Methane (marsh gas)	16
Carbon	12	Sulphur	2x32	Carbon disulphide	76
Sulphur	32	Oxygen	2x16	Sulphur dioxide	64
Sulphur	32	Oxygen	3x16	Sulphur trioxide	80
Sulphur	32	Manganese	55	Manganese sulphide	87

Element	No of Grams	Element	No. of Grams	Product	Grams in Product
Sulphur	32	Mercury	200	Mercuric sulphide	232
Mercury	200	Oxygen	16	Mercuric oxide	216
Mercury	2x200	Oxygen	16	Mercurous oxide	416
Mercury	200	Chlorine	35.5	Mercurous chloride	235.5
Mercury	200	Chlorine	2x35.5	Mercuric chloride	271
Sulphur	32	Chlorine	4x35.5	Sulphur tetrachloride	174
Carbon	12	Chlorine	4x35.5	Carbon tetrachloride	154

From the foregoing facts, which have been determined by repeated experimentation, it appears that the relative combining masses of the several elements are simple multiples of definite values.

The relative combining mass of hydrogen is 1 or a multiple of it.
“ “ “ “ oxygen is 16 “ “ “
“ “ “ “ chlorine is 35.5 “ “ “
“ “ “ “ nitrogen is 14 “ “ “
“ “ “ “ manganese is 55 “ “ “
“ “ “ “ carbon is 12 “ “ “
“ “ “ “ sulphur is 32 “ “ “
“ “ “ “ mercury is 200 “ “ “

These comparisons might be extended to include every chemical compound known, with the same results—definite combining proportions by weight of all the different elements in all the compounds which they severally form with one another.

134. The combining proportions of hydrogen and chlorine whenever they unite to form hydrogen chloride are invariably as 1 part of hydrogen to 35.5 parts of chlorine, or 35.5 times as much chlorine as hydrogen by weight. Hydrogen and chlorine cannot be made to combine in any other proportions. And if a mass of 36.5 kilograms of hydrogen chloride be decomposed it will give 1 kilogram of hydrogen and 35.5 kilograms of chlorine.

135. Two hypotheses were formulated by John Dalton to express the definite combining proportions of the elements as exemplified in the preceding paragraphs:

A. **The Law of Definite Proportions.**—*Any given chemical compound always contains the same component elements and in the same mass proportions.*

B. **The Law of Multiple Proportions.**—*Whenever any two elements unite with each other in more than one mass proportion, simple multiples of a fixed mass unit of either unite with a fixed mass unit or with multiples of a fixed mass unit of the other element.*

Any two compounds containing the same two elements but in different proportions have different properties and are different compounds. When the compound contains more than two elements the proportions are also equally simple and definite.

136. The Atomic Hypothesis. Dalton explained the definite combining proportions of the elements by adopting the ancient hypothesis that all matter is composed of indivisible individual particles, and by assuming that all such particles of any one element have the same mass but that the particles of one element have a different mass from that of the particles of any other element: *Each element consists of indivisible atoms of fixed mass.*

137. If this atomic hypothesis be accepted as true, then the fixed chemical combining proportions by weight are thereby explained and seen to be the inevitable result of the fixed atomic masses. If, on the other hand, the atomic theory be rejected, then the fixed combining weights of the elements remain unintelligible, for no other sufficient explanation thereof has yet been made.

The atomic hypothesis is a lucid and reliable working theory, and the system of chemistry built upon it leads to fixed results which may be expected and realized with absolute certainty and uniformity.

All known facts of chemistry agree with the atomic theory.

138. Atomic Weight. The numbers expressing the relative masses of the atoms of different elements are called their atomic weights. The unit of expression of atomic weights is the mass of the hydrogen atom. The specific atomic weight of hydrogen is, therefore, 1 and that of oxygen is 16, because an atom of oxygen weighs 16 times as much as an atom of hydrogen. The atomic weight of chlorine is 35.5; that of nitrogen is 14; that of manganese is 55; that of carbon is 12; that of sulphur is 32; and that of mercury is 200.

The atomic weights are the smallest relative masses of elements that can enter into chemical combination with other elements.

A table of the elements and their atomic weights was given in Lesson Four, VI, paragraph 122.

139. Molecular Weight. As all molecules consist of atoms and as all atoms have fixed masses, it follows that the molecule of any given element or chemical compound must also have a fixed mass, which is the sum of the masses of the atoms contained in it.

A few elemental molecules consist of single atoms, and the molecular weight of any element having monatomic molecules is of course identical with its atomic weight.

The molecule of hydrogen consists of two atoms of hydrogen. Hence, as the atomic weight of hydrogen is 1, its molecular weight is 2.

A molecule of ordinary oxygen contains two atoms. Hence, as the atomic weight of oxygen is 16, its molecular weight is 32. But there is another form of oxygen called ozone, each molecule of which consists of three oxygen atoms; the molecular weight of ozone is, therefore, 48.

The molecule of water contains two atoms of hydrogen and one atom of oxygen; the molecular weight of water is accordingly 18.

140. Vapor Densities. The specific weights of all gases and vapors are expressed in units of the density of hydrogen. The specific weight of hydrogen in the gaseous state, or its vapor density, is 1. The vapor density of any other gas or vapor is the quotient obtained when the weight of any given volume of it is divided by the weight of the same volume of hydrogen.

One liter of hydrogen at 0° C. weighs 0.09 gm.; one liter of oxygen at 0° C. weighs 1.43 gm.; a liter of chlorine at 0° C. weighs 3.17 gm.; and a liter of nitrogen at 0° C. weighs 1.26 gm. Hence, as the vapor density of hydrogen is 1, that of oxygen must be 16, that of chlorine must be 35.5; that of nitrogen 14. These numbers coincide with the atomic weights; we shall presently learn why.

141. Avogadro's Law. Equal volumes of all gases or vapors at the same temperature and under the same pressure contain the same number of individual particles of matter.*

Now, as the vapor density of hydrogen is 1 and its atomic weight also 1, and as its molecule contains two atoms so that its molecular weight is 2, we see that its molecular weight is twice its vapor density.

The vapor density of oxygen is 16, for one liter of it weighs 16 times as much as one liter of hydrogen at the same temperature and pressure. The molecular weight of oxygen is 32, for its molecule contains two atoms and its atomic weight is 16. Hence the molecular weight of oxygen is twice its vapor density, just as the molecular weight of hydrogen is twice the vapor density of that element. The vapor density of ozone, however, is not 16 but 24. Why? Because each individual particle or molecule of ozone consists of

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*This hypothesis is usually expressed as follows: "Equal volumes of all gases contain the same number of molecules." But this statement is inconsistent with the definition of the term molecule (IV, par. 68), which refers to the *smallest* particle of any kind of matter, as *the* molecule.

three atoms of oxygen, and as equal volumes of all gases contain the same number of individual particles of matter, each individual particle of ozone must weigh 24 times as much as each individual particle of hydrogen, and as each particle or molecule of hydrogen weighs 2, since it consists of 2 atoms, the individual particle or molecule of ozone must weigh 48 and must consist of three atoms of oxygen. It is true that, in a way, a molecule of ozone is a triatomic molecule of oxygen; it contains only oxygen. But *the* molecule of oxygen is diatomic, and *the* molecular weight of oxygen is 32.

Below 500° C. the vapor of iodine weighs 126.5 times as much as the same volume of hydrogen at the same temperature and pressure. Hence that iodine vapor must consist of diatomic particles, or particles consisting of two atoms each. But at 1700° the vapor of iodine has a density of only 63.25, or weighs only 63.25 times as much as an equal volume of hydrogen at the same temperature and pressure; this iodine vapor at 1700° C. must accordingly consist of particles weighing only half as much as the particles of iodine vapor below 500° C. Therefore, the particles of iodine at 1700° must contain only one atom each instead of two. The question may then be asked: is the diatomic particle of iodine its molecule, or is the monatomic particle its molecule? The answer must be that *the* molecule of iodine is its atom, and that *the* molecular weight of iodine is identical with its atomic weight, for the monatomic particles of iodine are the smallest particles of that element exhibiting the specific properties by which the individuality of iodine is determined.

Ferric chloride is a chloride of iron composed of iron and chlorine in the proportion of 56 parts of iron to 106.5 parts of chlorine. Its vapor at temperatures below 700° weighs 162.5 times as much as the same volume of hydrogen; this corresponds to the formula Fe_2Cl_6, and the weight of each particle must be 325. But the vapor of ferric chloride at 1000° C. weighs only 81.25 times as much as hydrogen, which proves that the individual particles of the compound at that temperature must consist of $FeCl_3$. *The* molecule of ferric chloride is, therefore, now represented as $FeCl_3$ and *the* molecular weight is given as 162.5. It was formerly represented as Fe_2Cl_6 and its molecular weight was then, of course, put down as 325. It would be confusing to recognize two different molecules and two different molecular weights. The smaller particle is then adopted as *the* molecule. The double molecule Fe_2Cl_6 may be represented as $(FeCl_3)_2$.

142. Gay-Lussac's Proposition.—*Gaseous elements combine in simple volume proportions, and the volumes of the products bear simple relations to the volumes of the component elements.*

This conclusion is self-evident from the law of Avogadro and Dalton's laws of combining proportions by weight.

One liter of hydrogen and 1 liter of chlorine combine to form 2 liters of hydrogen chloride, because the molecules of hydrogen, chlorine and hydrogen chloride are all diatomic, or contain two atoms each.

One liter of oxygen and 2 liters of hydrogen combine to form 2 liters of water vapor, because while the molecules of hydrogen and oxygen contain two atoms each, the molecule of water contains three atoms (=HOH), or is triatomic.

Three liters of hydrogen with 1 liter of nitrogen must produce only 2 liters of ammonia, H_3N, because while the hydrogen and nitrogen molecules are diatomic the molecule of ammonia contains four atoms, or is tetratomic.

143. Specific Heat. The relative quantity of thermal energy (heat) required to raise the temperature of a given mass of any substance one degree is called the specific heat of that substance.

The specific heat of water is the unit in which the specific heat of any other substance is expressed. Therefore the specific heat of water is 1, and it signifies the quantity of heat energy required to raise the temperature of one weight unit of water one degree. The specific heat of mercury is 0.0319, because only $\frac{3190}{100000}$ as much heat energy is required to raise the temperature of mercury one degree as is necessary to raise the temperature of an equal quantity of water one degree.

144. The Law of Dulong and Petit.—*All atoms have the same capacity for heat.* This means that it requires exactly the same amount of heat energy to raise the temperature of any atom of any kind one degree.

The specific heat of any element is inversely as its atomic weight.

The product obtained by multiplying the atomic weight of any element by its specific heat is a constant number; it is approximately 6.4, and that number is called the atomic heat. Hence when 6.4 is divided by the specific heat of any element the quotient must be approximately the atomic weight of that element.

The atomic weight of any element can, therefore, be approximately deduced from or verified by its specific heat. [$6.4 \div 0.0319 = 200.$]

145. Neumann and Regnault proved that the specific heats of *compounds* are inversely proportional to their *molecular* weights (just as we have seen that specific heats of *elements* are inversely as their *atomic* weights).

The sum of the atomic heats of the atoms of any molecule is the molecular heat of that molecule. Hence, when the molecular heat of any substance is divided by 6.4 the quotient is the number of atoms contained in the molecule, whether elemental or compound. Molecular weights can, therefore, be deduced from or verified by the specific heats of substances.

146. There are, furthermore, other methods by which molecular weights can be verified. These methods would be wholly out of place in elementary lessons like these, but their existence is referred to simply to indicate that the atomic theory is amply confirmed by many facts in chemical physics which have been discovered and demonstrated independently of one another and of the atomic hypothesis itself.*

Test Questions

In general, it is not expected that you will refer to your text in the preparation of your answers to Test Questions. We have indicated some things that should be committed to memory. Other things should be thoroughly understood. At the same time there may be occasions when the use of your text is almost necessary in the solution of problems. You may not remember, for instance, the numbers which are necessary. Under such circumstances you are at liberty to refer to the text of your lesson, but should never do so for principles and laws. If you know and understand a law you can apply it. The purpose of these test questions is to see whether you know and do understand. If you deceive us, even unintentionally, you suffer the consequences, for, unless you are perfectly fair with us, we cannot give you the assistance we should like to render. It is what you know, not what you can take from a book, that we wish to determine. If your papers are not fairly prepared, you lose the best part of that for which you paid when you enrolled in the School.

1. If a given chemical compound consists of carbon and oxygen and the carbon in it weighs 6 grams, what will be the weight of the oxygen?

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* The atomic hypothesis is subject to doubt and controversy, because recently observed facts would seem to prove that atoms are not indivisible. But even if it should be conclusively demonstrated that the atoms are divisible into still smaller particles ("electrons"), the facts upon which the atomic theory is based will, of course, remain unaltered, the atomic weights will be as real as ever; our conception of the atomic structure of molecules will not be materially changed, and the truth of the law of Dulong and Petit will not be shaken. New discoveries concerning the structure of matter may modify the atomic hypothesis and render it clearer, but will not destroy it.

2. How much sulphur can be held in combination by 50 grams of mercury?

3. How much chlorine can be held in combination by 27.5 grams of manganese?

4. How much chlorine can be held in combination by 7 grams of nitrogen?

5. If a mass of 108 grams of a compound of mercury and oxygen be decomposed into its constituent elements, how much will the mercury weigh and how much will the oxygen weigh?

6. Formulate the laws of Dalton concerning chemical combining proportions.

7. What is the atomic theory?

8. How does it explain the law of multiple proportions?

9. What is the molecular weight of any substance?

10. What would you call the minimum relative mass of any element capable of chemical combination with other elements?

11. If the atomic weight of chlorine is 35.5, what is its molecular weight, assuming that its molecules are diatomic?

12. What would be its molecular weight if the molecules are monatomic?

13. If the vapor-density of mercury is 200, what is its atomic weight, assuming that the molecule of mercury contains half as many atoms as are contained in the molecule of hydrogen?

14. What is Avogadro's law?

15. Is the smallest individual particle of any kind of matter capable of independent existence necessarily *the* molecule?

16. If the vapor-density of any given gas is twice as great at 500° as at 1000°, what does that difference indicate?

17. If a certain gas when heated to 2000° doubles in volume, how do you explain that expansion?

18. Can any gas be increased in volume by an increase of temperature without a division of its molecules? If so, what rate of expansion is possible?

19. State the proposition of Gay-Lussac.

20. If you cause 3 liters of oxygen to enter into chemical combination with 6 liters of hydrogen, what will be the compound formed, and how many liters will you obtain of the compound in the state of vapor? Why?

21. State the law of Dulong and Petit.

22. Define specific heat.

23. If you divide the atomic weight of an element by 6.4, what is the relation of the quotient to the specific heat of that element?

24. How can the molecular weight of any substance be verified by its specific heat?

25. How can the molecular weight of any substance be verified by its vapor-density?

LESSON SIX

To the Student:

In this lesson, particularly in the Test Questions, you will find compounds named by abbreviated formulas as a more convenient method than by the full name. From the table of elements given in Lesson Five you learned the symbols of the separate elements. The symbol alone is supposed to represent one atom; thus, H indicates one atom of hydrogen; O, one atom of oxygen. If a small Arabic numeral is placed at the right and a little below this letter, it indicates the number of atoms; as, H_2 means two atoms of hydrogen; O_2, two atoms of oxygen. Water is composed of two atoms of hydrogen and one atom of oxygen, so the formula H_2O names water and indicates also its molecular composition. H_2SO_4 means two atoms of hydrogen combined with one of sulphur and four of oxygen. The compound is sulphuric acid. Bearing these facts in mind, you will have no difficulty in understanding the formulas used in this lesson. A fuller explanation will be made to you later.

VIII

Chemical Polarity

147. Positive and Negative Elements. Metals and hydrogen resemble each other in their chemical behavior. They can take each other's places in many kinds of molecules without radical changes of their general character and structure.

No truly metallic element forms any truly chemical compound by direct union with hydrogen.

All truly non-metallic elements do form chemical compounds with hydrogen.

Water is a compound of hydrogen and oxygen. Hydrogen and oxygen are essentially chemical opposites.

The most decidedly typical metals, *chemically considered*, are the alkali metals—cæsium, rubidium, potassium, sodium and lithium. These metals take the oxygen away from water.

The most decidedly typical non-metallic elements are fluorine, chlorine, bromine and iodine. These take the hydrogen away from water.

When water is decomposed by an electric current, the hydrogen collects at the negative pole of the battery and the oxygen at the positive pole. Hence, as opposites attract each other while likes repel each other, hydrogen is called a positive element and oxygen a negative element.

When a metallic compound is decomposed in a solution, the electric current causes the metal to be collected at the negative pole and the non-metallic element (or the group of non-metallic elements with which the metal was in chemical combination) is collected at the positive pole.

Hence, all true metals are called positive elements, and the non-metallic elements are negative elements *as compared with hydrogen and the metals.*

But while the metals and hydrogen are invariably positive in relation to all other elements, and while oxygen and fluorine are invariably negative in relation to all other elements, the elements boron, carbon, silicon, nitrogen, phosphorus, arsenic, antimony, sulphur, selenium, tellurium, chlorine, bromine and iodine are negative toward the metals and hydrogen, but positive toward oxygen and fluorine.

148. Chemical Polarity. By this term is meant the opposite qualities of elements entering into direct combination with each other. No two elements enter into direct combination unless they are of opposite qualities *with respect to each other.* Only a positive element can enter into direct combination with a negative element, and *vice versa.*

149. Fluorine, chlorine, bromine and iodine have a greater affinity for hydrogen than for oxygen. In fact, fluorine does not enter into combination with oxygen at all, and the other three elements named have but a feeble inclination to combine with oxygen to form certain compounds called salts, in which they are directly united to oxygen, which links them indirectly to positive elements, and these salts, called chlorates, bromates, iodates, perchlorates, periodates, hypochlorites and hypobromites, are all comparatively unstable compounds. Chlorine and iodine are the only two of these four elements that form any oxides.

150. In III, par. 106, it was stated that certain compounds in solution in water undergo dissociation or are split up into two *ions*, the positive ion or *kation* and the negative ion or *anion*. This kind of decomposition or dissociation is called *electrolysis*, and the compounds capable of electrolysis are called *electrolytes*.

The positive electrode of an electrical battery is called the *anode* and the negative electrode is called the *katode*.

When an electrolyte in solution is dissociated into its two ions and a galvanic current is passed through the solution, the positive ion or kation is collected at the katode and the negative ion or anion is collected at the anode.

Water cannot be decomposed by the galvanic current except after adding to it some substance to act as a conductor. Sulphuric acid is used for that purpose. The water can then be decomposed by the electric current, with the result that the hydrogen of the water is invariably collected at the negative pole and the oxygen at the positive pole.

When the chloride of any metal or of hydrogen is dissociated, the metal or the hydrogen is the positive ion and the chlorine is the negative ion.

When potassium chloride, composed of potassium and chlorine, is dissociated, the potassium constitutes the positive ion and the chlorine constitutes the negative ion.

When potassium chlorate, composed of potassium, oxygen and chlorine, is dissociated, potassium again alone constitutes the positive ion, but the oxygen and chlorine together constitute the compound negative ion.

151. Omitting the elements that do not form any chemical compounds (neon, argon, krypton and xenon), and omitting all invariably positive elements (hydrogen and the metals), and the two invariably negative elements (oxygen and fluorine), we find that thirteen non-metallic elements remain which are capable of exercising either positive or negative polarity, or both concurrently. A part of the valence of an atom of carbon, or of nitrogen, or of phosphorus, or of sulphur, may be negative and the remainder positive.

Whenever any one of the thirteen elements, *chlorine*, *bromine*, *iodine*, *sulphur*, *selenium*, *tellurium*, *nitrogen*, *phosphorus*, *arsenic*, *antimony*, *carbon*, *silicon* and *boron*, is in direct combination with hydrogen or with a metal it must be negative; it is positive whenever it is in combination with oxygen or fluorine.

Whenever any two of the thirteen elements named are in combination with each other, then the one named first in the list is negative toward the one named after it. This order is determined by the relative positions of the elements in the periodic system or, in other words, by their respective atomic weights and valences.

Thus, chlorine is negative toward all the other twelve, so that every binary compound* of chlorine is a chloride except its compounds with fluorine or with oxygen, and as the combining value of the negative element in any of its binary compounds is invariably the same, the combining value of the chlorine in every chloride is 1.

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* A "binary compound" is composed of but two elements.

Bromine is negative toward any one of the eleven elements named after it, but positive toward chlorine, fluorine and oxygen. Hence, every binary compound of bromine must be a bromide except its compounds with chlorine or fluorine.* Fluorides and chlorides of bromine can never contain more than one bromine atom, because negative chlorine and fluorine always have the combining value of 1.

Iodine is positive toward chlorine and bromine, but negative toward the other ten elements capable of varying polarity. Iodine has a combining value of 1 whenever it is in combination with any one of those ten, but no fluoride, chloride or bromide of iodine can contain more than one iodine atom, while it may contain one or three or five or seven atoms of F, Cl or Br.

Sulphur is positive toward chlorine, bromine and iodine, but negative toward the other nine; nitrogen is positive toward the halogens and the elements of the sulphur family, but is negative toward carbon; etc.

All the thirteen are negative toward hydrogen and the metals, but positive toward oxygen and fluorine.

Whenever any one of these thirteen elements capable of varying polarity is directly combined with two or more other elements its polarity is still determined by the same natural law. Thus, if nitrogen is in direct combination with both hydrogen and oxygen, as in the compound represented by H_4NOH, in which the nitrogen atom, N, holds four hydrogen atoms and is at the same time in combination with the oxygen atom, O, the nitrogen atom is relatively negative toward the hydrogen, which is positive, but relatively positive toward the oxygen, which is negative. In the molecule H_3CCl the carbon atom, C, is negative to the hydrogen but positive to the chlorine.

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* No *binary* compound of bromine with oxygen is known.

Test Questions

1. Which is the positive element and which the negative element in a compound consisting of boron and hydrogen?

2. Which is the positive element and which the negative element in a compound of copper and arsenic? of sulphur and oxygen? nitrogen and iodine? phosphorus and sulphur? chlorine and bromine? sulphur and carbon? nitrogen and hydrogen? nitrogen and oxygen? antimony and chlorine? antimony and hydrogen?

3. Which is the positive and which the negative ion of potassium iodide?

4. What is electrolysis?

5. What is the difference between the kation and the anion? between the katode and the anode?

6. Name the kation of sodium nitrate ($NaNO_3$); the anion of potassium nitrate (KNO_3).

7. What is the kation of sulphuric acid (H_2SO_4)?

8. What is the positive ion of any acid?

9. Can any element in chemical combination be partly positive and partly negative?

10. Can any element be positive in some of its combinations and negative in other combinations?

11. How can you identify the chemical polarity of any atom in combination?

12. Name the chemical polarity of each of the atoms in $NaOCl$.

13. Which of the following molecular formulas are possible and which are evidently fictitious: IF_5, FCl_3, BrF, BrF_5, $ClBr_5$, ClF_5, IBr_7, BrI_7?

14. Identify the positive and negative elements in the compound represented by H_4NCl and in H_4NONO_2.

LESSON SEVEN

IX

Binary Compounds

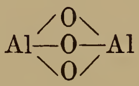
152. A **binary compound** is a molecule composed of but two elements—one positive and the other negative—united to each other in such a way that each atom of one is held in direct combination with each atom of the other.

The most simple chemical compound possible is a binary compound consisting of but two atoms, one atom of each element. As examples of such compounds we may mention sodium chloride, represented by the molecular formula $NaCl$; lime or calcium oxide, represented by CaO; and hydrogen chloride, HCl.

Other binary compounds contain one atom of one element and two of the other; as, for example, water, H_2O, and calcium chloride, $CaCl_2$.

Other binary compounds contain one atom of one element united to three or four or five or six atoms of the other; or two atoms of one united to two, three, five or seven atoms of the other.

But no compound consisting of two elements is truly a binary compound if it contains two or more atoms of one and the same kind directly united to each other. Thus, any compound containing two or more oxygen atoms held to each other, or two or more atoms of carbon directly joined to each other, or two or more atoms of any one other element directly united together, is not a true binary compound. In the compound called hydrogen dioxide there are two hydrogen atoms and two oxygen atoms; the two atoms of oxygen are assumed to be united to each other, and of the two hydrogen atoms one is united to each oxygen atom so that the arrangement of the four atoms may be represented by a chain, thus: HOOH. Hence H_2O_2 is not a true binary compound, although it contains but two elements. But aluminum oxide, Al_2O_3, is a true binary compound, because its two atoms of aluminum are both held to be directly united to all the three oxygen atoms which it contains, as represented by the following structural formula:



153. The names of binary compounds are derived from their negative elements and they are given the ending "—ide." Thus a binary compound of oxygen is called an oxide; all binary compounds of fluorine are called fluorides; all binary compounds of chlorine are called chlorides, except the oxides of chlorine (and the fluorides if any exist); all the binary compounds of bromine are called bromides, except its compounds with chlorine and fluorine;* iodides are the binary compounds formed by iodine with all elements except bromine, chlorine, fluorine and oxygen. All binary compounds of the metals are named after their non-metallic elements, because the metals are invariably positive and any element in direct combination with a metal is consequently negative in such a compound and must be a non-metallic element.

154. The truly binary compounds, then, are of fifteen classes (and only fifteen), according to their negative elements, namely:

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* Bromine does not form any known binary compound with oxygen.

Fluorides,	containing		fluorine.
Oxides,	containing		oxygen.
Chlorides,	containing	negative	chlorine.
Bromides,	“	“	bromine.
Iodides,	“	“	iodine.
Sulphides,	“	“	sulphur.
Selenides,	“	“	selenium.
Tellurides,	“	“	tellurium.
Nitrides,	“	“	nitrogen.
Phosphides,	“	“	phosphorus.
Arsenides,	“	“	arsenic.
Antimonides,	“	“	antimony.
Carbides,	“	“	carbon.
Silicides,	“	“	silicon.
Borides,	“	“	boron.

No other binary compounds are known.

155. True binary compounds containing fluorine, chlorine, bromine or iodine are called **Halides**. They never contain more than one atom of the element united to the negative halogen.

Compounds such as S_2I_2 (consisting of two atoms of sulphur and two of iodine) and Fe_2Cl_6 (composed of two atoms of iron and six of chlorine) exist, but they are not true binary compounds. In S_2I_2 the sulphur atoms are united directly to each other as well as to the iodine (see par. 152). The compound Fe_2Cl_6 is a "double molecule" or a combination of $FeCl_3$ with $FeCl_3$, and it is not understood how these two molecules of $FeCl_3$ are held to each other (unless the iron atoms are tetrads and directly united to each other. The position of iron in the periodic system favors this view).

156. The fluorides, chlorides, bromides and iodides of the metals are all solids at ordinary temperatures. Those of the non-metallic elements are either solids, liquids or gases.

157. **Sulphides** are formed by nearly all elements except oxygen, fluorine, chlorine, bromine, iodine, neon, argon, krypton, and xenon.

The sulphides of metals are solids, and those formed by the heavy metals are all insoluble in water.

The **nitride** of hydrogen is commonly called *ammonia* and is composed of three hydrogen atoms and one nitrogen atom, so that the molecule is represented by the formula H_3N.

The **phosphide** of hydrogen is called *phosphine* and is H_3P. There is also an **arsenide** of hydrogen, H_3As, called *arsine*, and a hydrogen antimonide, H_3Sb, called *stibine*. All of these hydrogen compounds are gaseous.

Saturated hydrogen **carbide** containing but one carbon atom is called "marsh gas," or *methane*, and has the molecular formula H_4C, the carbon atom holding four hydrogen atoms in combination with itself.

Hydrogen **silicide** is H_4Si, and hydrogen **boride** is H_3B.

158. From this chapter the student will perceive that binary compounds have a comparatively simple structure.

No true binary compound can have molecules containing more than nine atoms, as in Mn_2O_7.

X

The Hydroxides, Acids, Bases and Salts

159. The Hydroxides. One atom of hydrogen and one of oxygen united to each other form an atomic group called *hydroxyl*. This group cannot exist alone, but it forms numerous compounds. The compounds which single elements form with hydroxyl are called *hydroxides*.

The symbol for an atom of hydrogen being H and that for the oxygen atom O, the formula representing the radical called hydroxyl is HO or OH.

The most common of all hydroxides is water, for the formula HOH is more significant of the true character of the compound than H_2O. Water is the oxide of hydrogen, but it is also the hydroxide of hydrogen. It is the only compound which is at once both an oxide and a hydroxide.

All *true* acids contain hydroxyl, and several other important classes of compounds also contain the group OH.

160. Acids. Vinegar is acid or sour because it contains *acetic acid.* Lemon juice is sour from *citric acid.* Sour milk owes its sour taste to *lactic acid.* Pie plant contains *oxalic acid.* All acid or acidulous fruits contain some organic acid or some compound formed by it. Sour grapes are *tart* because they contain a compound called *acid tartrate of potassium*, which is formed by *tartaric acid* and which in its purified state is called *cream of tartar*, the sour taste of which is familiar.

Acetic acid, citric acid, lactic acid, oxalic acid and tartaric acid are all *organic acids*, because they are acids contained in or obtained from organic substances, or substances belonging to the vegetable and animal worlds.

But several *inorganic acids* having an even more decidedly sour or acid taste are common. Among them are sulphuric acid, nitric acid, hydrochloric acid and phosphoric acid. The commercial impure strong sulphuric acid was formerly called *oil of vitriol;* nitric acid was known as *aqua fortis*, and impure strong hydrochloric acid was called *muriatic acid.* These names are still used by persons to whom the scientific names are not known. These strong acids are corrosive or destructive in their effects upon numerous other substances, including nearly all vegetable and animal matter. They are therefore poisonous and dangerous and must be handled with great caution. They should never be tasted except after dilution with at least ten times their weight of water, and even after that dilution they are still destructive. Many of the metals dissolve in the strong acids.

Characteristic and strong acids, if water-soluble, have an acid or sour taste, and even after great dilution with water they change the color of blue litmus to red. They lose these properties, partially or entirely, when brought into contact with bases, forming salts which are not destructive in their effects upon other substances.

But not all acids have an acid taste, or corrosive properties, nor do all acids turn blue litmus red. Many acids are insoluble in water and have no taste; others are but feebly acidulous, and affect litmus but slightly. But all acids, however feeble, have the power to overcome the corrosive properties of the strongest alkalies and to form salts. Any substance is an acid if its composition and structure are analogous to those of the sour acids mentioned, and if it forms a salt with any alkali.

Some acids are liquids; others are solids, and still other acids are gaseous.

All acids contain hydrogen. If in any hydrogen compound all or a part of the hydrogen can be replaced by any metal *with the result that a salt is thereby produced*, that hydrogen compound is an acid.

161. Four kinds of so-called acids, and only four, are each composed of only two elements, one of which is hydrogen. They are: hydrofluoric acid, composed of hydrogen and fluorine; hydrochloric acid, composed of hydrogen and chlorine; hydrobromic acid, composed of hydrogen and bromine; and hydro-iodic or hydriodic acid, composed of hydrogen and iodine. They are called *hydrogen acids*, or *hydracids*. But the structure of those compounds differs radically from that of the hydroxyl acids, which contain oxygen as well as hydrogen, and distinction must in any scientific classification be made between the hydrogen acids, which are binary compounds, being the halides of hydrogen, and the hydroxyl acids, which contain more than two elements.

The true scientific names of the so-called hydrogen acids are hydrogen fluoride, hydrogen chloride, hydrogen bromide and hydrogen iodide.

162. Hydroxyl acids are the acids formed by the chemical elements with hydroxyl, or with hydroxyl and oxygen, or with hydroxyl hydrogen and oxygen. All the true inorganic acids are hydroxyl acids. They are also frequently called "oxygen acids."

Boric acid is composed exclusively of boron and hydroxyl and its molecular formula is $B(OH)_3$, because it contains one boron atom united to three groups of OH. Sulphuric acid is written $(HO)_2SO_2$, because it is composed of one sulphur atom, two groups of OH and two additional oxygen atoms. Hypophosphorous acid is written $HOPH_2O$, because it is composed of one phosphorus atom, one group of hydroxyl, two hydrogen atoms, and one oxygen atom.

The organic acids contain the group CO, called *carbonyl*, as well as the hydroxyl group, or they are described as containing COOH, which is called *carboxyl*.

163. Alkalies. "Caustic potash," "caustic soda" and "ammonia" are the principal *alkalies*. Potash and soda are white solids. Ammonia is the gaseous hydrogen nitride, but a water solution of it, commonly called "ammonia" or "water of ammonia," is familiar to most persons.

A solution of caustic potash in water is called "potash-lye," and a solution of caustic soda is "soda-lye." Strong potash-lye and soda-lye are so corrosive and destructive that they "eat into" wood, dissolve flesh, and disintegrate bone. Strong ammonia solutions also attack organic matter in a destructive way.

These alkalies have a burning, caustic, alkaline, lye-like taste; but their destructive character is such that they should not be tasted except after very great dilution with water.

Strong alkalies, being so destructive, and, therefore, also poisonous, must be handled with great caution.

Even after large dilution the solutions of alkalies change the color of red litmus to blue.

164. Opposite Properties of Acids and Alkalies. While the strong acids and the strong alkalies are alike destructive in their effects upon animal and vegetable tissues, they are chemically opposites, for, when an acid and an alkali are mixed together in certain definite proportions, the corrosive or destructive properties of each are entirely removed or neutralized, the power of the acid to turn blue litmus red and that of the alkali to turn red litmus blue is taken away, and the sour taste of a strong acid is overcome by the alkali and the alkaline taste of the alkali is overcome by the acid, the product of the two having a taste altogether different from that of either acid or alkali.

When acids and alkalies mutually neutralize or saturate each other they form a new compound called a *salt*. But the corrosive or destructive action and other properties of a strong acid are never diminished by the addition of another acid, nor are the characteristic properties of a strong alkali changed or diminished by the addition of another alkali or a base.

165. Experiments to Prove the Opposite Properties of Acids and Alkalies. Take a small quantity of vinegar, which is diluted acetic acid, or of any other diluted acid, and dip a strip of blue litmus paper in it; it will turn the paper red. Taste the diluted acid and note its sour taste.

Dip a strip of red litmus paper in some diluted ammonia water; it will turn the paper blue. Taste the diluted ammonia and note its lye-like taste.

Add ammonia water gradually to a little of the vinegar and test the mixture repeatedly with blue litmus paper. Observe that the power of the vinegar to turn the blue litmus paper red is gradually lessened as more ammonia is added, and that finally, when enough ammonia has been used, the mixture does not change the color of the blue litmus paper at all. When this point has been reached the liquid has no longer a sour taste. If the quantity of ammonia added is just sufficient to neutralize the acetic acid, the liquid will neither turn blue litmus paper red nor red litmus paper blue, and the taste of the mixture will be neither that of vinegar nor that of ammonia, but a saline taste which is altogether different. If an excess of ammonia is added the liquid will then turn red litmus blue and its taste will be that of the ammonia.

If the order of mixing be reversed, the vinegar being gradually added to the ammonia, then the power of the ammonia to turn red litmus paper blue will be gradually weakened and will be completely overcome as soon as enough vinegar has been added; and if more vinegar is added the liquid will acquire the power to turn blue litmus red and will then have an acidulous or acid taste, imparted by the excess of acetic acid.

Like results will be obtained whatever may be the kind of acid used or the kind of alkali or base.

As alkali carbonates also have the property of neutralizing acids, the experiment may be made with baking soda or sodium bicarbonate instead of ammonia.

166. Bases. By a *base* is meant, in inorganic chemistry, any hydroxide (or any oxide) having the power to neutralize acids and form salts by reaction with them.

The alkalies are accordingly bases, for they are hydroxides capable of neutralizing acids and forming salts with them. The alkalies are in fact the strongest bases known.

But very few bases have decidedly alkaline properties.

Only the water-soluble metallic hydroxides and ammonia solutions are called alkalies.

Most of the inorganic bases are not only insoluble in water, but on that account tasteless and apparently chemically inert in their behavior toward other substances, except the acids and some of the non-metallic elements. Insoluble metallic oxides and hydroxides do not change the color of litmus at all; but they have the power wholly or partly to neutralize acids, and to form salts with them.

The great majority of bases are solids; but some are liquid and others gaseous. The metallic bases are all solids.

167. Basic Properties and Functions. The most important characteristic property of bases is their power to form salts with the acids. This property or function is in any metallic base due to the metal or *basic element* in it. All metals having oxides or hydroxides which exhibit basic properties are said to have the power to exercise the *basic function.* In fact, any metal which forms any salt with any acid exercises a basic function in the formation of that salt, whether any oxide or hydroxide of that metal exists or not.

168. Acidic Properties and Functions. The property of acids to form salts with the bases, or to exchange their hydrogen, or a part of it, for a metal, thereby forming salts; is their most important characteristic. It is due to the acidic element or acidic atomic group contained in the acid.

The true inorganic acids are compounds formed by an *acidic element* with hydrogen and oxygen. The acidic element of the most strikingly characteristic acids is a non-metallic element. In fact, all non-metallic hydroxides are acids. But several of the metals also have the power to form acids or to exercise the acidic function under certain conditions.

Sulphuric acid is composed of hydrogen, oxygen and sulphur; the sulphur is the acidic element and performs the acidic function in that acid. Nitrogen is the acidic element of nitric acid, which is composed of hydrogen, oxygen and nitrogen. Carbon is the acidic element in carbonic acid; phosphorus in phosphoric acid; chromium in chromic acid; chlorine in chloric acid; arsenic in arsenous acid; etc.

169. Salts are chemical compounds formed by the acids with the bases.

As the inorganic bases are either oxides or hydroxides of the metals, it follows that the inorganic salts are all metallic compounds or contain metals in chemical combination.

The metallic salts formed by the inorganic acids, therefore, generally contain three elements—the basic element, the acidic element and oxygen.

In the salt called potassium nitrate the basic element is potassium, the acidic element is nitrogen, and the third element is the oxygen; the formula is commonly written KNO_3, because it contains one atom of each of potassium and nitrogen, but three atoms of oxygen. In sulphate of copper the basic element is copper, the acidic element sulphur, and the common formula is $CuSO_4$. In permanganate of potassium the basic element is potassium, and the acidic element manganese; the common molecular formula is $KMnO_4$.

But a salt may contain more than one basic element, as in $AlK(SO_4)_2$; or hydrogen as well as metals, as in Na_2HPO_4; or hydrogen united directly to the acidic element, as in $NaPH_2O_2$.

The difference between the composition of a hydroxyl acid and a metallic salt formed by such an acid is that the acid contains hydrogen instead of the metal and the salt contains metal instead of the hydrogen or part of it. The composition of sulphuric acid is expressed by the common formula H_2SO_4, and the composition of its potassium salt, called potassium sulphate, is expressed by the formula K_2SO_4.

The acids may, therefore, be consistently regarded as the salts of hydrogen, with hydrogen performing the basic function.

170. Halides. The compounds formed by the action of "hydrogen acids" upon the bases are called *halides.* Their structure is radically different from that of the true salts or oxygen salts described in the preceding paragraph, formed by the true acids or hydroxyl acids, for the metallic halides contain only two elements, one of which is either fluorine, chlorine, bromine or iodine, while the other is a metal. The halides are scientifically called the fluorides, chlorides, bromides and iodides of the metals.

As to structure, the halides formed by the metals are perfectly analogous to the fluorides, chlorides, bromides and iodides of the non-metallic elements. The structure of trichloride of phosphorus is represented by PCl_3 and that of chloride of aluminum by $AlCl_3$.

171. Scientific classification and nomenclature are necessary to a clear understanding of the composition and structure of matter. Many of the common names applied to chemical compounds are unfortunately unscientific, inconsistent, or misleading.

Solid substances made by early chemists were commonly called salts if they resembled sodium chloride in outward form and appearance, and especially if they were soluble in water. But many substances that look like salts are not salts at all, as, for instance, boric acid, oxalic acid, ice, snow, rock candy, and numerous other common kinds of matter. On the other hand, glass, olive oil, chalk, marble, limestone, clay, soap, oil of wintergreen and butter, none of which bear any outward resemblance to our common salt or sodium chloride, are really all of them salts, for they have the chemical structure of salts, and are formed by acids with bases. Sodium chloride is not a true salt, because it does not have the structure of a salt, but is a simple binary compound, whereas all true salts contain at least three elements.

172. The names of salts are derived from the names of the acids by which they are formed. Thus all salts formed by nitric acid are called nitrates; those formed by sulphuric acid are called sulphates; those of phosphoric acid are phosphates; acetic acid forms acetates; carbonic acid, carbonates; oxalic acid, oxalates; citric acid, citrates; tartaric acid, tartrates; and chloric acid, chlorates. Nitrous acid forms nitrites; sulphites are the salts of sulphurous acid; and the salts of arsenous acid are called arsenites.

173. As the salts are generally produced out of the acids and bases, so the salts can be decomposed again and the acids and bases of which they were made reproduced, or one salt may be transformed into another salt by chemical means. Nitric acid can be made from nitrates, sulphuric acid from sulphates, acetic acid from acetates, nitrous acid from nitrites, etc.

174. Some Familiar Salts. *Saltpeter* is potassium nitrate, or the potassium salt of nitric acid, and is composed of potassium, nitrogen and oxygen.

Washing soda is sodium carbonate, or the sodium salt of carbonic acid, and is composed of sodium, carbon and oxygen.

Baking soda is another sodium salt of carbonic acid. It is called "bicarbonate of sodium" or "acid carbonate of sodium," because in this sodium carbonate there is but one sodium atom, while in the other there are two, so that the quantity of the group CO_3 *in proportion to sodium* is twice as great in the bicarbonate. The composition of sodium carbonate is commonly represented by Na_2CO_3; that of the bicarbonate by $NaHCO_3$.

Epsom salt is magnesium sulphate, or the magnesium salt of sulphuric acid, composed of magnesium, sulphur and oxygen.

Green vitriol is one of the iron salts of sulphuric acid, or, in other words, a sulphate of iron.

White vitriol is zinc sulphate, and *blue vitriol* is copper sulphate.

True *alum* is a double sulphate; it has two basic elements, namely aluminum and potassium.

Limestone, *chalk* and *marble* are all different forms of calcium carbonate.

175. An elementary lesson in the chemistry of limestone will serve to show the relations of oxides, hydroxides, acids, bases and salts to one another.

When calcium carbonate (limestone) is strongly heated or "calcined" in a limekiln it is decomposed into calcium oxide or "lime" and carbon dioxide, which is a colorless gas. *Lime* or calcium oxide is caustic and destructive to animal and vegetable tissues. It is a powerful basic oxide.

When water is added to lime the two substances act upon each other chemically and *calcium hydroxide* is formed. This is strongly alkaline, and turns red litmus blue.

When *carbon dioxide* is collected in water it forms *carbonic acid* with the water, and carbonic acid turns blue litmus paper red.

Now if either the calcium oxide ("quick lime") or the calcium hydroxide ("slaked lime") be exposed to the action of the carbon dioxide ("carbonic acid gas") or to the carbonic acid solution, we will get calcium carbonate back again. This does not change the color of either blue or red litmus paper.

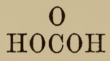
But although calcium oxide and water may be said to unite to form calcium hydroxide, and although this calcium hydroxide when strongly heated splits up again into calcium oxide and water, there is in reality neither water nor calcium oxide in the calcium hydroxide.

And although carbon dioxide and water form carbonic acid together, and although carbonic acid may be easily split up so as to form water and carbon dioxide, carbonic acid is not composed of water and carbon dioxide.

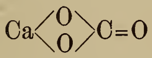
To the beginner in chemistry these statements doubtless must appear paradoxical; but there will be no difficulty in understanding them by the aid of symbolic formulas.

Water is composed of two hydrogen atoms and one oxygen atom, the two hydrogen atoms being both of them united directly to the oxygen atom, so that the molecular formula is best represented as HOH. But there is no HOH in either carbonic acid or in calcium hydroxide.

If calcium be represented by Ca, hydrogen by H, oxygen by O, and carbon by C, then the relative positions of the several atoms composing calcium oxide, water, calcium hydroxide, carbon dioxide and carbonic acid, respectively, may be pictured as follows:

CaO	HOH	$HOCaOH$
Calcium Oxide.	Water.	Calcium Hydroxide.
OCO	HOH	 $HO\overset{O}{C}OH$
Carbon Dioxide.	Water.	Carbonic Acid.

If sulphuric acid be added to calcium carbonate we get calcium sulphate water and carbon dioxide:



$$Ca\langle{}^{O}_{O}\rangle C{=}O \quad + \quad (HO)_2SO_2 \quad = \quad CaO_2SO_2 \quad +$$

Calcium Carbonate. Sulphuric Acid. Calcium Sulphate.

$$HOH \quad + \quad OCO$$

Water. Carbon Dioxide.

Test Questions

1. Which of the following formulas represent binary compounds and which of them do not represent such compounds: Fe_2O_3, $Fe(OH)_3$, H_2S_2, Ag_2O ?

2. What name would you give a binary compound containing tellurium ?

3. What is the negative element in a phosphide ? What is the positive element in an arsenide ?

4. To what class of compounds would you refer a substance

composed of copper and sulphur? To what, a substance composed of copper and zinc?

5. What kind of a compound is KOH? MnO_2?

6. What is HO? H_2O? H_2O_2?

7. What is your understanding of what constitutes an acid?

8. What is the true scientific name of hydrobromic acid?

9. What elements are contained in all true acids, as well as in all alkalies? Mention six acids; three alkalies.

10. What is the difference between a base and an alkali?

11. What elements can exercise basic functions? Can any metals exhibit acidic properties?

12. What is the basic element of caustic soda? of caustic potash?

13. What is the acidic element of boric acid? of carbonic acid? of chloric acid? of iodic acid? of antimonic acid? of permanganic acid? What is a salt?

14. What is the common name of hydrogen borate?

15. What is the difference between hydrogen chlorate and potassium chlorate?

16. What is a halide? a phosphite? a phosphate? a sulphite? a sulphate? an arsenite?

17. What is baking soda, chemically considered? What is the difference between baking soda and washing soda?

18. What is the difference between green vitriol, blue vitriol and white vitriol?

19. Mention three common forms of calcium carbonate.

20. What is the difference between lime and limestone? between lime and slaked lime? between carbon dioxide and carbonic acid? between carbonic acid and chalk?

21. What is the difference between water and calcium hydroxide?

LESSON EIGHT

XI

Atomic Valence

176. The number of atoms of any one kind which can be held in combination by any given number of atoms of any other kind is subject to natural law. Thus, for example, the number of hydrogen atoms which can be held in direct chemical combination by a single atom of any one other element in a binary compound is a constant number. One atom of either fluorine, chlorine, bromine or iodine can hold in combination with itself only one hydrogen atom; one atom of either oxygen, sulphur, selenium or tellurium can hold neither more nor less than two hydrogen atoms in combination with itself; a single atom of nitrogen, phosphorus, arsenic, antimony or boron can hold in combination with itself neither more nor less than three hydrogen atoms; and neither more nor less than four hydrogen atoms can be held in direct combination by a single atom of either carbon or silicon *to form a binary compound.*

No one single individual atom of any kind can hold in direct combination with itself more than four hydrogen atoms.

The individual combining value of one single atom of any given element as compared with the combining value of one single atom of any other given element is called its **valence.** It is also called the combining power, or combining value, or saturating capacity, or saturation value, or valency, or quantivalence of the element.

177. The *hydrogen valence* of an element is the number of hydrogen atoms which a single atom of the element can hold in direct combination with itself, when united by all of its combining power directly or exclusively to hydrogen.

From the preceding paragraphs it will be seen that the hydrogen valence of any given element is constant and that it may be 1, 2, 3 or 4, but can in no case exceed 4.

178. To find the *oxygen valence* of any element the following rule is generally applicable: *Divide the number of oxygen atoms contained in one molecule of the oxide of the element by one-half the number of the other atoms in the same molecule.*

By the application of this rule we find from K_2O that the oxygen valence of K is 1; from CaO that the oxygen valence of Ca is 2; from Al_2O_3 that the oxygen valence of Al is 3; from CO_2 that the oxygen valence of the C in that compound is 4; from CO that the oxygen valence of the C in CO is 2. We find that the oxygen valence of the N in N_2O is 1, that it is 2 in NO, 3 in N_2O_3, and 5 in N_2O_5.

But we cannot discover the oxygen valence of the Fe in the compound expressed by the formula Fe_3O_4 by the application of the rule given, because Fe_3O_4 is not a true binary compound, but either a combination of two molecules —FeO and Fe_2O_3—or it may be a salt (Fe_2O_4Fe, or Fe_2FeO_4).

179. The valence of the hydrogen atom is invariably 1, because the hydrogen atom is the adopted standard of comparison. Thus, the valence of any other atom is the number of hydrogen atoms which it equals in combining power, or the number of hydrogen atoms for which it can be exchanged, or the number of hydrogen atoms which it is capable of holding in combination.

180. The valence of the oxygen atom in combination is invariably 2. Hence any single atom of any other element which holds in direct combination with itself one single atom of oxygen must also have a valence of 2. (Compare this statement with par. 178.)

181. The following named elements have a constant valence:

The valence of H, Li, Na, K, Rb, Cs, Ag and F is invariably 1.

The valence of Be, Mg, Ca, Sr, Ba, Zn, Cd and O is invariably 2.

The valence of Al and B is invariably 3.

182. The highest possible valence attainable by any atom is 8. But only two elements are known to attain that valence, namely Os and Ru.

Whenever any atom attains a valence exceeding 6 it is in combination with oxygen.

No single atom of any element can hold in direct combination with itself more than four oxygen atoms *to form a binary compound.*

No single atom of any element can hold in combination with itself more than six chlorine atoms.

183. Bonds. The term *bond* is very conveniently employed to express the unit of valence.

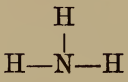
Thus we say that the hydrogen atom, having a valence of 1, has 1 bond. The oxygen atom has 2 bonds, because its valence is 2. The atom of Os has 8 bonds in the compound OsO_4. Sulphur has 6 bonds in SO_3. Carbon has 4 bonds in CO_2.

184. Atoms having an even number of bonds (2, 4, 6 or 8) are called *artiads;* atoms having an odd number of bonds (1, 3, 5 or 7) are called *perissads.*

Atoms	having	a valence of	1	are	called	monads	and	have	1	bond
“	“	“	2	“	“	diads	“	“	2	bonds
“	“	“	3	“	“	triads	“	“	3	“
“	“	“	4	“	“	tetrads	“	“	4	“
“	“	“	5	“	“	pentads	“	“	5	“
“	“	“	6	“	“	hexads	“	“	6	“
“	“	“	7	“	“	heptads	“	“	7	“
“	“	“	8	“	“	octads	“	“	8	“

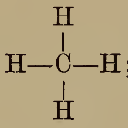
Monads are univalent.
Diads are bivalent.
Triads are trivalent.
Tetrads are quadrivalent.
Pentads are quinquivalent.
Hexads are sexivalent.
Heptads are septivalent.
Octads are octivalent.

185. The manner in which atoms are held in combination with each other in the formation of molecules may be represented by picturing their bonds as connecting links between them. Using lines to represent the bonds or units of valence, we may readily see that HCl is H— —CL; that H_2O_2 must be represented as H—O—O—H; that H_3N and H_4C must be



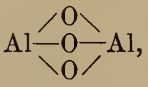
$$\begin{array}{c} H \\ | \\ H—N—H \end{array}$$

and

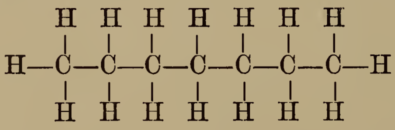


$$\begin{array}{c} H \\ | \\ H—C—H \\ | \\ H \end{array}$$

; that Al_2O_3 must be



, and that C_7H_{16} may be represented as



$$\begin{array}{ccccccccccccccc} & & H & & H & & H & & H & & H & & H & & H \\ & & | & & | & & | & & | & & | & & | & & | \\ H & — & C & — & C & — & C & — & C & — & C & — & C & — & C & — & H \\ & & | & & | & & | & & | & & | & & | & & | \\ & & H & & H & & H & & H & & H & & H & & H \end{array}$$

The student must keep in mind that the term "bond" is used only in a figurative sense to express *units of valence*, and that atoms are not possessed of any links, or ligaments, arms, projections, handles, or points of attachment, by which they may be tied or united or held to each other.

186. Atomic Linking. The relative positions of the atoms in a molecule and the way in which they are held to each other according to their respective valences is called the *atomic linking* of the molecule. It is of supreme importance as the only means at present known by which the structure of chemical compounds may be understood and the compounds themselves scientifically classified, especially in organic chemistry.

187. Variable Valence. A variable atomic combining value or valence is possible only to atoms exercising positive polarity, or, in other words, to atoms having positive bonds.

188. All atoms of exclusively negative polarity have a constant valence, or a fixed valence according to their kind. Thus, negative fluorine, chlorine, bromine and iodine are invariably monads; atoms of sulphur, selenium and tellurium are invariably diads whenever their bonds are all negative; boron, nitrogen, phosphorus, arsenic and antimony atoms invariably have three bonds whenever all their bonds are negative; carbon and silicon atoms invariably have four bonds whenever their bonds are all of negative polarity. See also paragraphs 176 and 177.

189. All bonds by which hydrogen is held in combination must be negative bonds, because hydrogen itself is invariably of positive polarity in all its compounds.

190. All bonds by which oxygen is held in combination must be positive bonds, because all the bonds of oxygen itself are invariably of negative polarity in all its compounds.

191. The valences of *positive* elements are found from the composition of their oxides, chlorides and salts.

The valence of any *negative* element is the number of hydrogen atoms which one single atom of it can hold in combination.

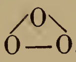
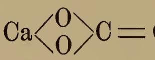
192. It is evident that any atom having but one bond can be in combination with only one other atom, as in KCl, HBr, or AgI.

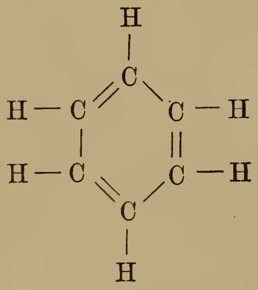
Any atom having two bonds, as, for instance, the oxygen atom, can hold either one other atom having the same number of bonds, as in CaO, or two other atoms having one bond each, as in HOH and KOH.

Any atom having three bonds can hold in combination either one other atom having three bonds, as in BN; or one atom having two bonds and another having one bond, as the Bi in OBiCl or the N in H_2NHgCl, or it can hold three atoms having one bond each, as in H_3N or NI_3.

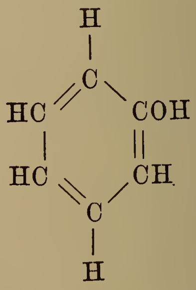
Any atom having four bonds may hold four other atoms having one bond each, as in H_4C, CCl_4, H_3CCl, H_2CCl_2, $HCCl_3$, etc.; or it may hold one other atom having three bonds and one having but one bond, as the C in HCN; or it may hold two other atoms having two bonds each, as the C in OCO, or CO_2.

Any atom having five bonds may hold one other atom with four bonds and one with but one bond; or it may hold five other atoms with one bond each; or any number of other atoms having a total of five bonds.

Other combinations possible are shown in WCl_6, N_2O_5, Mn_2O_7, and in ,  $Ca\left\langle {}^{O}_{O} \right\rangle C=O$ and



and



193. There can be no free or uncombined bond in any molecule.

194. The total number of bonds in any molecule must be an even number, and one half of the whole number must be positive bonds and the other half negative bonds, for every bond must be met by and united to another bond of opposite polarity.

XII

The Algebraic Combining Numbers of Atoms

195. While the valence of an atom is the number of its bonds in actual combination, there is clearly a radical difference between an atom having only positive bonds incapable of assuming negative polarity, another atom having only negative bonds incapable of assuming positive polarity, and a third atom having both positive and negative bonds, even if the total number of bonds of each atom be the same.

Metals and hydrogen can be held in combination with other elements only by negative bonds. Oxygen and fluorine can be held in combination with other elements only by positive bonds. Atoms having both positive and negative bonds can hold metals or hydrogen by their negative bonds, and at the same time oxygen by their positive bonds.

To indicate such differences the positive bonds may be designated by the plus sign (+) and the negative bonds by the minus sign (–). If we then add together *algebraically* all the bonds of any one atom in actual combination, the sum will express truly the real combining value of that atom. The writer of this book has elsewhere called this sum the "polarity-value" of the atom. It may also be called the **algebraic combining number** of the atom.

196. The algebraic combining number of any atom having only positive bonds, or one having a greater number of positive than of negative bonds, is of course a plus quantity. The algebraic combining number of any atom having only negative bonds, or one having a greater number of negative than of positive bonds, must be a minus quantity. And the algebraic sum of any atom having an equal number of positive bonds and negative bonds must be 0.

197. By this method we will be able to see clearly that the range of true combining value possible to any one atom never exceeds 8 units. Thus the lowest algebraic combining number of the chlorine atom is –1, for negative chlorine is always a monad; and the highest combining number of chlorine, shown in $KClO_4$, is +7, because the four oxygen atoms together have 8 negative bonds and hence the K and Cl must together have 8 positive bonds, of which only 1 belongs to the potassium. The same range is seen in iodine.

The lowest algebraic combining number of sulphur is –2, which is its value in all sulphides; and its highest algebraic combining number is +6, as in SO_3.

The lowest algebraic combining number of nitrogen, as shown in ammonia (H_3N) and in all ammonium compounds, is –3; and its highest combining value, as shown in N_2O_5 and in the nitrates, is +5.

The nitrogen has an algebraic combining number amounting to –3 in all ammonium compounds, as may be shown here by one example. The molecule of ammonium chloride is H_4NCl; hence the nitrogen atom here has four negative bonds which hold the positive hydrogen atoms in combination and one positive bond holding the negative chlorine atom, and the sum of –4 and +1 is –3.

The lowest algebraic combining value of carbon is –4, as shown in H_4C; its highest combining value is +4, as shown in CO_2.

In all the cases referred to it will be seen that the total range, from highest to lowest, of the algebraic combining value of each element is just 8 units.

That this is not mere chance but the result of natural law may be inferred from the fact that the quantity of any oxidizing agent required to increase the algebraic combining number of any atom from +1 to +5 is the same as the quantity required to increase it from –4 to 0, or from –1 to +3, or from –2 to +2, or from –3 to +1, or from +2 to +6, or from +3 to +7, and it is twice as great as the quantity of oxidizing agent required to raise the algebraic combining number of any atom from –4 to –2, or from –2 to 0, or from 0 to +2, or from +1 to +3, etc. To increase the algebraic combining number of nitrogen from –3 to +5, as when ammonia is converted into nitric acid, requires just 8 units of oxidizing power, and to change H_2S into H_2SO_4 also requires just 8 units of oxidizing power, because the value of the sulphur in H_2S is evidently –2 and that of the sulphur in H_2SO_4 is evidently +6 (see next paragraph).

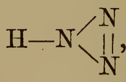
198. As one half of all the bonds of all the atoms composing any molecule are positive bonds and the other half negative bonds, it follows that the algebraic sum of all must in every case be 0. If, therefore, the algebraic combining number of two out of three elements in any molecule be known, the combining number of the third is easily found, for it must be in every case the difference between 0 and the algebraic sum of the combining numbers of the other two.

In H_2SO_4 we have eight negative oxygen bonds, because each of the four oxygen atoms has two negative bonds; the two hydrogen atoms have together two positive bonds; the sulphur atom must, therefore, have six positive bonds, for –8 and +2 and +6 added together make the sum of 0.

199. The algebraic combining number of any free atom is of course 0. It cannot be known how many bonds any atom has, nor what its polarity is, except from its actual combinations, for we have seen that many elements have a variable valence and at least thirteen elements are positive in some compounds and negative in others. Thus, a free chlorine atom is neither positive nor negative and its actual combining number is 0. If it enters into chemical combination with hydrogen, or with any metal, it then assumes negative polarity, and its algebraic combining number will be −1; but if it enters into direct combination with oxygen in the formation of molecules of NaOCl, the chlorine atom assumes positive polarity and its value will be +1, and if it forms $KClO_3$ the chlorine assumes an algebraic combining number of +5.

The carbon atom in any carbon compound usually has 4 bonds. In the free or uncombined state its algebraic combining number is 0. When it is united to four hydrogen atoms, H_4C, the carbon atom has a combining number of −4; if it holds three (positive) hydrogen atoms and one (negative) chlorine atom, H_3CCl, its value is −2; if it holds two (positive) hydrogen atoms and two (negative) chlorine atoms, H_2CCl_2, its value is 0; if it holds one hydrogen atom and three chlorine atoms, its value is −2.

200. Whenever two atoms of the same element are directly united to each other it must be assumed that they are held to each other by bonds of opposite polarities. Hence it follows that one of the hydrogen atoms in a molecule of hydrogen (composed of two atoms) must be positive and the other negative. In a molecule of oxygen containing two atoms of that element we must conclude either that each atom has one positive and one negative bond or that one has two positive bonds and the other two negative bonds, for the algebraic sum of all the bonds in any molecule must always be zero.

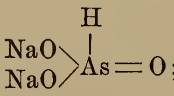
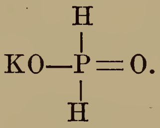
201. In the molecule HN_3 it is impossible to escape the conclusion that the atomic linking must be  $H{-}N\left\langle\begin{matrix}N\\ \| \\ N\end{matrix}\right.$, which shows that the hydrogen atom with its one positive bond is united to one of the nitrogen atoms by one negative nitrogen bond, while of the other six nitrogen bonds three are positive and the other three negative.

In HOOH we assume that the algebraic sum of the bonds of both oxygen atoms together must be -2, because the hydrogen atoms together must be $+2$ and the total must be 0; hence one of the oxygen atoms must have one positive and one negative bond and the other oxygen atom must have two negative bonds. The two bonds by which the two oxygen atoms are held to each other must therefore be one of them positive and the other negative. We must assume that *the algebraic sum of the bonds by which any two atoms of the same element are held in direct combination with each other is always zero, because one half of them must be positive and the others negative.*

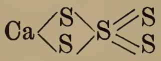
202. To find the algebraic combining number of any atom in any molecule of simple structure is usually an easy task, unless two or more atoms of one and the same element are directly united to each other. The student can readily find the combining numbers of combined elements from the atoms known to have constant values, such as H, K, Na, Li, Ba, Sr, Ca, Mg, Al, B, Ag, Zn, and F; also from the oxygen in any molecule, unless two oxygen atoms are united directly to each other; also from the negative atoms of chlorine, bromine, iodine, sulphur and nitrogen.

Since a varying algebraic combining number is possible only to elements having positive polarity, the student should find the algebraic combining numbers of any atom of such an element from the atom or atoms with which it is in direct combination; or, in other words, from any atoms in the molecule the algebraic combining values of which are constant and, therefore, known.

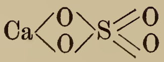
203. The algebraic combining number of the acidic element in any inorganic acid composed of that element together with hydrogen and oxygen, is found by deducting the algebraic sum of the oxygen and hydrogen bonds from 0. The oxygen atoms in the molecule of such an acid are the only atoms having exclusively negative bonds; the hydrogen atoms are all positive, and either all or a majority of the bonds of the acidic element are positive.

In HNO_3 the N must have five positive bonds; in H_3PO_4 the P must have five positive bonds. But in Na_2AsHO_3 the As has an algebraic combining number of only +3, although it has five bonds, for the structure of the molecule is known to be  $\begin{matrix}NaO\\NaO\end{matrix}\!>\!\overset{\overset{H}{|}}{As}=O$; and in KPH_2O_2 the P has an algebraic combining number of only +1, although it has five bonds, because the structure is  $KO-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{P}}=O$.

204. In the molecule commonly but erroneously written CaS_5 we know that the algebraic sum of all the bonds of the five sulphur atoms must be –2, because Ca (as shown by its position in the periodic system) can never have any other value than +2. No compound of calcium is known in which that metal has any other combining value than 2. It follows that the two positive calcium bonds must be in combination with two negative sulphur bonds and that of all the remaining sulphur bonds one-half must be positive and one-half negative. This leads to the structural formula



in which the central sulphur atom is acidic and has six positive bonds, while all the other sulphur atoms each have two negative bonds, the molecule being perfectly analogous to $CaSO_4$, which has the structure

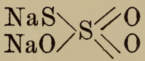


There is a molecule erroneously written K_2S_3 which has the structure

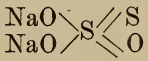
K—S—S—S—K.

In this molecule the central sulphur atom is acidic and has a combining value of +2, while all the other four sulphur bonds are negative, because the structure is perfectly analogous to that of KOSOK.

There is a compound erroneously called "hyposulphite of sodium," which is commonly represented as $Na_2S_2O_3$. But with the aid of our conception of the algebraic combining numbers of the component atoms of molecules we can readily see that the structure must be



or



and chemists now write it Na_2SO_3S, to show that one sulphur atom performs the acidic function while the other performs the same function as any of the oxygen atoms in Na_2SO_4.

205. The algebraic sum of all the carbon bonds in any molecule composed of carbon, hydrogen and oxygen (and a vast majority of organic substances are composed of those elements) is at once found by subtracting the algebraic sum of all the bonds of the atoms of hydrogen and oxygen from 0. It is further known that all the carbon atoms in such compounds have each four bonds. The total number of positive

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carbon bonds and the total number of negative carbon bonds can, therefore, be readily found. It is also known that the algebraic sum of all bonds by which any of the carbon atoms are united to each other must be 0. These facts are helpful in determining the actual atomic linking.

Test Questions

1. Define valence.
2. What is the valence of the boron in H_3B? in B_2O_3?
3. What is the difference arithmetically between the valence of the boron in H_3B and in B_2O_3?
4. What is the difference between the algebraic combining number of the boron in H_3B and the boron in B_2O_3?
5. What are the respective valences of the elements forming a binary hydrogen compound?
6. How do you find the valence of each of the two elements in any oxide?
7. Can you name an element having a valence of 10?
8. What is the number of chlorine atoms in the chloride of an element having a valence of 8?
9. What is the number of hydrogen atoms in the hydride of an element having a valence of 6?
10. How many chlorine atoms are there in the chloride of a heptad?
11. How many oxygen atoms are there in the oxide of a tetrad and how many in the oxide of a pentad?
12. Name two octads.
13. How many bonds has a potassium atom?
14. How many bonds has aluminum?
15. Name the number of bonds of the zinc atom.
16. Draw a figure showing the atomic linking of As_2O_3; C_2H_6.

17. Under what circumstances can the valence of an element vary?

18. State the number of bonds of each element in the molecule OSbCl.

19. State the number of bonds of each element in (a) KNO_3; (b) $Na_4P_2O_7$; (c) $CaSO_4$; (d) CaH_2SO_5; (e) H_5PO_5; (f) H_3PO_4; (g) HPO_3; (h) H_3PO_3; (i) HPO_2; (j) HPH_2O_2; (k) H_2PHO_3; (l) $KMnO_4$; (m) K_2MnO_4.

20. State which of the following molecular formulas are right and which are wrong: (a) $AgCl_3$; (b) KO; (c) Mg_2O_3; (d) H_3O; (e) Na_2S_5.

21. What is the valence of the sulphur in SO_2 and what is the algebraic combining number of each of the two elements in that molecule?

22. What is the algebraic combining number of the sulphur in H_2S?

23. What is the difference between the valence of the sulphur in H_2SO_2 and in H_2S and what is the difference between the algebraic combining number of the S in those two molecules?

24. What is the algebraic combining number of the N in HNO_3 and in H_4NBr?

25. What is the algebraic sum of the carbon bonds in $C_6H_{10}O_5$?

26. What is the algebraic combining value of the Br in a bromide?

27. Can bromine under any circumstances have a higher algebraic combining number, and if so, when?

28. If the valence of sulphur, with negative polarity, is 2, what is the highest possible algebraic combining number of sulphur?

29. If zinc phosphide is Zn_3P_2, then what is the highest possible algebraic combining number of phosphorus?

30. What is the algebraic combining number of uncombined carbon?

31. State the algebraic combining numbers of the three different elements in $Na_2S_2O_3$.

32. What is the algebraic sum of the carbon bonds in $HC_2H_3O_2$?

LESSON NINE

XIII

Chemical Notation

206. We have already made use of several chemical symbols and self-explanatory formulas. Before proceeding further we will now learn something of the principles governing the construction of symbolic formulas.

In order to represent at a glance the composition and structure of molecules a **system of chemical notation** was invented by Berzelius, which is still in use, modified and adapted to correspond to the development of the science of chemistry since his day.

207. Each atom of any given element is represented by a specific **symbol** unlike the symbol of any other element. The symbol consists of one or two letters which are the initials of the latinic or other names of the elements. Two letters are used for some of the symbols in cases where the names of two or more elements begin with the same letter. The additional letter used is not always the second letter of the name, but one which will best serve to make the symbol distinctive. As the names of chlorine and chromium both begin with Ch, their symbols are made Cl and Cr.

The first letter of any symbol of two letters is a capital letter; the second is not.

208. The symbol of any element stands not merely for its name, but for one atom of it and for its atomic weight or combining mass.

Thus S, the symbol for sulphur, means one atom of sulphur and also 32 parts of sulphur.

209. Symbolic formulas are constructed out of one or more symbols together with one or more numerals, or of two or more symbols with or without numerals.

KI is a symbolic formula because it is composed of two symbols, K and I; Cl_2 is a formula because it is composed of a numeral as well as a symbol; 2Cl is also a formula for the same reason; O_3, H_2O, $CaCl_2$ and HNO_3 are also symbolic formulas.

Symbolic molecular formulas of compounds are so constructed that they show not only all of the elements composing them but the number of atoms of each.

210. The numerals used are of two kinds—large and small.

A large numeral placed in front of a symbol multiplies it, but it also indicates that the atom represented by the symbol is a free or uncombined atom. Thus 9O means nine oxygen atoms not united to one another. A small numeral placed after a symbol also multiplies the atom, but it signifies that all the atoms are in chemical combination either with one another or with other atoms. Thus O_3 means three atoms of oxygen in combination with one another, or, in other words, a molecule of ozone. The formula $3O_3$ means three molecules of ozone each containing three atoms of oxygen; but 9O means nine *single* oxygen atoms and not three molecules of ozone.

A large numeral in front of any symbolic molecular formula multiplies the whole molecule, but a small numeral is never used to multiply a molecule; the latter is placed to the right of the symbol which it is intended to multiply and a little below the line, as in O_3. Thus, the formula $C_6H_{10}O_5$ means one molecule composed of six carbon atoms, ten hydrogen atoms and five oxygen atoms, and $2C_6H_{10}O_5$ means two such molecules.

The following examples will suffice to make these things clear:

Hg stands for one atom of mercury.

Hg also stands for one molecule of mercury, because each molecule of mercury contains but one atom.

2H means two free hydrogen atoms.

3H means three free hydrogen atoms.

H_2 means two hydrogen atoms united to each other to form one molecule.

$2H_2$ means two molecules of hydrogen of two atoms each.

4HCl means four molecules of hydrogen chloride.

$5H_2O$ means five molecules of water.

211. How to Write Molecular Formulas. The symbols representing the elements composing the molecules are to be written, and where more than one atom of the element enters into the molecule the number of atoms of *each* element is indicated by an "inferior" (lower) numeral to the right of the symbol a little below the line, as shown in Fe_2O_3, a molecule consisting of two atoms of iron and three atoms of oxygen.

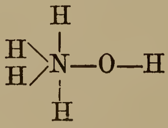
In writing the molecular formula of a binary compound the positive element (or ion) is always to be placed first and the negative element (or ion) last. Hence, the symbol of the metal is always written first in the molecular formula of any binary compound of a metal.

In writing the molecular formula of any compound containing three or more elements, the ions, if known, are placed in the same order as in the molecular formulas of binary compounds. Such compounds must contain at least one ion composed of more than one element, and the elements of each ion are written in the same order as the ions themselves—the positive elements before the negative elements—whenever practicable; or the elements are written in the order determined by their respective valences and indicative of the actual atomic linking, so far as practicable.

Two elements having or exercising the same polarity in any molecule may be placed beside each other for the sake of convenience and brevity, if the formula is not intended to show the relative positions of all the atoms but only to show the ions. But whenever the whole system of atomic linking is to be shown it is evident that any two atoms placed immediately beside each other must be of opposite chemical polarity with respect to each other. We write KNO_3 for convenience, because K is the positive ion and NO_3 is the negative ion; but K is not the only positive atom, for N is also of positive polarity, so that K is not directly united to N and the actual atomic linking is therefore not shown in the formula KNO_3. If the atomic linking of potassium nitrate is to be shown the formula should be written $KONO_2$, for the K is directly united to one atom of oxygen and that atom of oxygen is at the same time directly united to the N, which, having five bonds, also holds the other two oxygen atoms in direct combination with itself.

Molecular formulas are sometimes written in a manner inconsistent with the foregoing rules, because these rules are not explicitly stated in the text-books, although the commonly written molecular formulas in nearly all cases conform to them and no good reasons apparently exist which explain the few exceptions.

H_4NOH is a correctly written molecular formula, because the nitrogen atom is admittedly directly united to four hydrogen atoms and to the oxygen atom, and the fifth hydrogen atom is directly united to the oxygen atom and not to the nitrogen; but the formula NH_4HO, often seen, is inconsistent because it separates the nitrogen from the oxygen. The actual structure of this molecule is



which may well be represented by H_4NOH, but not by NH_4HO.

The formula NH_4Cl is inconsistent, because the nitrogen is really directly united to the Cl and the Cl is not united to hydrogen, for the nitrogen atom has five bonds and the atoms of hydrogen and chlorine have only one bond each, so that the correct formula is H_4NCl, and four of the nitrogen bonds (holding the hydrogen atoms) are of negative chemical polarity, while the fifth bond (holding the chlorine atom) is a positive bond.

212. Large (or ordinary) figures or numerals are used to multiply single molecules. A true molecule has but one (or a continuous or undivided) system of atomic linking.

Two or more molecules may be held to each other in some way not yet understood (not consistent with our conception of atomic valence), and such molecular combinations are represented by formulas which show the several combined molecules by means of their own respective molecular formulas and numerals indicating the number of molecules of each kind.

The formula $BaCl_2.2H_2O$ or $BaCl_2+2H_2O$ represents a combination of one molecule of $BaCl_2$ with two molecules of H_2O. This molecular combination has three separate and distinct systems of atomic linking—one for the $BaCl_2$ and another for each of the two molecules of water.

The formula $2K_2CO_3+3H_2O$ represents a molecular combination of two molecules of K_2CO_3 with three molecules of water. This combination has five separate systems of atomic linking.

All molecular combinations have as many separate systems of atomic linking as the number of molecules they contain, for each molecule has its own.

When any symbols or molecules are embraced in parentheses and a numeral is placed outside the parentheses, that numeral multiplies all that is enclosed within the parentheses. Thus $3(2K_2CO_3+3H_2O)$ means three times $2K_2CO_3+3H_2O$; Fe $(SO_4)_3$ means Fe united to three times SO_4; and the expression $4MgCO_3.Mg(OH)_2.5H_2O$ means a combination of 4 molecules of $MgCO_3$ with one molecule of $Mg(OH)_2$ and 5 of water.

The formula $K_4Fe(CN)_6$ represents a chemical compound known as ferrocyanide of potassium. It is recognized as a ferrous compound, which means that the iron atom in it has two bonds. The potassium atoms have one bond each. The combination consists of 4 potassium atoms, one iron atom and 4 times the group CN. The group CN, consisting of the tetrad C and the triad N, is a univalent radical. It is impossible to escape the conclusion that there must be six independent systems of interatomic linking in this combination, or that the only formula for it which is consistent with our conceptions of atomic valence must be $4KCN+Fe(CN)_2$.

213. **Empiric formulas** are formulas expressing in the simplest terms the relative numbers of the atoms of each element contained in a compound.

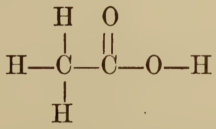
The empiric formula for acetic acid is CH_2O. This simply indicates that we have in the composition of acetic acid two hydrogen atoms and one oxygen *for each carbon atom.* It does not show the actual number of atoms of each kind contained in one molecule.

214. **Molecular formulas** show the actual number of atoms of each kind which form one molecule of the substance.

The molecular formula of acetic acid is not CH_2O but $C_2H_4O_2$, or $HC_2H_3O_2$, or $H_3C.CO.OH$, for the vapor density of acetic acid proves that its molecular weight must be the sum of the weights of two carbon atoms, four hydrogen atoms, and two oyxgen atoms, which would be most simply expressed by $C_2H_4O_2$. The formula $HC_2H_3O_2$ is one which shows that one of the four hydrogen atoms can be replaced by a metal or that the two ions of acetic acid are H and $C_2H_3O_2$.

215. The constitutional or structural formula of any compound is one that shows the relative positions of the atoms, or their grouping, or their interatomic linking. The structural or constitutional formula for acetic acid is $H_3C.CO.OH$, because the three recognized atomic groups composing its molecule are methyl (H_3C), carbonyl (CO), and hydroxyl (OH).

A graphic structural formula showing the interatomic linking of acetic acid in detail is



$$\begin{array}{ccccccccc} & & H & & O & & & & \\ & & | & & \| & & & & \\ H & - & C & - & C & - & O & - & H \\ & & | & & & & & & \\ & & H & & & & & & \end{array}$$

216. To construct the molecular formula of any binary compound is an easy problem if the valence of each of the two elements is known. To do so, *multiply the symbol of each element by the valence of the other:*

The molecular formula of bismuthous oxide must be Bi_2O_3. To arrive at it, first write down Bi for bismuth and O for the oxygen. Then, as the valence of bismuthous bismuth is 3, write that numeral after the O, and as the valence of O is 2, we write that numeral after the Bi.

To construct the molecular formula of any compound of two known ions is an equally simple proposition: *First write the two ions and then multiply each ion (or radical) by the valence of the other.*

Thus, the molecular formula of tricalcium phosphate is $Ca_3(PO_4)_2$, because the valence of Ca is 2 and that of PO_4 is 3. The valence of PO_4 is 3, because the algebraic combining number of P in all phosphates is +5, and the valence of the oxygen atom is −2, so that PO_4 has five phosphorus bonds and eight oxygen bonds and the difference between 5 and 8 is 3, representing 3 oxygen bonds not in combination with the P.

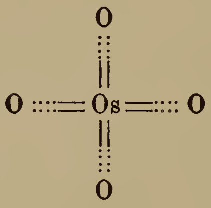
The number of bonds of the positive ion must be the same as the number of bonds of the negative ion, or the total bonds of each must be a common multiple of the respective valences of both. Ca_3 represents 3 calcium atoms which together have 6 bonds, and $(PO_4)_2$ represents twice PO_4, having also a total of 6 bonds.

217. The student can readily learn to write structural molecular formulas showing the combining values and interatomic linking, and also the common molecular formulas from the following:

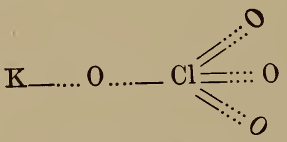
Each unit of combining value is represented by a line or dash, which is a solid line if the unit or "bond" is of positive polarity but dotted if the bond is a negative one.

The algebraic combining values range from +8 to −4.

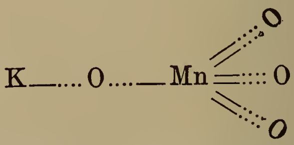
Osmium forms a tetroxide which may be represented as



Chlorine, iodine and manganese may each exercise a value of +7 in the compounds called perchlorates, periodates and permanganates:

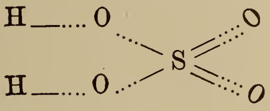


Potassium Perchlorate.

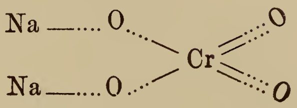


Potassium Permanganate.

A combining value of +6 is exercised by S in sulphuric compounds, Cr in chromic acid and chromates, Mn in manganates, Mo in molybdates and Fe in ferrates:

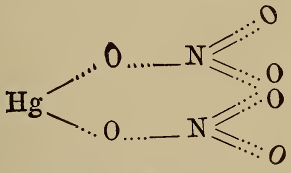


Sulphuric Acid.

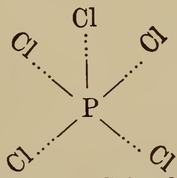


Sodium Chromate.

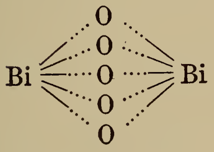
A combining value of +5 is shown by N in nitric acid and other nitrates, P in phosphoric compounds, As in arsenic compounds, Sb in antimonic and Bi in bismuthic compounds; also by Cl in chloric, Br in bromic and I in iodic compounds:



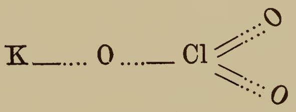
Mercuric Nitrate.



Phosphoric Chloride.

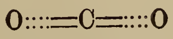


Bismuthic Oxide.

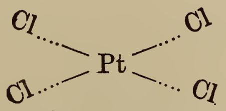


Potassium Chlorate.

A combining value of +4 is exercised by C in carbonic compounds, Si in silicic and Sn in stannic compounds; by Pt in platinic compounds, Ce in ceric, Pb in perplumbic, S in sulphurous compounds, Fe in ferrites, Mn in manganites and in MnO_2, Mo in MoO_2 and by N in NO_2.



Carbonic Oxide.



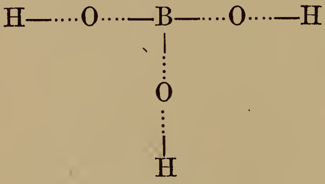
Platinic Chloride.

$O::::=Pb=::::O$

Peroxide of Lead.

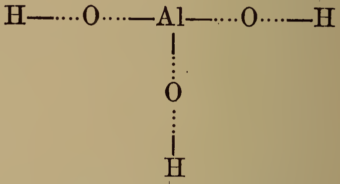
Sulphurous Acid.

An algebraic combining value of +3 is exercised by B in boric compounds, Al in all its compounds, Fe in ferric halides and salts, Ni in nickelic and Co in cobaltic compounds, Cr in Cr_2O_3 and several other compounds, Mo in Mo_2O_3, Mn in Mn_2O_3, MnCl, etc., Au in auric compounds; by N in nitrous, P in phosphorous, As in arsenous, Sb in antimonious and Bi in bismuthous compounds; and by Cl in chlorous, Br in bromous, and I in iodous compounds:



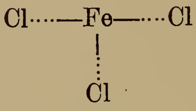
$$\begin{array}{rcl} H\text{—}\cdots O\cdots\text{—} & B & \text{—}\cdots O\cdots\text{—}H \\ & | & \\ & \vdots & \\ & O & \\ & \vdots & \\ & | & \\ & H & \end{array}$$

Boric Acid.



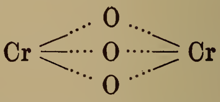
$$\begin{array}{rcl} H\text{—}\cdots O\cdots\text{—} & Al & \text{—}\cdots O\cdots\text{—}H \\ & | & \\ & \vdots & \\ & O & \\ & \vdots & \\ & | & \\ & H & \end{array}$$

Aluminum Hydroxide.



$$\begin{array}{rcl} Cl\cdots\text{—} & Fe & \text{—}\cdots Cl \\ & | & \\ & \vdots & \\ & Cl & \end{array}$$

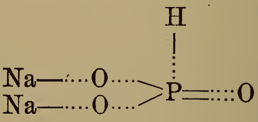
Ferric Chloride.



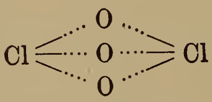
Dichromium Trioxide.

$H\text{—}\cdots O\cdots\text{—}N=::::O$

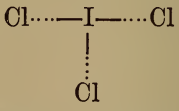
Nitrous Acid.



Sodium Phosphite.



Chlorous Oxide.



$$\begin{array}{rcl} Cl\cdots\text{—} & I & \text{—}\cdots Cl \\ & | & \\ & \vdots & \\ & Cl & \end{array}$$

Iodine Trichloride.

A combining value of +2 is exercised by Mg, Ca, Sr, Ba, Zn and Cd in all their compounds; by Cu in cupric and Hg in mercuric compounds; by Fe in ferrous, Ni in nickelous, and Co in cobaltous compounds; by Cr in chromous, Mo in molybdous and Mn in manganous compounds; by Sn in stannous and Pb in plumbic compounds; by Pt in platinous compounds; by C in carbonous compounds; by S in hyposulphurous compounds; and by N in NO:

Mg═::::O

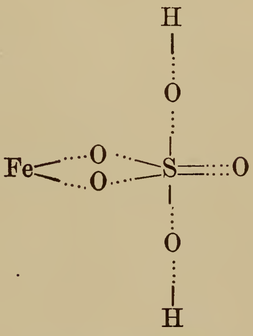
Magnesium Oxide.

Cl·····—Ca—·····Cl

Calcium Chloride.

H—·····O·····—B—·····O·····—H

Barium Hydroxide.

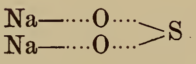


$$\begin{array}{ccc} & & H \\ & & | \\ & & O \\ & & | \\ Fe< & \begin{matrix} O \\ O \end{matrix} & >S=O \\ & & | \\ & & O \\ & & | \\ & & H \end{array}$$

Ferrous Sulphate.

C═::::O

Carbonous Oxide.



$$\begin{matrix} Na—O \\ Na—O \end{matrix}>S$$

Sodium Hyposulphite.

An algebraic combining value of +1 is exercised by H, Li, Na, K, and Ag in all their compounds; by Cu in cuprous, Hg in mercurous, Au in aurous compounds; by Cl in hypochlorous, Br in hypobromous and I in hypo-iodous compounds; by N in hyponitrous and P in hypophosphorous compounds:

H—····O····—H

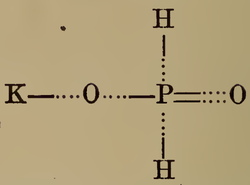
Water.

Hg—····Cl

Mercurous Chloride.

Na—····O····—Cl

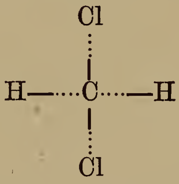
Sodium Hypochlorite.



$$\begin{array}{c} \qquad\quad H \\ \qquad\quad | \\ K-O-P=O \\ \qquad\quad | \\ \qquad\quad H \end{array}$$

Potassium Hypophosphite.

An algebraic combining value of 0 is exercised by one of the oxygen atoms in HOOH and by one of the sulphur atoms in H—····S····—S····—H; also by C in many compounds, as in

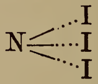


$$\begin{array}{c} Cl \\ | \\ H-C-H \\ | \\ Cl \end{array}$$

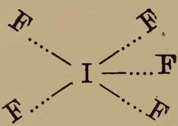
A combining value of –1 is shown by F in all fluorides, Cl in all chlorides, Br in all bromides and I in all iodides:

I—····Br

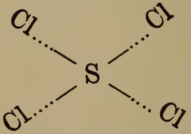
Iodine Monobromide.



Nitrogen Iodide.



Iodine Pentafluoride.



Sulphur Tetrachloride.

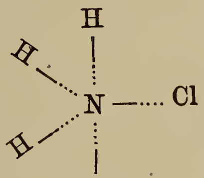
F has a combining value of –1 in all its compounds; Cl has a value of –1 in all its compounds with all elements except F and O; Br exercises the combining value of –1 in all the compounds it forms with all elements except Cl, F and O; I exercises that value in all the compounds it forms except with Br, Cl, F and O.

A combining value of –2 is exercised by O in all the compounds in which it is directly united to any other element. In other words, it exercises that value in all cases except where two oxygen atoms are directly united to each other, in which event one of the oxygen atoms has a value of 0.

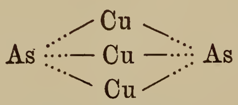
Sulphur, whenever it exercises negative polarity, has a combining value of –2; it accordingly has a value of –2 whenever it is in direct combination with any element except O, F, Cl, Br and I.

The carbon atom exercises a combining value of –2 in all compounds in which it has one positive and three negative bonds, as in H_3CCl.

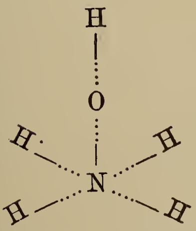
The combining value of –3 is exercised by B in H_3B; by N in all compounds in which the nitrogen atom is negative and not united to another nitrogen atom, and it, therefore, has that value in H_3N and in all ammonium compounds, in alkaloids, and in numerous organic compounds. Negative P, negative As and negative Sb also have a combining value of –3:



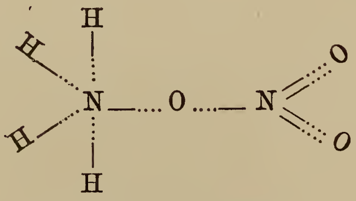
Ammonium Chloride.



Cupric Arsenide.

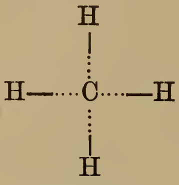


Ammonium Hydroxide.



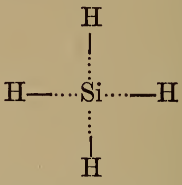
Ammonium Nitrate.

A combining value of –4 is exercised by the C in H_4C and by Si in H_4Si.



$$\begin{array}{c} H \\ | \\ H-C-H \\ | \\ H \end{array}$$

Marsh Gas.



$$\begin{array}{c} H \\ | \\ H-Si-H \\ | \\ H \end{array}$$

Hydrogen Silicide.

XIV

Chemical Nomenclature

218. We have already learned that classes of binary compounds are given generic titles ending with *ide*, as, for instance, oxides, sulphides, chlorides, bromides, etc; and that salts are named after their corresponding acids, such as sulphates, named after sulphuric acids; nitrates, named after nitric acids; sulphites, named after sulphurous acid; nitrites, after nitrous acid, etc.

The adjectives used in the nomenclature of inorganic chemical compounds and the relation of these adjectives to the other technical terms require careful consideration, and also the prefixes which are employed wherever necessary.

The substantive nouns ending in *ide*, *ate* and *ite* are derived from the names of the negative radicals, whereas the adjectives used are derived from the names of their positive radicals, or from positive elements.

219. In the chapter on Atomic Valence, we learned that many elements when exercising positive polarity may have two, three or four valences, and that, accordingly, they may have several oxides or sulphides or chlorides or hydroxides. These must be distinguished from one another in a systematic way.

220. The Endings ic and ous. When any element exercises *two* different combining values, the higher value is indicated by an adjective ending in *ic* and the lower combining value is indicated by an adjective ending in *ous*. Carbon, mercury and iron will serve as examples to illustrate this rule.

Carbonic carbon is positive carbon with an algebraic combining number of +4; carbonous carbon is positive carbon with an algebraic combining number of +2. Positive carbon has no other algebraic combining numbers.

Mercury has two combining values; its higher value is +2 and is called mercuric mercury, while its lower combining number is 1 and mercury with that combining number is called mercurous mercury.

Carbonic oxide is CO_2, carbonous oxide is CO, mercuric chloride is $HgCl_2$, and mercurous chloride is $HgCl$.

When iron exercises basic functions and when it forms binary compounds, it may have a combining value of either +2 or +3. Iron with a value of +2 is called ferrous iron; iron with a value of +3 is called ferric iron.

221. The Prefixes hypo and per. When an element exercising positive polarity has *three* different combining values, the highest is indicated by an adjective ending in *ic*, the middle value is indicated by an adjective ending in *ous*, and the lowest value is indicated by an adjective ending with *ous* in addition to the prefix *hypo*, which means below or under.

Sulphur, for instance, is sulphuric sulphur when it exercises the algebraic combining number of +6; it is sulphurous when it has the combining number +4; it is hyposulphurous when it has the combining number of +2.

When an element exercising positive polarity has *four* different combining values, the lowest value is indicated by the prefix *hypo* and the ending *ous*, the next higher value is indicated by the ending *ous* without any prefix, the third value is indicated by an adjective ending in *ic* without any prefix, and the fourth and highest value is indicated by the ending *ic* and the prefix *per*. Thus, positive chlorine forms hypochlorous compounds, chlorous compounds, chloric compounds and perchloric compounds.

222. But even these devices are not always sufficient. We shall accordingly learn now all the prefixes commonly employed in inorganic chemical nomenclature. They are as follows:

(a) Prefixes derived from Greek numerals:
- *Mono* or *mon*, meaning one, single or once.
- *Di* or *dis*, meaning two or twice.
- *Tri* or *tris*, meaning three or thrice.
- *Tetra*, meaning four.
- *Penta*, meaning five.
- *Hexa*, meaning six.
- *Hepta*, meaning seven.
- *Octo*, meaning eight.
- *Deca*, meaning ten.

(b) Prefixes derived from Latin numerals:
- *Un* or *uni*, meaning one or single.
- *Duo*, *bi*, *bin*, or *bis*, meaning two or twice.
- *Ter* or *tri*, meaning three or thrice.
- *Quadri* or *quadra*, meaning four.
- *Quinque* or *quinqui*, meaning five.
- *Sexa* or *sexi*, meaning six.
- *Septi* or *sept*, meaning seven.
- *Octo* or *octi*, meaning eight.

(c) Other prefixes:
- *Hypo*, meaning under, lower or below.
- *Sub*, meaning under, lower or below.
- *Per*, meaning thorough, through or to the full extent.
- *Meta*, meaning altered, different, after or beyond.
- *Para*, meaning changed, different or altered.
- *Ortho*, meaning straight, regular, common, usual or original.
- *Pyro*, meaning as produced by fire or high heat.
- *Thio*, from *theion* (sulphur), meaning containing sulphur.

The following illustrations will suffice to render clear the mode of employment of the foregoing prefixes:

A monochloride is a chloride containing but one chlorine atom; a dioxide is an oxide containing two oxygen atoms; a tri-iodide contains three iodine atoms; a tetroxide contains four oxygen atoms; a pentafluoride contains five fluorine atoms; a hexachloride contains six chlorine atoms; a heptoxide contains seven oxygen atoms.

A bicarbonate contains twice as large a proportion of the carbonate radical CO_3 as a carbonate contains in proportion to the basic element, as shown by the molecular formulas $KHCO_3$ and K_2CO_3, in which K is the basic element.

Subsulphate of mercury contains a smaller quantity of the sulphate radical SO_4 in proportion to the mercury than the sulphate of mercury contains. Subnitrate of bismuth is a name given to $OBiNO_3$, containing the NO_3 only once, while bismuth nitrate is $Bi(NO_3)_3$.

A thiocarbonate is a carbonate in which the oxygen is in part or wholly replaced by sulphur. A thiosulphate is a sulphate containing a larger proportion of sulphur than is contained in the other sulphates, some or all of the oxygen of the sulphate being replaced by sulphur atoms. Thus, sulphate of calcium is $CaSO_4$, while thiosulphate of calcium is $CaSS_4$, and other calcium thiosulphates are $CaSO_3S$, $CaSO_2S_2$, and $CaSOS_3$.

223. Meta-compounds. The prefix *meta* when used in connection with hydroxides and salts has a specific meaning. It signifies a compound formed by the removal of the elements of water from another compound of normal structure.

A normal hydroxide or a hydroxide of normal composition contains no hydrogen or oxygen, except the hydrogen and oxygen of its hydroxyl. In other words, it contains an equal number of atoms of hydrogen and oxygen, and every hydrogen atom in such a hydroxide is directly united to an oxygen atom.

Thus, ferrous hydroxide is $Fe(OH)_2$, because ferrous iron is a diad and can therefore hold in combination two groups of hydroxyl, OH. Normal ferric hydroxide is $Fe(OH)_3$, because ferric iron is a triad and can accordingly hold in combination three hydroxyl groups. But OFeOH is a meta-hydroxide formed out of $Fe(OH)_3$ by its dissociation, resulting in the formation of one molecule of water, H_2O, and one molecule of the OFeOH, which is all that remains of the $Fe(OH)_3$ when one molecule of water has been split off from it.

Normal sulphuric hydroxide or normal sulphuric acid is, of course, $S(OH)_6$, because sulphuric sulphur is a hexad and can hold six hydroxyl groups. But if one molecule of water be split off from the $S(OH)_6$, we would have $(HO)_4SO$ left, which is mono-meta-sulphuric acid, or mono-meta-sulphuric hydroxide, the prefix *mono* indicating that only one molecule of water was split off. But if two molecules of water be split off from $S(OH)_6$ or $(HO)_6S$, which is the same thing, then di-meta-sulphuric hydroxide or di-meta-sulphuric acid is formed, the formula of which is $(HO)_2SO_2$ or H_2SO_4, which is our common sulphuric acid. A tri-meta-sulphuric acid containing but one atom of sulphur is impossible, because if three molecules of water be split off from $(HO)_6S$, the remainder would be simply SO_3, which is not a hydroxide nor an acid, but sulphuric oxide.

The name orthophosphoric acid means the common or ordinary phosphoric acid. The prefix *ortho* does not indicate its composition, but the ending *ic* indicates that the phosphorus in it has the combining number +5, which is the highest of the three positive algebraic combining numbers possible to phosphorus. The formula for orthophosphoric acid is H_3PO_4 or $(HO)_3PO$. A normal phosphoric hydroxide is, of course, $(HO)_5P$. Accordingly, it is evident that orthophosphoric acid is a mono-meta-acid, and the name mono-meta-phosphoric acid is sufficient to indicate the structure of the compound or its true molecular formula. The glacial phosphoric acid commonly called meta-phosphoric acid has the formula HPO_3, or $HOPO_2$. It is therefore a di-meta-acid or $(HO)_5P$, or H_5PO_5 with two molecules of water split off from it, leaving HPO_3. What is commonly called pyrophosphoric acid is a phosphoric acid produced by heating orthophosphoric acid, or a pyrophosphate is obtained by heating the corresponding orthophosphate. The common phosphate of sodium is Na_2HPO_4. It is accordingly disodium monohydrogen mono-meta-phosphate. But the pyrophosphate of sodium is $Na_4P_2O_7$. The name pyrophosphate does not indicate the composition, whereas the explicit technical term sodium tri-meta-di-phosphate at once tells the whole story of its structure, for it tells us that the acidic element in the compound is phosphoric phosphorus. The term diphosphate tells us that it contains two phosphorus atoms, and the term tri-meta informs us that it differs by three molecules of water from the normal structure of two molecules of sodium phosphate added together. Two molecules of normal phosphoric hydroxide added together would make the formula $H_{10}P_2O_{10}$. Three molecules of water split off from that formula would leave $H_4P_2O_7$. The sodium salt corresponding to $H_4P_2O_7$ is $Na_4P_2O_7$.

Borax is a sodium penta-meta-tetra-borate, because it is the sodium salt formed out of a boric acid resulting from the splitting off of five molecules of water from four molecules of normal boric hydroxide. It is called a tetra-borate because it contains four boron atoms. A borate must, of course, be formed from boric acid, and boric boron has a valence of 3. Normal boric hydroxide is accordingly $(HO)_3B$ or H_3BO_3. Four molecules of H_3BO_3 would be $H_{12}B_4O_{12}$, and after splitting off five molecules of water from $H_{12}B_4O_{12}$, we would have $H_2B_4O_7$ left, which is penta-meta-tetra-boric acid, and the sodium salt of it is accordingly $Na_2B_4O_7$.

224. From the facts stated in the foregoing paragraphs, the student will see that hypochlorous fluoride would be ClF; hypochlorous oxide must be Cl_2O; hypochlorous acid must be HOCl; potassium hypochlorite is KOCl; and calcium hypochlorite $Ca(ClO)_2$.

Hypophosphorous oxide must be P_2O. Hypophosphorous acid may be either HOP or it may be $HOPH_2O$, in which the student can readily see that the algebraic combining number of the phosphorus is still +1. Phosphorous oxide must be P_2O_3; phosphorous chloride must be PCl_3; and phosphorous acid may be either $(HO)_3P$ or HPO_2, or it may be even $(HO)_2PHO$, for in all of these formulas of acids it is clearly seen that the phosphorus atom has an algebraic combining number of +3. The student can readily see at once that H_5PO_5, H_3PO_4, HPO_3, and $H_4P_2O_7$ must all be different kinds of phosphoric acid, because in every one of them the phosphorus atom clearly has an algebraic combining value of +5.

Upon examination of the formulas H_6SO_6, H_4SO_5, and H_2SO_4, it is seen that these formulas all represent different kinds of sulphuric acid, the first being normal sulphuric acid or sulphuric hydroxide, the second mono-meta-sulphuric acid, and the third di-meta-sulphuric acid, because in all of them the sulphur atom is seen to have a combining value of +6.

The formula CaH_4SO_6 evidently represents a calcium sulphate derived from normal sulphuric hydroxide. CaH_2SO_5 is a sulphate derived from the mono-meta-sulphuric acid, and $CaSO_4$ is calcium di-meta-sulphate. FeH_2SO_5 is ferrous mono-meta-sulphate, which is common ferrous sulphate, or green vitriol, minus its water of crystallization.

Test Questions

1. What is the meaning of Ag?
2. Why is the symbol representing lead Pb instead of L?
3. What is I_2 and what is the difference between 2I and I_2?

4. What is the difference between 4H and $2H_2$ and H_4?

5. Which of the following formulas are correct and which are incorrect: (a) HgO; (b) Hg_2O; (c) HgO_2; (d) Hg_3; (e) H_4; (f) O_4; (g) H_2Cl_2?

6. Name the two ions of each of the following: ferrous chloride, ferric chloride, sodium nitrate, potassium hydroxide, phosphoric acid, ammonium sulphate, ammonium chloride, arsenous oxide, antimonous sulphide, potassium antimonite.

7. Write the molecular formulas of the following named compounds: (a) carbonic acid; (b) sodium carbonate; (c) calcium bromide; (d) potassium fluoride; (e) silver iodide, (f) nitrogen iodide; (g) barium sulphide; (h) calcium oxide; (i) sulphide of carbon; (j) sulphide of trivalent arsenic; (k) the sulphide of quinquivalent antimony; (l) the hydroxide of boron; (m) three molecules of the sulphate of trivalent iron; (n) two molecules of aluminum sulphate; (o) seven molecules of magnesium hydroxide; (p) two molecules of bismuth nitrate, containing the bismuth as a triad.

8. In which of the two molecules $Bi_2(CO_3)_3$ and $(OBi)_2CO_3$ is the bismuth trivalent, and what is the combining value of the bismuth in the other?

9. Write the empiric formula of H_2O_2.

10. Write the empiric formula for $H_2C_2O_4$.

11. Write the molecular formula for the phosphate of triad iron.

12. Write the molecular formula for barium phosphate.

13. Write the molecular formulas for: (a) hypochlorous acid; (b) chlorous acid; (c) chloric acid; (d) perchloric acid; (e) sodium bromate; (f) potassium periodate; (g) hyposulphurous acid; (h) sulphuric acid; (i) sulphurous acid; (j) magnesium sulphite; (k) ferrous sulphate; (l) mercuric sulphate; (m) mercurous sulphate; (n) mercuric oxide; (o) sulphurous oxide; (p) hyponitrous acid; (q) nitrous acid;

(r) nitric acid; (s) hypophosphite of magnesium; (t) ferrous hypophosphite; (u) ferric hypophosphite; (v) phosphoric oxide; (w) carbonic chloride; (x) ammonium phosphate.

14. What is the difference between sulphuric sulphur, sulphurous sulphur and hyposulphurous sulphur?

15. What is the difference between nitric nitrogen, nitrous nitrogen and hyponitrous nitrogen?

16. What is the difference between hypochlorous chlorine, chlorous chlorine, chloric chlorine and perchloric chlorine?

17. What is the combining value of periodic iodine?

18. What is the algebraic combining value of phosphoric phosphorus?

19. What is the highest algebraic combining number possible to carbon, and what is carbon with its highest combining value called?

20. Give the technical name of CO and of CO_2? of H_4C.

21. What is the algebraic combining number of the acidic element in: (a) hypophosphorous acid; (b) calcium nitrate; (c) ferric sulphate; (d) ferrous sulphate; (e) sodium periodate; (f) potassium chlorate; (g) potassium antimonite; (h) sodium arsenate; (i) sodium hyposulphite; (j) sodium tetraborate; (k) pyrophosphate of iron; (l) orthophosphate of iron; (m) metaphosphate of iron; (n) any decaborate?

22. How many different kinds of phosphoric acids are possible, containing only one phosphorus atom?

23. How many different kinds of sulphuric acids are possible, containing only one sulphur atom?

24. What kind of a meta-acid is $H_2B_4O_7$?

25. Write the formula for normal nitric hydroxide.

26. Write the formula for nitric mono-meta-hydroxide.

27. Write the formula for nitric di-meta-hydroxide.

28. Write the formula for normal sulphuric hydroxide.

29. Write the formula for carbonic hydroxide of normal composition

30. Write the formula for mono-meta-carbonic hydroxide.

31. What kind of a carbonate is $CaCO_3$?

32. What kind of a carbonate would you call CaH_2CO_4?

33. What kind of a carbonate would you call $KHCO_3$?

34. What kind of a carbonate is K_2CO_3?

35. Why are all the compounds just named called carbonates?

36. What is the difference between a chlorate and a perchlorate, and why are both called chlorates?

37. What is a thiosulphate and what is a hyposulphite?

38. Give the formula for thiocarbonic acid of normal structure.

39. What would you call a compound of potassium oxygen and pentad iodine?

40. What would you call a salt containing carbon as its acidic element?

41. What would you call a salt in which the acidic element is silicon?

42. What would you call a salt in which the acidic element is tetrad sulphur?

43. What would you call a salt in which antimony with five bonds is the acidic element?

44. How many bonds does the nitrogen have in a hyponitrite?

45. How many different numbers of bonds can the nitrogen atom have in nitrates?

46. How many different numbers of bonds can the arsenic atom have in arsenites?

47. Write the formula for tri-meta-di-phosphoric acid.

48. Write the formula for di-meta-phosphoric acid.

49. If such a compound existed as penta-meta-tetra-phosphoric acid, what would be its formula?

50. How many kinds of ferric hydroxide can exist containing but one iron atom?

51. Write the formula for tri-meta-di-ferric hydroxide.

52. Write the formula for a salt containing hexad chromium as its acidic element.

53. What is the difference between acidic manganic manganese and permanganic manganese?

54. Write the formula for potassium dichromate and state why it is called a dichromate.

LESSON TEN

XV

The Relative Intensity of the Chemical Combining Energy of Different Elements

225. Different elements possess widely different degrees of intensity of chemical energy, or tendency to combine with other elements or to attack other substances chemically.

Among the strikingly energetic elements are fluorine, chlorine, bromine, phosphorus, potassium and sodium. Oxygen also may be said to show considerable inclination to enter into chemical combination, at least at temperatures somewhat above the common.

Among the elements of comparatively indifferent chemical energy under ordinary conditions are carbon, silicon, boron, nitrogen, gold and platinum.

Neon, argon, krypton and xenon show no inclination whatever to enter into chemical combination.

The properties of the element fluorine can be studied only with the greatest difficulty, if at all, because whenever that element is liberated from one of its compounds, it instantly attacks some other substance and forms some new chemical combination by uniting with some element in that other substance.

Chlorine and bromine are also strikingly energetic in their chemical action upon other substances.

Fluorine, chlorine and bromine decompose water and take the hydrogen away from it, setting the oxygen free. They also attack metals vigorously by combining with them. Fluorine attacks and decomposes glass.

Phosphorus ignites and burns fiercely in oxygen and in chlorine and also combines with great velocity with bromine. It decomposes potassium chlorate with great violence.

Potassium and sodium and, in still greater measure, cæsium and rubidium, decompose water by combining with the oxygen of the water, or with its hydroxyl, and liberating hydrogen. The alkali metals must be preserved submerged in benzoin or some other liquid hydrocarbon (hydrocarbons contain only carbon and hydrogen), to prevent their instant and violent oxidation or combination with oxygen.

Carbon is so indifferent chemically that diamond, graphite, coal and charcoal remain permanently unaltered in the presence of an abundance of oxygen, except when heated strongly.

Crystallized silicon, adamantine boron and nitrogen are even more indifferent than carbon. But silicon and boron immediately ignite in fluorine gas, owing to the intense chemical energy of the latter.

226. Elements differing widely from each other in their chemical quality show the greatest inclination to enter into combination with each other. Compounds formed by very energetic positive elements with very energetic negative elements are stable; but compounds formed by elements exhibiting a low degree of intensity of chemical energy are comparatively unstable.

The fluorides and chlorides of the alkali metals and alkaline earth metals are very stable compounds, because fluorine and chlorine are the most energetic of the decidedly negative elements and the alkaline earth metals are the most energetic of the decidedly positive elements. But most of the compounds formed by nitrogen show a remarkable tendency to decompose, often with explosive violence, because of the indifferent ability or inclination of nitrogen to hold other elements in combination with itself.

227. Some acids are much more corrosive or destructive or energetic in their chemical action than other acids, and this difference does not depend upon their hydrogen or oxygen, since those elements belong to all true acids. But it must depend at least primarily upon the acidic element which characterizes the acid. Carbonic acid is H_2CO_3, or rather $(HO)_2CO$. Sulphurous acid is H_2SO_3, or rather $(HO)_2SO$. Sulphurous acid is a much more energetic acid than carbonic acid, and the difference between them is evidently due to the fact that the acidic element in one is sulphur, while in the other it is carbon.

It is true that we have three kinds of hydroxyl acids in which sulphur is the acidic element, and that these three acids nevertheless differ greatly in their energetic action upon other substances. Sulphuric acid, H_2SO_4, is decidedly stronger than sulphurous acid, H_2SO_3, for sulphuric acid decomposes the salts of sulphurous acid and changes them into sulphates, while sulphurous acid does not decompose sulphates or change them into sulphites, and so sulphates are much more stable compounds than sulphites. Hyposulphurous acid, H_2SO_2, is weaker than either sulphuric or sulphurous acid. It may be said that the difference between these three acids, all containing sulphur as the acidic element, may be due not to that acidic element, since that is the same in all three, but to the differences in the proportion of oxygen, were it not for the fact that acids containing a larger proportion of oxygen are sometimes weaker acids than others that contain less oxygen. Boric acid, H_3BO_3, is a much more feeble acid than phosphorous acid, H_3PO_3, although the boric acid contains a larger proportion by weight of oxygen, the weight of the boron atom being only 11, while that of the phosphorus atom is 31. Sulphuric acid, H_2SO_4, is more destructive and energetic than chromic acid, H_2CrO_4.

An element performing the acidic function forms a stronger acid if it exercises a high combining value than the same element forms if it has a lower algebraic combining number. The sulphur in sulphuric acid is by no means identical in all respects with the sulphur in sulphurous acid, nor with the sulphur in hyposulphurous acid, for the chemical combining value of the sulphuric sulphur contained in sulphuric acid and all other sulphuric compounds is +6; the chemical combining value of sulphurous sulphur contained in all sulphurous compounds is +4, and that of hyposulphurous sulphur contained in all hyposulphurous compounds is only +2. This, then, explains the differences between sulphuric acid, sulphurous acid and hyposulphurous acid.

228. Some alkaline hydroxides are more corrosive and destructive, or more decidedly alkaline or stronger, or chemically more energetic than others. This difference cannot be due to the oxygen and hydrogen, which are common to all of them; it must be due to the basic element in them. Potassium hydroxide is decidedly more powerful as a base than lithium hydroxide. This must be due to the difference between potassium and lithium.

229. The relative intensity and power of different elements as chemical agents depend upon their polarity, valence, atomic weight, specific weight and their relative position in the natural system of classification of the elements known as the periodic system.

It is also affected by physical conditions, as by solubility or want of solubility or different degrees of solubility of the compounds formed, or by their volatility or want of volatility.

The apparent energy of one element is further decidedly influenced by the character and quantity of the element or elements with which it enters into combination.

230. Elements capable of performing the basic function form more powerful bases if their specific weight is low; weaker bases if their specific weight is high. In other words, the light metals are strongly basic and the heavy metals less strongly basic. The hydroxides of most of the light metals are destructive, while the hydroxides of heavy metals are not so.

231. Of the light metals, those having a low valence are more decidedly energetic in their chemical action and form stronger bases than those having a higher valence. It is equally true of the heavy metals that they are more strongly basic when of low valence than when exercising a high valence.

Metals exercising a valence of more than 3 do not perform a basic function at all, but may instead perform the acidic function.

232. Light metals belonging to the same natural family or group, and therefore having the same valence, differ from one another as to the intensity of their chemical energy, according to their atomic weights, those having the higher atomic weights being more energetic and more powerfully basic than those having smaller atomic weights.

233. The hydroxides of all non-metallic elements are acids. In general, the hydroxyl acids formed by the non-metallic elements are more decidedly acid in their character the higher their algebraic combining number is, other things being equal. But non-volatile acids form more permanent salts than volatile acids, and more volatile acids form less permanent salts than less volatile acids.

234. The halogens, fluorine, chlorine, bromine and iodine, when they exercise negative polarity or form fluorides, chlorides, bromides and iodides, exhibit an intensity of chemical energy in the inverse order of their atomic weights. The student should note that this behavior of the halogens is the very opposite of the behavior of the alkali metals.

Fluorine is the most energetic of the halogens, because it has the smallest atomic weight of all of them, while cæsium is the most energetic of the alkali metals, because it has the largest atomic weight of all of those metals.

But when chlorine, bromine and iodine perform the acidic function and accordingly exercise positive polarity, the stability of the salts they form is in the order of their atomic weights. Iodates are more permanent than bromates and chlorates, and the bromates are more permanent than the chlorates; the chlorides are more permanent than the bromides or iodides, and the bromides are more permanent than the iodides.

XVI

Chemical Reactions

235. Chemical changes are called chemical reactions. They are rearrangements of the atomic linking in the molecules of matter.

The substances which take part in chemical reactions are called the **factors**, and the substances formed by the reaction are called the **products.**

The factors may be two or more, but chemical changes sometimes take place in one single substance, so that we may have but one factor.

The products are most frequently two, but there may be more than two, and there may be but one product.

When two factors form one product, the reaction is called a **synthesis.**

When one factor splits up into two or more products, we call the reaction **dissociation.**

When two factors react upon each other and both of the factors are decomposed, with the result that two new products are formed, the reaction is called a **metathesis**, or double decomposition.

In any reaction where one element displaces another element in a compound factor, with the result that two products are formed, one of which is or contains the displaced element, we call the reaction **substitution**.

The following examples will suffice to illustrate these several kinds of reactions:

$Fe+2I=FeI_2$ represents a synthetical reaction.

$CaCO_3=CaO+CO_2$ represents a dissociation.

$CaO+CO_2=CaCO_3$ represents a synthetical reaction.

$ZnO+2HCl=ZnCl_2+H_2O$ is an equation representing a metathesis.

$Zn+2HCl=ZnCl_2+H_2$ represents substitution.

$H_4C+2Cl=H_3CCl+HCl$ is also a case of substitution.

236. In order to explain the course of chemical reactions we shall find it convenient to use the term radical to indicate any atom or group of atoms transferred from one molecule to another, or liberated from a molecule, or entering into combination with another atom or group of atoms.

A radical differs from a molecule in that the radical has unused combining power by means of which it can enter into combinations, while a molecule has all the combining power of its atoms fully occupied, so that the molecules do not enter into chemical combination in any manner dependent upon valence.

The student has also learned that molecules may be divided into two ions—the positive ion and the negative ion. These ions are radicals. In the molecule $KClO_4$, K is the positive ion and the group ClO_4 is the negative ion. K is the positive radical and ClO_4 is the negative radical.

237. Malaguti's Doctrine. Chemical reactions are subject to a tendency toward the pairing of the strongest radicals of opposite polarity. In other words, the strongest positive radical present has a tendency to unite with the strongest negative radical present, because the strongest positive radicals form the most stable and permanent compounds with the strongest negative radicals, and it is self-evident that the tendency of all matter in the universe must be in the direction of the formation of molecules of the greatest degree of stability, or in other words, molecules best able to resist change.

We have already observed that some acids are stronger than other acids, and that some bases are stronger than other bases. These facts depend upon the same tendency. The light metals are more strongly basic than the heavy metals, and the metals having a low valence are more strongly basic than those having a higher valence. Of any two metals having the same valence and belonging to the same natural family in accordance with the periodic system, the metal having the highest atomic weight is a stronger positive radical than another metal having a smaller atomic weight. Acidic elements having a higher algebraic combining number form stronger acids than the same elements when they exercise a lower algebraic combining number.

238. But physical conditions affect chemical reactions very decidedly. The degree of solubility or of volatility of the products may nullify the tendency indicated by Malaguti s doctrine. Chemical reactions proceed more readily and more nearly to completion when one of the products is eliminated from the arena of chemical action as fast as formed

239. Berthollet formulated the following doctrine: Whenever the formation of a **volatile product** is possible at the temperature at which the reaction occurs, then the course of the reaction will be determined accordingly, and that volatile product will be formed. The same proposition may be stated in this way: Chemical reactions are facilitated and rendered more complete when one or more of their products are gases.

Calcium carbonate can be decomposed by heat, because one of the products is the gas CO_2. Ammonium chloride and calcium oxide heated together produce calcium chloride, water and ammonia, because the water and ammonia are volatile. Mercury sulphate and sodium chloride heated together form mercury chloride and sodium sulphate, if the temperature is high enough to vaporize the chloride of mercury.

240. Another doctrine formulated by Berthollet is to the effect that whenever by any double decomposition between compounds in solution an **insoluble or less soluble** compound can be formed, then that insoluble or less soluble compound will be formed. An equivalent statement in different words is that chemical reactions between substances in a state of solution are facilitated and proceed to completion when one of the products is insoluble or only sparingly soluble in the liquid.

If you know that phosphate of iron is insoluble in water, then you know also that you cannot mix a water-solution of any phosphate with a water-solution of any iron salt without getting a precipitate of phosphate of iron. A solution of acetate or nitrate of lead or any other soluble lead compound mixed with any solution of a sulphate will give a precipitate of lead sulphate, because lead sulphate is insoluble. The well known fact that calcium oxalate is insoluble tells us that if it is desired to remove the calcium from any solution, all that is necessary is to add a solution of some oxalate, because that would cause the formation of calcium oxalate, which would be precipitated. To know that the oxides, hydroxides, sulphites, carbonates, oxalates and phosphates of the heavy metals are all insoluble in water is to know that solutions of the water-soluble salts of those metals cannot be mixed with the solutions of any of the soluble hydroxides, sulphites, carbonates, oxalates or phosphates without producing precipitates.

241. Malaguti's doctrine would lead us to the conclusion that when a mixture is made of a solution of sulphate of potassium and acetate of lead, no precipitate would be formed, and in fact no reaction would take place, because, of the two positive radicals, potassium and lead, potassium is the stronger, and of the two negative radicals, the sulphate radical and the acetate radical, the former is the stronger, and the tendency toward the union of the stronger positive radical with the stronger negative radical would prevent any change, because the potassium and the sulphate radical are already united. But a reaction does take place and sulphate of lead is formed, despite Malaguti's doctrine, because lead sulphate is insoluble.

The tendency toward the formation of insoluble compounds by double decomposition always annuls or overcomes the tendency toward the pairing of the strongest positive and negative radicals, unless both tendencies operate in the same direction.

242. From what has been said, it is evident that a good chemist must know the relative solubilities and volatilities of chemical compounds in order to be able to make a prognosis of chemical reactions.

243. Substances in a solid state do not readily react upon each other.

Gaseous substances react with each other more freely than solids, but less favorably than liquids.

Substances in a liquid condition react most readily and completely, especially when held in solution by a liquid taking no part in the reaction.

Solids react with liquids more readily than with other solids or with gases.

Gases react readily with substances in a liquid condition.

Substances which do not react upon each other at all in a dry condition may do so immediately upon being wetted.

Solids which do not react upon each other at all at the ordinary temperature may react upon each other comparatively freely when heated to the temperature at which they liquefy or the temperature at which one of the products formed by the reaction becomes liquid.

244. Chemical Solution. Water-soluble salts and some other water-soluble compounds are generally produced by chemical solution; that is, by the action of one factor in liquid form upon another factor in the solid or liquid or gaseous form.

The solvents used are most commonly acids or alkalies, but occasionally solutions of salts.

The acids or other chemical solvents are said to be neutralized or saturated by metals or metallic compounds dissolved in them.

Acids are among the most common materials used in the laboratory for the production of other salts.

Metals or their oxides, hydroxides or carbonates are dissolved in hydrogen chloride or so-called hydrochloric acid to produce metallic chlorides; in nitric acid to produce nitrates; in sulphuric acid to make sulphates; in acetic acid to produce acetates, and so on. This method is practicable whenever the products are water-soluble salts together with water, or water-soluble salts together with gaseous products, or both water and gas together with the salt.

245. The Action of Heavy Metals upon the Common Acids. In common parlance, it is said that the acids attack certain metals, but it is clearly more consistent to say that the metals attack the acids, because while the metals are dissolved and turned into metallic compounds, they are not decomposed, while it is strictly true that the metal causes the acid to decompose.

Gold and the *platinum metals* do not attack any acid, but they dissolve in the mixture of nitric acid and hydrogen chloride which is called nitro-hydrochloric acid, or *aqua regia*. Chlorides of gold and platinum are formed with the free chlorine contained in that mixture.

Aluminum decomposes hydrochloric acid, forming aluminum chloride and setting the hydrogen free. It does not attack other acids.

Antimony is only physically a metal and therefore does not perform the basic function. Hence, when it decomposes nitric acid, it is simply oxidized to form insoluble antimonious oxide. Other acids are not affected by antimony.

Tin decomposes strong nitric acid, forming what is called meta-stannic acid. It also decomposes hydrochloric acid, forming stannous chloride. Sulphuric acid is not decomposed by tin.

Bismuth quickly decomposes nitric acid, forming bismuth nitrate. It also attacks hot concentrated sulphuric acid, but not hydrochloric acid.

Silver decomposes dilute nitric acid, forming silver nitrate. It also decomposes hot concentrated sulphuric acid, but it does not act upon hydrochloric acid.

Lead dissolves in and decomposes nitric acid, forming lead nitrate, but it scarcely affects hydrochloric and sulphuric acid.

Copper vigorously attacks nitric acid and also decomposes hot strong sulphuric acid, but it is not dissolved by hydrochloric acid or diluted sulphuric acid.

Nickel decomposes hydrochloric acid, sulphuric acid and nitric acid, forming nickelous salts.

Iron and *zinc* readily decompose the diluted acids.

246. *Hydrochloric acid* dissolves zinc, aluminum, iron, nickel and tin. It does not dissolve lead, copper, mercury, silver, gold, platinum, arsenic, antimony and bismuth.

Diluted sulphuric acid dissolves zinc, iron and nickel, setting hydrogen free, but it does not dissolve aluminum, lead, copper, mercury, silver, gold, platinum, tin, arsenic, antimony and bismuth.

Concentrated sulphuric acid dissolves copper and, if hot, it is also attacked by mercury, silver and bismuth.

When mercury, silver or bismuth attacks sulphuric acid, the products formed, in addition to the sulphates, are water and SO_2.

Moderately dilute nitric acid, especially when warm, dissolves zinc, iron, nickel, lead, copper, mercury, silver, arsenic and bismuth. Arsenic is oxidized to arsenic acid and the other metals form nitrates. So much of the nitric acid used as does not enter into the formation of the nitrate yields water and the gas NO, which oxidizes in the air to red vapors of N_2O_4 or NO_2, or both, according to the temperature. It is commonly said that "red nitrous vapors" are formed when metals are dissolved in nitric acid.

Cold and very dilute nitric acid dissolves iron and zinc, forming ferrous nitrate or zinc nitrate, together with ammonium nitrate and water. This fact is particularly interesting and instructive, for it will be seen that the ammonium nitrate can only be formed by changing the algebraic combining number of a part of the nitrogen from +5, which is the combining value it possesses as the acidic element of nitric acid, to −3, which is the combining value it has in any ammonium compound. This may most clearly be shown by the following equation: $4Zn+10HONO_2=4Zn(NO_3)_2+H_4NONO_2+3H_2O$. The four zinc atoms before the metal is dissolved in the nitric acid have an algebraic combining number of 0. But in the four molecules of zinc nitrate which the metal forms, the zinc atoms have a total algebraic combining number of +8, for zinc in combination has a valence of 2. The four zinc atoms, therefore, gained eight units of combining value. The first nitrogen atom in the molecule H_4NONO_2, or the nitrogen of the ammonium, has five bonds, four of which hold the four hydrogen atoms, while the fifth connects the H_4N to the oxygen atom standing between the two nitrogen atoms of the H_4NONO_2, and as the four bonds holding the hydrogen are negative bonds, while the fifth bond must be a positive bond, and as −4 added to +1 makes −3, the nitrogen atom of the H_4N has a value of −3. Inasmuch as that nitrogen atom was furnished by the original $HONO_2$, in which all the nitrogen has a value of +5, it follows that the nitrogen reduced lost eight units, for the difference between +5 and −3 is, of course, eight units. These eight units lost by the nitrogen atom are the eight units gained by the four zinc atoms.

Concentrated nitric acid is not attacked by iron, but dissolves lead, copper, mercury, silver, arsenic and bismuth. It is not affected by gold and platinum. It oxidizes tin to insoluble so-called meta-stannic acid, and antimony to insoluble antimonious oxide.

247. The foregoing statements must not be construed to mean that metals which are not dissolved by the acids named may not be superficially affected to a considerable degree.

Diluted sulphuric acid does take up copper and form copper sulphate, so that copper vessels are corroded by diluted sulphuric acid. But the diluted acid dissolves the metal so slowly and to such a limited extent that we would not think of using diluted sulphuric acid for the purpose of dissolving copper.

Tin is not affected by sulphuric acid, but tinned iron or "tin plate," however heavily coated with pure tin, is comparatively soon destroyed by not only very dilute sulphuric acid, but even by boric acid solutions and by very weak acetic acid, probably because the tin coating is not so impervious that the iron is absolutely protected.

248. Acids are readily attacked by metals if the salts formed by the reaction are soluble in the liquid. But metals cannot be dissolved in the acids if the salts formed are insoluble in the liquid. Thus, strong nitric acid does not attack iron, because the iron nitrate is not soluble in strong nitric acid, but diluted nitric acid does attack iron, because the iron nitrate is soluble in diluted nitric acid and in water. Again, lead is not soluble in moderately diluted sulphuric acid, because lead sulphate is insoluble both in diluted sulphuric acid and in water. But the lead is acted upon by concentrated sulphuric acid, because lead sulphate is soluble in that acid when of sufficient strength.

249. Chemical reactions occurring in processes of manufacture of chemical compounds are very generally of such character that the products formed are easily separable from each other. Were not this the case, they would be practically useless.

A double decomposition resulting in the formation of one product soluble in the liquid in which the reaction takes place and another insoluble in that liquid is useful or practicable, because the insoluble substance is easily separated from the soluble.

A reaction resulting in the formation of one product which is volatile and another which is not volatile is also workable, because the volatile product can be easily dissipated and separated from the non-volatile.

Reactions in which water is the only by-product are also useful, because water is volatile and can be eliminated, or, if the principal product is obtained dissolved in the water, it can be recovered from the solution by evaporation of the water and crystallization of the solid.

Metallic salts are successfully made by the solution of the metal in the appropriate acid, because the by-product is either hydrogen or some other gas. Metallic salts are easily made from metallic oxides by dissolving these in acids, because the by-product is water. Salts can readily be made by saturating acids with carbonates of the metals, because the by-products are water and the gas CO_2.

250. **Neutralization** is effected in solutions by mixing acids and alkalies, or acids and alkali carbonates, or acids and bases, etc., in the requisite proportions, adding either the acid to the metallic compound or the metallic compound to the acid. Acid salts are also neutralized by alkalies and alkali carbonates.

Whenever practicable, the point of exact neutralization of an acid by a base or of a base by an acid is determined by a color reagent. The most common and useful reagent of this kind and for this purpose is *litmus*, which is generally employed in the form of litmus paper, which is unsized paper dipped in a solution of litmus and then dried.

Litmus is a blue pigment which is very readily turned red by acids and blue by alkalies. Blue litmus paper is made from the unaltered solution of the pigment, while red litmus paper is made from a litmus solution to which just enough pure hydrochloric acid has been added barely to turn its color red. Litmus paper can also be made in such a way that it is neither red nor blue, by carefully adding just enough of the hydrochloric acid to the litmus solution used.

A liquid which turns blue litmus paper red is said to have an *acid reaction* on test paper; one that turns red litmus paper blue is said to have an *alkaline reaction* upon test paper. A liquid which does not change the color of either red or blue litmus paper is said to have a *neutral reaction* on test paper, or to be neutral to test paper. The test is made by touching a small strip of the test paper with the liquid.

251. Salts of normal structure formed by strong acids with weak bases have an acid reaction on test paper, but those formed by weak acids with strong bases have an alkaline reaction on test paper. Only salts formed by strong

acids with strong bases or weak acids with weak bases have a neutral reaction on test paper.

Salts still containing some of the replaceable hydrogen of the acid are said to be acid salts, or to have an acid structure. Bicarbonate of potassium is such a salt, but bicarbonate of potassium, although of acid structure, has an alkaline reaction on test paper, because potassium is one of the most powerful basic elements, while the carbonate radical is a very feeble acid-radical.

A salt containing a larger proportion of the basic element than that contained in a salt of normal structure is called a basic salt. Subsulphate of iron is such a salt, though a solution of subsulphate of iron has an acid reaction on test paper, because iron is not sufficiently strongly basic to form salts of neutral reaction with such a powerful acid as sulphuric acid. A solution of alum has an acid reaction, because aluminum is very feebly basic, although alum also contains potassium.

252. When acids are saturated with the metal or with metallic oxides, hydroxides or carbonates, the proportions of these materials employed are determined beforehand according to the atomic and molecular weights, even if an excess of the metal or metallic compound is to be used. When salts of normal composition are to be prepared and the reaction on test paper does not indicate the composition, the exact theoretical proportions are used.

When iron or zinc is dissolved in sulphuric acid, the metal is added *in excess*, because the acid cannot possibly dissolve any more of the metal than the quantity required to form the sulphate. But when mercury is dissolved in nitric acid, it is necessary that the proportions of mercury and nitric acid be carefully attended to, because if the nitric acid is in large excess, mercuric nitrate is formed, while with a less proportion of nitric acid, mercurous nitrate of normal structure is formed, and with a still smaller amount of nitric acid, a basic mercurous nitrate is obtained.

253. The proportions to be employed of the factors of a chemical reaction are, of course, indicated by the molecular weights and atomic weights. In constructing a working formula, it is therefore necessary first to write down the chemical equation that represents the reaction taking place in the process, and when this equation is properly balanced, the atomic or molecular weights will show the quantities required of the factors, and also the quantities obtained of the products. But the proportions found in this way are only the theoretical proportions, and they may not be workable, because it is generally the case that the reaction is not complete under those conditions.

If it is necessary that one of the factors in a chemical reaction be completely decomposed or consumed, then the other factor or factors must be used in greater proportion than that required by theory.

If a double decomposition between A and B is to be effected, A must be used in excess over the theoretical proportion, if it is necessary that B shall be completely decomposed; if A must be completely decomposed, then B must be used in excess.

In other words, the course and relative completeness of chemical reactions may be materially affected by the relative masses of the factors.

When a solution of sodium sulphate and a solution of barium acetate are mixed in the proportions required for even or complete metathesis, barium sulphate and sodium acetate will be formed, and the reaction proceeds to completion, because the barium sulphate is insoluble. But if barium sulphate is placed in water containing a large amount of sodium carbonate in solution, the sodium carbonate will gradually decompose the barium sulphate so that sodium sulphate and barium carbonate are formed, and the insoluble solid matter in the liquid will become a mixture of barium carbonate and barium sulphate. If the sodium salts, which are soluble, are removed from time to time and fresh portions of sodium carbonate added, the entire amount of barium sulphate can be finally converted into barium carbonate. **Mass reactions** of this kind are numerous.

254. The most common and numerous chemical reactions **are double decompositions,** and, as already shown, double decompositions are most readily effected between reagents in a state of solution, under Berthollet's law with regard to the formation of insoluble or less soluble products. In other words, they are precipitations.

Other common reactions between acids and bases are also double decompositions.

The student should therefore learn to write chemical reactions representing double decompositions. He should bear in mind that any double decomposition between two substances is simply a mutual interchange of radicals. It is like an exchange of partners in a quadrille; two couples meet and exchange partners. Each factor in a chemical reaction such as is called double decomposition is a couple, consisting of the positive radical and the negative radical. The positive radical of one factor gives up its negative radical to the positive radical of the other factor and takes the negative radical from that factor in exchange. For example, silver nitrate meets sodium chloride. The silver and the sodium are the positive radicals, the nitrate radical (NO_3) and the chlorine are the negative radicals. The silver gives up its NO_3 to the sodium, taking the chlorine in exchange.

This double interchange may also be likened to an exchange of horses between two riders. A red man on a white horse and a white man on a red horse meet, and the two men exchange horses. Both men are still there and so are the horses, but they have changed positions. That is precisely what takes place between the several radicals concerned in a double composition.

When mercuric chloride and potassium iodide, both in solution in water, are mixed with each other, the mercury leaves the chlorine and takes up the iodine instead, while the potassium, giving up the iodine to the mercury, takes up the chlorine in exchange. We started with a combination of mercury and chlorine and a combination of potassium and iodine; we finish with a combination of mercury and iodine and a combination of potassium and chlorine.

The equation representing the reaction is as follows: $HgCl_2+2KI=HgI_2+2KCl$.

The reason why two molecules of KI are necessary is that the mercury atom has a valence of 2, whereas the atoms of chlorine, potassium and iodine each have a valence of only 1, and as we must have the same number of positive bonds as of negative bonds in any molecule, it follows that a molecule of mercuric chloride must contain two chlorine atoms to the one mercury atom, and a molecule of mercuric iodide must contain two iodine atoms to the one mercury atom. The two chlorine atoms contained in $HgCl_2$ require two potassium atoms to form potassium chloride, and two molecules of KI are required to furnish those two potassium atoms for the potassium chloride, as well as to furnish the two iodine atoms for the mercuric iodide.

The easiest rule to follow is this: *Find the valence of the positive radicals of the two factors, and then take the number of atoms or molecules of each that will give you a common multiple of the numbers expressing those valences.*

For example, if the valence of one of the positive radicals concerned is 1 and the valence of the other positive radical is 2, then multiply the factor containing the radical having a valence of 1 by 2, and multiply by 1 that factor the positive radical of which has a valence of 2. If the valence of the positive radical of one factor is 2 and that of the other is 3, then multiply the 2 by 3 and the 3 by 2.

In the reaction represented by the equation $Na_2CO_3+CaCl_2=CaCO_3+2NaCl$, the student will see that the positive radicals are the Na and the Ca. The valence of Na is 1 and the valence of Ca is 2, but as the Na is multiplied by 2 already and since the formula of the sodium carbonate is Na_2CO_3, one molecule of Na_2CO_3 is sufficient, for the two sodium atoms together form two bonds, and the single calcium atom having a valence of 2 has also two bonds.

The fact which the student should keep clearly in view is that the total number of bonds of the positive radical of one of the factors must be the same as the total number of bonds of the positive radical of the other factor. In order that the exchange may be even, it takes two five-dollar bills to match five two-dollar bills.

Test Questions

The number of questions in this and some of the following lessons may seem too great. Theoretically, it would be better if the lessons were more uniform in length, but as the real purpose of the Course is to insure a thorough understanding on the part of the student, the number of questions bears a close relation to the importance of the subject.

It is not necessary that long answers should be written nor that all answers should be expressed in complete sentences. Occasionally "yes" or "no" may serve as an answer. Still, every answer must be clear and precise.

If numerical computations are necessary, it is always desirable that the entire work of the problem should be submitted. If merely the answer is given and it is wrong, the instructor has no clue as to what is really the reason for the student's mistakes and so no assistance can be rendered.

1. What is meant by the factors of chemical reactions ?

2. How many factors are necessary in a chemical reaction ?

3. How many products are formed by any chemical reaction ?

4. What is meant by dissociation ?

5. How many factors are concerned in metathesis ?

6. How many factors are necessary in a synthesis ?

7. What general expression is used to signify an alteration in the atomic linking of any molecule or molecules ?

8. What is the difference between an elemental factor and a compound factor ?

9. What is the algebraic combining value of an elemental factor in a chemical reaction ?

10. When two elements enter into direct combination with each other, what is the algebraic combining number of each before the reaction and after the reaction ?

11. What is meant by substitution ?

12. What would you call a reaction in which two factors form but one product ?

13. What would you call a reaction in which one factor furnishes two or three products ?

14. What is the technical term used to designate a reaction in which two factors form two products without any change in the algebraic combining numbers of any of the ions ?

15. Write a chemical equation representing a dissociation reaction.

16. Write a chemical equation representing a synthesis.

17. Write a chemical equation representing a substitution reaction.

18. Write a chemical equation representing a double decomposition.

19. What is the difference between a radical and an ion ?

20. What is the difference between a radical and a molecule ?

21. What radicals are contained in sodium nitrate?

22. Write symbolic formulas representing the radicals contained in ammonium sulphate.

23. By what means is it possible to determine which of several positive radicals is the most powerful and which of several negative radicals is most powerful, in order to predict the result of a chemical reaction under Malaguti's law?

24. Under what circumstances will the strongest positive radical unite with the weakest negative radical present in a reaction?

25. Under what circumstances will the results of a metathesis be the direct opposite of those indicated by Malaguti's doctrine?

26. State the laws of Berthollet governing the direction of metathetical reactions.

27. What happens if you mix a solution of the sulphate of a heavy metal with a solution of phosphate of sodium?

28. What chemical change, if any, will take place when you mix a solution of ferric chloride with a solution of sodium hydroxide?

29. What chemical change, if any, will take place if you mix a solution of ferric chloride with a solution of sodium chloride? Give the reason for your answer.

30. Why will zinc oxide be obtained when zinc carbonate is strongly heated? What else is formed at the same time? Why does this reaction take place and what is it called?

31. What reaction, if any, will take place when you mix a solution of sodium phosphate with a solution of sodium carbonate? Give the reason for your answer.

32. What reaction will take place when you mix two bromides with each other?

33. What reaction will take place when you mix several potassium salts with one another? Give the reason for your answer.

34. Will any chemical change take place when you mix a solution of potassium permanganate with a solution of potassium sulphite? If so, why, and what products are possible?

35. Write the formula for oxalate of barium and state how it can be made by double decomposition.

36. Lead iodide being insoluble, how would you make it?

37. What materials are necessary for the preparation of lead phosphate?

38. If you mix a solution of zinc sulphate with a solution of sodium oxalate, what reaction will take place, if any? State the products formed and what class the reaction belongs to.

LESSON ELEVEN

XVII

Changes of the Algebraic Combining Numbers of Atoms

255. Starting out with the assumption that the total algebraic sum of the positive and negative combining units or bonds of all atoms, free or combined, of all matter is at all times 0, we are led to the conclusion that whenever the algebraic combining number of any atom is increased the algebraic combining number of some other atom or atoms must necessarily be diminished in exact proportion, and *vice versa.*

If one atom gains one unit of combining value, that unit must be lost by some other atom. If any atom loses one unit, some other atom must gain it. If any atom gains two or more units of combining value, it must have received them from one or more other atoms.

256. Units of combining value can be *transferred* from one atom to another, but their total cannot be added to nor diminished.

Whether this proposition be called a chemical law or a mere mathematical device, it is extremely valuable and may be employed as an infallible rule. It serves to clear up many puzzling problems in chemistry, and gives a direct answer to many questions which cannot be readily solved without it.

257. The term oxidation in its narrowest sense means combination with oxygen. But when $HgCl_2$ is converted into HgO by double decomposition,

$$HgCl_2+2KOH=2KCl+HgO+H_2O,$$

this change is not oxidation, although the Hg gives up its Cl and enters into combination with O instead.

It is also frequently stated that oxidation includes any case in which any compound already containing oxygen is changed into another compound containing a greater proportion of oxygen. But this is not always true.

When Na_2SO_3S is mixed with H_2SO_4 the products formed are $Na_2SO_4+S+SO_2+H_2O$. The Na_2SO_3S contains a smaller percentage of oxygen than either Na_2SO_4 or SO_2; but no one would say that Na_2SO_3S has been oxidized to Na_2SO_4 or to SO_2. We see instead that the Na_2SO_3S has been reduced to SO_2.

When Na_2SO_3 in water solution is boiled with S the product formed is $Na_2S_2O_3$. The Na_2SO_3 contains 48 parts of oxygen in 126, while the $Na_2S_2O_3$ (or Na_2SO_3S) contains only 48 parts of oxygen in 158 parts. The proportion of oxygen, therefore, is smaller in Na_2SO_3S than in Na_2SO_3; but the Na_2SO_3 *is oxidized* to $Na_2S_2O_3$, for the sulphur atom added performs the same use in the structure of the Na_2SO_3 as one of the oxygen atoms in the analogous compound Na_2SO_4.

The change of SO_3 to H_2SO_4 by means of H_2O,

$$SO_3+H_2O=H_2SO_4,$$

is not called oxidation, although the percentage as well as the number of atoms of oxygen is greater in H_2SO_4 than in SO_3.

The removal of hydrogen from an organic substance is commonly called oxidation; but such a change may be effected without reference to oxygen and in cases where no oxygen is contained in any of the compounds concerned. The substitution of chlorine or any other negative element in the place of hydrogen in any organic compound *is* oxidation of the atom which exchanges hydrogen for chlorine. But if another positive element or atom takes the place of the hydrogen united to any carbon atom in any organic compound, that carbon atom is *not* oxidized. If the group OH takes the place of a hydrogen atom in a hydrocarbon the change is oxidation, but the conversion of alcohol into ether,

$$2C_2H_5OH=(C_2H_5)_2O+H_2O,$$

is neither oxidation nor reduction.

The conversion of $FeCl_2$ into $FeCl_3$ is generally admitted to be oxidation, or is called oxidation of the $FeCl_2$ to $FeCl_3$, and yet no oxygen is concerned in it unless the laborious explanation (sometimes given) is accepted that the change can take place only in water; that the chlorine decomposes the water, taking the hydrogen from it to form hydrogen chloride; that the oxygen of the water thus decomposed by the chlorine combines with the Fe of the $FeCl_2$ and the chlorine of that $FeCl_2$ combines with other hydrogen from water, and the oxide of iron and hydrogen chloride thus formed produce $FeCl_3$ and H_2O, thus:

$$2FeCl_2+2Cl+3H_2O=Fe_2O_3+6HCl,$$

and

$$Fe_2O_3+6HCl=2FeCl_3+3H_2O.$$

It does not seem to be necessary to discuss the question of the possible steps by which the $FeCl_3$ is formed. These steps are not demonstrable. But the reaction represented by the simple equation $FeCl_2+Cl=FeCl_3$ is clear and intelligible and perfectly analogous to the reaction $HgI+I=HgI_2$, which is as truly a case of oxidation as the other and which does not require the presence of any other substance.

258. Reduction is generally defined as the opposite of oxidation.

The removal of oxygen from any compound is nearly always truly reduction. In the sense in which the writer of this book, in common with many others, would use the term oxidation, the removal of one of the oxygen atoms from HOOH is *not* reduction, because the atom removed is the one having an algebraic combining number of 0, so that not one of the atoms of the HOOH undergoes any change of value.

The transformation of $FeCl_3$ into $FeCl_2$ by means of zinc,

$$2FeCl_3+Zn=ZnCl_2+2FeCl_2,$$

is generally admitted to be a reduction, and we say that the zinc acts as a reducing agent and reduces the $FeCl_3$ to $FeCl_2$. But no oxygen is here concerned.

We also speak of reducing HgI_2 to HgI by triturating the HgI_2 with mercury:

$$HgI_2+Hg=2HgI.$$

When CaO is placed in contact with HCl we obtain $CaCl_2$ and H_2O:

$$CaO+2HCl=CaCl_2+H_2O,$$

but no chemist would speak of this reaction as reduction, although the Ca is deprived of its oxygen.

259. The manner in which the term oxidation is now used indicates that the original restricted meaning of the term is no longer adhered to. In its broadest sense that term now means *an increase of the algebraic combining number of any atom.*

The use of the word "oxidation" in this broad sense is objectionable on the ground that it is derived from the word *oxygen* and should, therefore, not be applied to signify changes with which oxygen has nothing to do, and on the further ground that many chemists still employ the term in its original sense. Nevertheless, the need of some term to denote an increase in the true combining value of an atom, or a partial or complete change of the chemical polarity of an atom from negative to positive, or any other kind of augmentation of its algebraic combining number, is so urgent that the word oxidation has been employed for want of a better term, and no other single word has been suggested or used for that purpose.

The whole subject of changes in the algebraic combining numbers of atoms is of so great importance that every student of chemistry must learn the fundamental facts concerning it before he can form any intelligent idea of some of the most common phenomena of chemical change.

260. Reduction, in its broadest sense, means *a diminution of the algebraic combining number of any atom.*

261. Oxidation and reduction, understood in accordance with their broader application as stated in paragraphs 258 and 259, must of course occur together. There can be no oxidation without corresponding reduction and no reduction without corresponding oxidation.

262. An oxidizing agent is any atom having an algebraic combining number which is capable of being reduced.

But the most useful and effective oxidizing agents are, of course, those atoms which most readily suffer a diminution of their algebraic combining value, and those whose algebraic combining number is so high that it may be reduced several units.

Free chlorine is an effective oxidizing agent because of the great intensity of the chemical energy with which it forms chlorides with other elements or radicals. The algebraic combining number of free or uncombined chlorine is 0. When it forms chlorides its combining number falls to -1. Hence each atom of chlorine furnishes only one unit of oxidation, for its algebraic combining number is diminished by only one unit. But it is nevertheless a powerful oxidizing agent, because it acts so readily.

The combined chlorine in $KClO_3$ is also an effective oxidizing agent, and in this case its tendency to form a chloride is not the only motive force which makes it a powerful oxidizing agent, for the chlorine of $KClO_3$ has a high algebraic combining number (+5) which can be reduced six units (to −1), so that, while one atom of free chlorine can furnish only one unit of oxidation, the one atom of chlorine in one molecule of $KClO_3$ furnishes six units of oxidation.

We say that nitric acid, HNO_3, is a powerful oxidizing agent because it is easily decomposed and reduced to the compound NO. Two molecules of HNO_3 are said to give one molecule of water, two molecules of NO and three atoms of oxygen,

$$2HNO_3 = H_2O + 2NO + 3O,$$

and the liberated oxygen is said to effect the oxidation. But we can also and more simply explain the power of nitric acid to increase the algebraic combining number of atoms by the statement that it is the nitrogen atom of the HNO_3 which is the real oxidizing agent; that nitrogen has a value of +5 in the HNO_3 and of only +2 in NO; each molecule of HNO_3 accordingly furnishes 3 units of oxidation.

Chromic anhydride, CrO_3, is a powerful oxidizing substance because the Cr in it has the high combining value of +6, which can be easily reduced to +3. Potassium dichromate, $K_2Cr_2O_7$, contains two chromium atoms, each of which has a value of +6 capable of reduction to +3. Potassium permanganate, $KMnO_4$, contains an atom of manganese having a value of +7 capable of reduction to +2, so that one molecule of $KMnO_4$ furnishes five units of oxidation.

263. Probably the strongest reasons for applying the term "oxidation" to any increase in the true combining value of any atom are these:

Oxygen is the most abundant of all oxidizing agents. It is inexhaustible.

Many of the most powerful oxidizing substances are oxygen compounds, and they may be said to act, at least indirectly, by giving up all or a part of their oxygen.

Owing to the fact that nearly all elements can unite with oxygen, that oxygen compounds are so numerous, and that elements attain their highest algebraic combining values only in direct combination with oxygen, it follows that an extremely large proportion of the observed cases of augmentation of atomic combining value (oxidation in the broadest sense) are coincident with oxidation in the most restricted sense of that term.

Even oxidizing agents that do not contain any oxygen may be seen to have derived their oxidizing power (an algebraic combining number capable of reduction) directly or indirectly from oxygen. For example, chlorine in the free state is obtained through the action of MnO_2, the Mn of which owes its high combining value (+4) to the oxygen with which it is combined. When the chlorine is liberated from HCl by reaction with MnO_2,

$$MnO_2+4HCl=MnCl_2+2H_2O+2Cl,$$

it will be seen that the value of the Mn falls from +4 to +2, and that two atoms of chlorine, therefore, change their value from −1 to 0.

Oxidations in which oxygen is not concerned are perfectly analogous to those in which combination with oxygen takes place or in which the proportion of oxygen in an oxygen compound is increased.

264. That there are strong reasons for using the term oxidation in its broader sense may be seen from the following examples:

1. Iodine is the oxidizing agent in the reaction,

$$6KOH+6I=5KI+KIO_3+3H_2O.$$

All of the iodine had a combining value of 0. After the reaction five iodine atoms are seen to have each a value of −1, while the sixth iodine atom has a value of +5.

KIO_3 is a powerful oxidizing agent. If this be ascribed to its oxygen, then the KOH which supplied all of this oxygen may well be regarded as also an oxidizing agent; and KOH in turn received its oxygen from some other source. But no chemist would say that KOH is an oxidizing agent. All chemists agree that iodine is an oxidizing agent and also that KIO_3 is one. The explanation most frequently made why iodine acts as if it were an oxidizing agent is that it decomposes water, combining with the hydrogen of that water, whereby its oxygen is liberated so that it—the oxygen—is the real oxidizing agent. To render this clear we should have to represent the chemical changes as follows:

$$5H_2O+10I=10HI+5O.$$
$$10KOH+10HI=10KI+10H_2O.$$
$$2KOH+2I+5O=2KIO_3+H_2O.$$

But KIO_3 cannot be made directly out of KOH and I and O.

A more direct and satisfactory explanation is that five iodine atoms lose one unit each and form 5KI, while the sixth iodine atom gains the five units lost by the other five and forms KIO_3.

One-sixth of the iodine acts here as a reducing agent, being oxidized.

2. Chlorine is the oxidizing agent in

$$6Ca(OH)_2+12Cl=5CaCl_2+Ca(ClO_3)_2+H_2O.$$

This is seen from the fact that 10 atoms of chlorine changed their algebraic combining number from 0 to -1, thus losing together 10 units; these 10 units were taken up by the other two chlorine atoms, which each acquired a value of $+5$ in the $Ca(ClO_3)_2$. The $Ca(OH)_2$ is said to be oxidized to $Ca(ClO_3)_2$. Two atoms of Cl were oxidized; ten of them were reduced.

3. Sulphur is the oxidizing agent in

$$Na_2SO_3+S=Na_2SO_3S.$$

The S in the Na_2SO_3 evidently has a combining value of +4. The free S has a value of 0. But one of the atoms of S in the Na_2SO_3S has a value of +6, while the other has a value of −2. Hence, the S of the Na_2SO_3 gained two units at the expense of the free sulphur.

The Na_2SO_3 is said to be oxidized to Na_2SO_3S.

4. Phosphorus is the oxidizing agent in this reaction:

$$3Ca(OH)_2+8P+6H_2O=3Ca(PH_2O_2)_2+2H_3P.$$

The student can readily see that while the P used had a value of 0, the P in the $Ca(PH_2O_2)_2$ must have a value of +1, for the three calcium atoms have each a value of +2, the twelve hydrogen atoms have each a value of +1, and the twelve oxygen atoms have each a value of −2, so that the six phosphorus atoms must have a value of +1 each, for if we add +6, +12, −24 and +6 we get the sum of 0. Therefore 6 atoms of phosphorus gained together six units, the total algebraic combining number of all of them being +6. The other two phosphorus atoms lost those six units, because the P in each molecule of H_3P must have a value of −3. Hence, 2 atoms of P acted as oxidizing agents and the other 6 atoms of P as the reducing agents.

5. Ten sulphur atoms are reduced and the two other sulphur atoms oxidized in

$$3Ca(OH)_2+12S=CaSO_3S+2CaSS_4+3H_2O.$$

The first sulphur atom in $CaSO_3S$ has a value of +6, and that is also the value of the first sulphur atom in $CaSS_4$. All the other sulphur atoms have each a value of −2.

6. In the following reaction,

$$3MnO_2+12HCl+6FeSO_4=2Fe_2(SO_4)_3+2FeCl_3+3MnCl_2+6H_2O,$$

we can see that the three manganese atoms were reduced from a value of +4 to one of +2 each. The six atoms of iron (Fe) changed their value from +2 to +3. That this is clearly a case of oxidation is admitted by all chemists; but it is difficult to explain why it is so if oxidation is combination with oxygen or an increase in the proportion of oxygen. It is true that the percentage of oxygen in $Fe_2(SO_4)_3$ is greater than it is in $FeSO_4$; but the same is true of the percentage of sulphur. The whole truth is that the proportion of SO_4 is greater in $Fe_2(SO_4)_3$ than in $FeSO_4$. We see that the Mn exchanged its two oxygen atoms for two chlorine atoms, and that change is truly reduction. But to say that this reaction is an oxidation because the H of the HCl takes the oxygen of the MnO_2 to form H_2O is a very unsatisfactory explanation.

The statement of fact that the three manganese atoms together lose six units and that the six iron atoms gain those six units is a more direct and satisfactory explanation.

The student is requested to observe that when a strong acid acts on MnO_2 the algebraic combining number of the manganese is forced *down* to +2. Compare this result with that shown in the next example.

7. In the equation,

$$3MnO_2+2KOH=K_2MnO_4+Mn_2O_3+H_2O,$$

one manganese atom rises from a value of +4 to one of +6, while the other two manganese atoms fall from +4 to +3 each.

The presentation of the strong alkali KOH to the manganese in the MnO_2 forces its value *up* from +4 to +6 in order that K_2MnO_4 may be formed. Compare this result with that in the preceding example.

8. No one will deny that the H_2SO_3 is oxidized to H_2SO_4 and that the $FeCl_3$ is reduced to $FeCl_2$ in

$$2FeCl_3+H_2SO_3+H_2O=2FeCl_2+H_2SO_4+2HCl.$$

But we do not say that the water is the oxidizing agent, although it does supply the oxygen atom which changes the H_2SO_3 to H_2SO_4. To say that one-third of the chlorine of the $2FeCl_3$ splits off from it, leaving $2FeCl_2$, and that the Cl thus set free decomposes the H_2O, taking the hydrogen from it to form the 2HCl, while the oxygen atom of the H_2O performs the oxidation of the H_2SO_3 to H_2SO_4, is a labored explanation. The most direct and satisfactory explanation lies in the evident fact that the two iron atoms of the $2FeCl_3$ lost two units and the S of the H_2SO_3 gained those two units of combining value.

9. In the reaction,

$$4Zn+10HNO_3=4Zn(NO_3)_2+H_4NONO_2+6H_2O,$$

the nitric acid certainly acts as an oxidizing agent, but only one molecule of it performs that function, for the other eight molecules form the zinc nitrate and the ammonium nitrate. The first N in the H_4NONO_2 has a combining value of –3, while the second N in that molecule and all the nitrogen in the $4Zn(NO_3)_2$ has a value of +5, which is also the value of all the N in the HNO_3. The one N which fell from +5 to –3 lost 8 units. What became of them? They went to the four zinc atoms, which have a value of 0 in the free state but of +2 in $Zn(NO_3)_2$.

10. In the reaction $H_4NONO_2=2H_2O+N_2O$ we can see that the nitrate is reduced to N_2O, but how? The first N in the H_4NONO_2 has a value of –3; the second has a value of +5. The nitrogen atoms in N_2O have each a value of +1. Therefore, one nitrogen atom gained 4 as it rose from –3 to +1, while the other lost 4 units as it fell from +5 to +1.

The difference between the valence and the algebraic combining number is strikingly shown in the foregoing, for each nitrogen atom in H_4NONO_2 has 5 bonds or a valence of 5, while one has an algebraic combining number of –3 (the sum of –4 and +1) and the other has five positive bonds or an algebraic combining number of +5.

11. In $H_4NONO=2H_2O+2N$, we see that the first N in the H_4NONO has an algebraic combining number of –3 and the second of +3. As both of these atoms were liberated, one gained 3 and the other lost 3.

12. In the reaction,

$$2HgCl_2+SO_2+2H_2O=2HgCl+2HCl+H_2SO_4,$$

it is of course possible to explain that two chlorine atoms of the $2HgCl_2$ decomposed one molecule of water, forming $2HCl$, and that the liberated oxygen formed one molecule of H_2SO_4 by combining with the SO_2 and the second molecule of water, but we prefer to say that the two mercury atoms lost two units of algebraic combining value which were both gained by the S of the SO_2, thus rendering the formation of H_2SO_4 possible.

13. In the reaction,

$$Cu+2H_2SO_4=CuSO_4+SO_2+2H_2O,$$

we might explain that the copper replaced the two hydrogen atoms of one of the molecules of the H_2SO_4 and that these two hydrogen atoms combined with one of the oxygen atoms of the other molecule of H_2SO_4, reducing it to H_2SO_3, after which this H_2SO_3 split up into SO_2 and H_2O. But as we know that hydrogen does not reduce H_2SO_4 to H_2SO_3 or decompose it in any way, we prefer to say that the copper gained two units and that the S of one of the molecules of H_2SO_4 lost those units and therefore formed SO_2.

265. Any atom having a low algebraic combining number capable of augmentation is a possible reducing agent. But an effective and convenient reducing agent is an atom which may be easily oxidized, and especially one which can have its algebraic combining number increased by several units.

Any true metal acts as a reducing agent whenever it enters into chemical combination with any element whatsoever, because a *free* element has an algebraic combining number of 0 and all metals *in combination* are positive.

Chlorine, whenever it forms $KClO_3$, or even $KClO$, is a reducing agent, because that chlorine is itself oxidized, just as carbon forms either CO_2 or CO when used to reduce metallic oxides and certain other oxygen compounds.

Hydrogen sulphide is a reducing agent because the sulphur of the H_2S has the low value of -2, which can be raised to 0, or to $+2$, or $+4$, or even to $+6$. Ammonia is a reducing agent because its nitrogen has a value of -3, capable of being raised to $+5$.

SO_2 is a reducing agent because its S can have its value increased from $+4$ to $+6$.

Test Questions

1. What is meant by the term algebraic combining number?

2. What is the algebraic combining number of metallic silver?

3. What is the algebraic combining number of chlorine?

4. What is the algebraic combining number of silver chloride?

5. In the reaction $H+Cl=HCl$, what are the algebraic combining numbers of the H, the Cl and the HCl?

6. What are the algebraic combining numbers of the Na in NaCl, the Ag in AgCl, the Na in $NaNO_3$ and the Ag in $AgNO_3$, and what are the algebraic combining numbers of NaCl, AgCl, $NaNO_3$ and $AgNO_3$?

7. When H_2O_2 is dissociated into H_2O and O, is that change an oxidation or a reduction? Give the reason for your answer.

8. Can the potassium of any potassium compound act as an oxidizing agent or as a reducing agent?

9. Can the silver of any silver compound act as an oxidizing agent or a reducing agent? If so, explain how.

10. Can sulphuric acid act as an oxidizing agent, and if so, how? What element in the sulphuric acid is reduced?

11. Why is permanganate of potassium so powerful an oxidizing agent?

12. Why is potassium chlorate an effective oxidizing agent?

13. Why is MnO_2 useful as an oxidizing agent?

14. What is formed when free sulphur acts as an oxidizing agent?

15. What is formed when free chlorine acts as an oxidizing agent?

16. What is formed when free phosphorus acts as a reducing agent?

17. Identify the oxidizing agent and the reducing agent in the equation: $3MnO_2+2KOH=K_2MnO_4+Mn_2O_3+H_2O$.

18. Identify the oxidizing element and the reducing element in the following reactions:

(a) $3P+5HNO_3+2H_2O=3H_3PO_4+5NO$.
(b) $6Sb+10HNO_3=Sb_2O_5+5H_2O+10NO$.
(c) $3H_2S+8HNO_3=3H_2SO_4+4H_2O+8NO$.
(d) $3Hg+8HNO_3=3Hg(NO_3)_2+4H_2O+2NO$.
(e) $3Hg+4HNO_3=3HgNO_3+2H_2O+NO$.
(f) $3Hg+3H_2SO_4+2HNO_3=3HgSO_4+4H_2O+2NO$.
(g) $SO_2+2HNO_3=H_2SO_4+2NO_2$.
(h) $HNO_3+8H=H_3N+3H_2O$.
(i) $HNO_3+3HCl=NOCl+2H_2O+2Cl$.
(j) $3MnO_2+KClO_3+6KOH=3K_2MnO_4+KCl+3H_2O$.
(k) $2MnO_2+KClO_3+2KOH=2KMnO_4+KCl+H_2O$.
(l) $2HgCl_2+SO_2+2H_2O=2HgCl+H_2SO_4+2HCl$.
(m) $C_2H_5OH+2Cl=C_2H_4O+2HCl$.
(n) $H_4NNO_3=2H_2O+N_2O$.
(o) $H_4NNO_2=2H_2O+2N$.

LESSON TWELVE

XVIII

The Periodic System

266. It has been found that the elements when arranged in certain periods according to their atomic weights naturally fall into groups, the members of which exhibit striking similarities of chemical behavior. This has been expressed as follows: "The chemical properties of the elements are periodic functions of their atomic weights"; and this statement is called the periodic law.

When the periodic system was first presented in the form in which we now state it, several of the now known elements had not yet been discovered. Nevertheless, the evidences of the fact of the periodicity of the regularities and similarities of valence and functions in accordance with the atomic weights were so overwhelming as to command attention immediately, and subsequent discoveries have confirmed the belief that the natural classification of the elements in accordance with this system is based upon natural law.

267. If the seven elements beginning with lithium and ending with fluorine, arranged in accordance with their increasing atomic weights, be set down in succession, we will have:

Li	Be	B	C	N	O	F
7	9	11	12	14	16	19

The elements are indicated by their symbols, and the numbers are their atomic weights. There are no known elements having atomic weights between 7 and 19 except those mentioned in this period of seven. Lithium, the first member of the period, is an alkali metal and the last is a halogen. The striking result of this arrangement is that the ruling valences of these seven elements in the order in which they stand are 1, 2, 3, 4, 3, 2 and 1. The element having the next higher atomic weight above 19 was sodium, with the atomic weight of 23, which is also an alkali metal, like lithium.

If we now set down another period of seven elements in the order of their atomic weights, beginning with sodium, we shall have

Na	Mg	Al	Si	P	S	Cl
23	24.2	27	28.4	31	32	35.4

No other elements with atomic weights between 19 and 36 are known. The seventh element is again a halogen, and the respective ruling valences of the elements in the order in which they are set down are again 1, 2, 3, 4, 3, 2 and 1.

But the ruling valences of elements are not their only important valences. If the polarity as well as the valence be considered in connection with this second period of elements, and the maximum algebraic combining numbers be given instead of the ruling valences, the result is even more striking, for the maximum algebraic combining numbers of these seven elements, beginning with Na, in the order in which they stand, are +1, +2, +3, +4, +5, +6 and +7.

The element next following chlorine in the order of increasing atomic weight is again an alkali metal, namely, potassium. If we now set down the seven elements, beginning with potassium, in the order of their atomic weights, we get:

K	Ca	Sc	Ti	V	Cr	Mn
39	40	44	48	51.5	52	55

In this period we find that the last element, manganese, is not a halogen, but the maximum algebraic combining numbers of these seven elements are again, as before, +1, +2, +3, +4, +5, +6 and +7. (The student will remember that the halogens are fluorine, chlorine, bromine and iodine.)

We have seen that two periods of seven elements, beginning with alkali metals, end with the halogens fluorine and chlorine. If we now set down bromine at the right and put down in front of it the six elements standing next to bromine in the order of their decreasing atomic weights, we get the following result:

Cu	Zn	Ga	Ge	As	Se	Br
63.5	65.3	70	72.5	75	79	80

Three elements are known having atomic weights between 55 and 63.5; namely, iron, nickel and cobalt. We have therefore a break here in the regular periodicity before noted. The maximum algebraic combining numbers of the elements from copper to bromine are +2, +2, +3, +4, +5, +6 and +5, so that in this period the first and the last elements do not appear to follow the same rule as before. Copper sometimes has the algebraic combining number +1, but no compound of bromine is known in which that element has a combining value as high as +7.

If we now set down another period of six, beginning with the alkali metal rubidium, which stands next after bromine in the magnitude of its atomic weight, we have:

Rb	Sr	Yt	Zr	Cb	Mo
85.5	87.5	89	90.5	93.5	96

The seventh element belonging to this period is evidently not yet known, for these six elements are closely related to K, Ca, Sc, Ti, V and Cr, and they have the combining values 1, 2, 3, 4, 5 and 6.

The next period may be made to begin at the right with the halogen iodine. Going backwards from iodine to silver, we get this result:

Ag	Cd	In	Sn	Sb	Te	I
108	112	114	119	120	125.5	126.5

In that period of seven elements, the maximum algebraic combining numbers are unmistakably +1, +2, +3, +4, +5, +6 and +7.

Evidently such results as these cannot be accidental. The reasons for the irregularities and exceptions to be observed in arranging the chemical elements in accordance with this system will doubtless some day be discovered.

268. Several tables have been arranged on this plan, and of these the most useful to the beginner will be found on page 171. At the top of the table are the maximum algebraic combining numbers, and in the last four columns below the maximum combining numbers the student will find the minimum algebraic combining numbers. All of the elements in the first column are alkali metals, and no alkali metals are found in any other column. In the second column or group are the alkaline earth metals. In the last column are all of the halogens, and in the next to the last column we find oxygen and the sulphur family, which are also closely related to each other. Indeed, throughout the whole table it will be found that the members of any group or family of elements placed in a vertical column possess certain similarities and exhibit certain gradations in differences which cannot be accidental.

Any element in the table will be found to possess properties intermediate between the properties of its neighbors on both sides, or above and below.

Some of the elements belonging in the vacant spaces in the table from the middle down are really known, though a little uncertainty exists in regard to their atomic weights.

At least six elements are known having atomic weights between 139 and 173. Some day these vacant places in the table will probably be filled with the elements that belong there but that have not yet been discovered.

269. At the time Professor Mendeleeff constructed his first periodic table, the element scandium was unknown, also the elements gallium and germanium, but their discovery and leading properties and atomic weights were predicted by Mendeleeff, and within three years they were discovered and his predictions found to be true. He knew that scandium, with an atomic weight of about 44, must exist; calcium had a valence of 2 and titanium a valence of 4, so that an element with a valence of 3 must belong between them, and, moreover, the difference between the atomic weights 40 and 48 was too large.

Gallium and germanium were believed to belong between zinc and arsenic, because zinc had a valence of 2 and arsenic a maximum algebraic combining number of +5, so that one element with a value of 3 and another with a value of 4 ought to exist having atomic weights between 65.3 and 75. Gallium and germanium fulfilled these requirements.

At the time of the construction of Mendeleeff's first table, the atomic weight 120 had been assigned to uranium, whereas antimony had that same atomic weight. Moreover, uranium could not belong in the same family with antimony and does not possess a combining value of 5, so that Mendeleeff declared that the atomic weight of uranium was probably not 120. It was subsequently shown that uranium had the atomic weight 240, which places it in the sixth group, where it properly belongs according to its combining value.

270. Some other striking facts brought out in the periodic table are as follows:

The range of combining values of all elements in the last four columns, so far as they have variable valences, is always eight units. The highest algebraic combining number of carbon and all the other elements in the same family is +4, and the lowest algebraic combining number, –4. In the next column, the highest value is +5 and the lowest –3. In the oxygen and sulphur group, the highest value is +6 and the lowest –2, and in the last column, the highest value is +7 and the lowest –1.

It will also be found that any element standing to the right, when in chemical combination with any element to the left, has a constant combining value, and also that any element standing above, when in chemical combination with any element standing below it, has a constant combining value. Thus, when chlorine is in combination with either sulphur, phosphorus or silicon, or any metal, the chlorine has a constant algebraic combining value of –1, but when chlorine is in combination with fluorine or with oxygen, it may have a combining value of +1, +3, +5 or +7. Sulphur, in combination with any element to the left, invariably has the combining value –2. But when in combination with oxygen or with any of the elements in the last column, it may have a combining value of +2, +4 or +6.

This fact may be stated in the following manner: *Any atom in combination with another element has invariably the same algebraic combining number, if that combining number is a minus quantity.* Thus, a single boron atom, whenever in combination with hydrogen or with any element standing to the left in the periodic table, always has a combining value of –3. A single carbon atom, in combination with any element or elements standing below it or to the left of it in the periodic table, can have no other combining value except –4. A single nitrogen atom, whenever it has a combining number represented by a minus quantity, has the algebraic combining

TABLE OF THE ELEMENTS ARRANGED ACCORDING TO THEIR ATOMIC WEIGHTS AND VALENCES

+1	+2	+3	+4	+5	+6	+7				+1	+2	+3	+4 —4	+5 —3	+6 —2	+7 —1
Li 7. 12.	Be 9. 4.5											B 11. 4.1	C 12. 3.6	N 14. 5.	O 16. 8.	F 19. 12.7
Na 23. 24.	Mg 24.2 14.	Al 27. 10.8											Si 28.4 11.3	P 31. 13.5	S 32. 15.7	Cl 35.4 25.3
K 39. 45.4	Ca 40. 25.4	Sc 44. 17.	Ti 48. 13.	V 51.5 9.3	Cr 52. 7.7	Mn 55. 6.9	Fe 56. 7.2	Ni 58.5 6.5	Co 59. 6.5	Cu 63.5 7.1	Zn 65.3 9.1	Ga 70. 11.7	Ge 72.5 13.2	As 75. 13.2	Se 79. 17.1	Br 80. 26.6
Rb 85.5 56.2	Sr 87.5 35.	Yt 89. 24.7	Zr 90.5 22.6	Cb 93.5 13.3	Mo 96. 11.1	.....	Ru 101.5 8.	Rh 103. 8.4	Pd 107. 9.	Ag 108. 10.1	Cd 112. 12.8	In 114. 15.4	Sn 119. 16.3	Sb 120. 18.	Te 126. 20.	I 126.5 25.3
Cs 133. 88.	Ba 137.5 34.3	La 138.5 22.6	Ce 139. 21.	.....	.....	.....	......	......	......	.....	.....	.....	.....	.....	.....	......
......	.....	Yb 173. 25.	.....	Ta 182.5 17.5	W 184. 9.7	.....	Os 191. 8.6	Ir 193. 8.6	Pt 195. 9.	Au 197. 10.	Hg 200. 14.7	Tl 204. 17.	Pb 206.5 18.	Bi 208. 20.	.....	......
......	.....	.....	Th 232.5 21.	.....	U 239.5 12.8	.....	......	......	......	.....	.....	.....	.....	.....	.....	......
+1	+2	+3	+4	+5	+6	+7				+1	+2	+3	—4 +4	—3 +5	—2 +6	—1 +7

number –3, and sulphur always has the combining value –2 whenever it is negative.

In other words, the relative polarities of any two elements in combination depend upon their relative positions in the periodic system. In the table here given, it will be seen that all the metals, together with hydrogen, are found in the first thirteen columns of the table, and that the non-metallic elements are all to be found in the upper right-hand corner of the table.

271. There are probably no elements having atomic weights between 9 and 11 and between 27 and 28.4. But lithium and beryllium certainly belong in the first two columns, and sodium, magnesium and aluminum belong in the first three columns, whereas the non-metallic elements surely belong in the last columns of the table. For this reason the first two periods of elements have been separated, as shown, in order that the natural families of elements may be preserved.

272. Another striking fact is that in the first column of elements and in the second, the greatest energy, or inclination to enter into chemical combination, is exhibited by those members having the highest atomic weights, all of these elements having positive polarity, whereas at the other end of the table, the elements having the lowest atomic weights exhibit the greatest energy if they exercise negative polarity. But when chlorine, bromine and iodine exercise positive polarity, iodine forms the most permanent compounds, bromine next and chlorine next.

273. While it is true that our present chemical nomenclature was devised long before the periodic system was known, we can readily see that with a few corrections, that nomenclature is in perfect accord with the periodic system. When any positive element has but two different combining values, its higher value is expressed by the ending *ic* and its lower value by the ending *ous*. When a positive element has three different combining values, the highest is generally expressed by the ending *ic*, the middle value by the ending *ous*, and the lowest value by the prefix *hypo* and the ending *ous*. When a positive element has four different combining values, the two middle values are indicated by the endings *ous* and *ic*, the lowest value by the prefix *hypo* and the ending *ous*, and the highest value by the prefix *per* and the ending *ic*. Thus carbonous carbon has a value of +2 and carbonic carbon has a value of +4. Phosphoric phosphorus has a value of +5, phosphorous phosphorus a value of +3 and hypophosphorous phosphorus has a value of +1. Sulphuric sulphur has the combining value +6; the algebraic combining number of sulphurous sulphur is +4 and that of hyposulphurous sulphur must be +2. Perchloric chlorine has a value of +7, chloric chlorine a value of +5, chlorous chlorine a value of +3 and hypochlorous chlorine a value of +1.

274. Four elements recently discovered in the atmosphere evidently belong next after the halogens. Neon, with the atomic weight 20, belongs between fluorine and sodium; argon, with an atomic weight of probably 39, belongs between chlorine and potassium; krypton, with an atomic weight of 82, belongs between bromine and rubidium, and xenon, with an atomic weight of 128.5, belongs between iodine and cæsium. Fluorine, chlorine, bromine and iodine as negative elements exhibit the most tremendous chemical energy, whereas sodium, potassium, rubidium and cæsium are invariably positive elements, and as such exhibit the greatest energy shown by any elements of positive polarity. What, then, should be expected of neon, argon, krypton and xenon except a neutral behavior? Standing between the extremely negative and the extremely positive elements, they exhibit no inclination to enter into combination at all.

Test Questions

1. What is meant by the periodic system?

2. What is the maximum algebraic combining number possible to any element in the fifth place of a period of seven elements?

3. What is the lowest algebraic combining number possible to an element contained in the seventh place of a period of seven elements containing any elements of negative polarity?

4. Name the sixth element in the period beginning with potassium, and the third element in the period beginning with sodium.

5. Name all the elements in the period beginning with copper.

6. How is it possible to predict approximately the properties of an undiscovered element?

7. What is the algebraic combining number of phosphorus in combination with any metal?

8. What is the algebraic combining number of sulphur in combination with any element standing below it or above it in the table of the periodic system?

9. What is the algebraic combining number of sulphur when in combination with oxygen or with any of the elements in the vertical column to the right of that in which the sulphur is placed?

10. What position in the periodic table is occupied by the two elements of invariably negative polarity?

11. What position in the periodic table is occupied by elements combining directly with both hydrogen and oxygen?

12. What elements form no compounds with either hydrogen or oxygen, and what position in the periodic table do they occupy?

13. What position in the periodic table is occupied by elements that combine with oxygen but not with hydrogen?

14. What elements form no compounds with oxygen?

15. What position is occupied in the periodic table by elements that form no compounds with any of the halogens nor any compounds with any metal?

16. What are the relative positions of the most decidedly positive and the most decidedly negative elements in the periodic table as presented in this chapter?

17. Which is the positive element and which the negative element in any compound consisting of bromine and chlorine?

18. Which is the positive element and which the negative element in any compound consisting of sulphur and tellurium? Why?

19. If potassium is brought in contact with a mixture of bromine and iodine and the amount of potassium is sufficient to combine with only one of them, what compound will be formed?

20. If bromine be added to a solution of chloride of potassium, what new binary compound will be formed, if any?

21. If bromine is added to a solution of iodide of potassium, what new binary compound will be formed, if any?

22. If 39.2 grams of potassium and 23 grams of sodium be put in a vessel containing 8 grams of pure oxygen, what will be formed and why?

23. Which is the more powerful basic element, cæsium or barium?

24. Which is the more powerful basic element, barium or calcium?

25. Which is the more powerful negative element, chlorine or bromine?

26. What elements form no chlorides as shown by the periodic table?

27. What elements form no oxides as shown by the periodic table?

28. Name the several elements with which positive sulphur can be in direct combination.

29. Name the several elements with which positive iodine can be in direct combination.

30. What binary compounds of bromine are not bromides?

31. What binary compounds of sulphur are not sulphides?

32. What binary compounds of carbon are not carbides?

33. What would you call a compound of boron and hydrogen?

34. What would you call a compound of boron and nitrogen?

35. What would you call a compound of calcium and carbon?

36. What would you call any binary compound formed by a metal with a non-metallic element?

37. What would you call a substance composed of two metals?

38. What is the probable reason why neon, argon, krypton and xenon form no chemical compounds?

LESSON THIRTEEN

XIX

Air and Water—Nitrogen, Oxygen and Hydrogen

275. Air is a mixture consisting almost wholly of the two colorless, odorless and tasteless gaseous elements called nitrogen and oxygen.

Each five liters of air contains about four liters of nitrogen and one of oxygen.

One cubic-decimeter of pure dry air at 0° C. under 760 mm. pressure weighs 1.29303 grams. One cubic decimeter of ordinary air at 16.67° C. weighs about 1.2125 grams.

276. Nitrogen may be obtained by burning phosphorus in air contained in a suitable closed vessel. The phosphorus takes up all the oxygen with which it enters into chemical combination, forming a white solid called phosphoric oxide, and the gas remaining in the vessel is the nitrogen, which is not combustible. Nitrogen can also be made in various other ways.

It requires a pressure of 35 atmospheres at or below the temperature of –146° C. to liquefy nitrogen.

One cubic-decimeter of pure nitrogen weighs about 1.26 grams.

Nitrogen does not readily enter into chemical combination with other elements. It is contained chemically combined with hydrogen, carbon and oxygen, in many animal substances. Among the most familiar nitrogen compounds are niter (saltpeter), from which nitrogen derives its name, and ammonia.

Many nitrogen compounds are powerful explosives, as nitroglycerin, guncotton, dynamite.

Nitric acid is a compound formed by nitrogen with oxygen and hydrogen, and this acid is one of the most destructive in its effects upon many other substances.

The substances called alkaloids, of which quinine, strychnine and morphine are well-known examples, all contain nitrogen.

The so-called "laughing gas" employed by dentists to render the patient unconscious of pain in extracting teeth is a compound of nitrogen and oxygen.

Nitrogen is quite harmless when inhaled, as we know from the fact that the air we breathe contains so large a proportion of it, and hyponitrous oxide is also harmless if pure and properly used. But many of the most fearful poisons known, as prussic acid (hydrocyanic acid), "cacodyl cyanide," toxines, strychnine and many other alkaloids, are nitrogen compounds.

277. When nitrogen enters into chemical combination with hydrogen alone, one single atom of nitrogen holds not more and not less than three atoms of hydrogen. The compound thus formed is a colorless gas called *ammonia*, which is readily soluble in water. The water-solution of it is also called ammonia and is much employed. Ammonia gas is excessively pungent, irritating, stifling, and dangerous in its effects upon the eyes, respiratory organs, etc., and the solution or "ammonia water," unless very dilute, is also destructive.

Ammonia has the power of neutralizing acids, and the compounds formed by such neutralization are called "ammonium salts."

278. When nitrogen combines chemically with oxygen alone, one nitrogen atom can hold either one or two oxygen atoms, or two nitrogen atoms together can hold one or three or five oxygen atoms in combination. Nitrogen, therefore, combines with oxygen in five different proportions. If we represent the nitrogen atom by its symbol N and the oxygen atom by O, the oxides of nitrogen are pictured by the following molecular formulas:

NO is a colorless gas composed of one atom of nitrogen and one of oxygen. It is nearly always produced when a metal acts chemically upon nitric acid, but as it comes in contact with the air it immediately combines with more oxygen, forming NO_2 or N_2O_4, or both, according to the temperature, and these constitute the well-known irritating "red nitrous vapors" observed when metals are dissolved in nitric acid and when that acid is decomposed by certain other substances. NO is commonly but erroneously called "nitric oxide"; its true scientific name is *nitrosyl.*

NO_2 is a red vapor above 150° C., and is called nitrogen peroxide. It is also called *nitryl.* But NO_2 may be condensed into an orange-colored liquid of the composition N_2O_4, which is called nitrogen tetroxide.

N_2O is a colorless gas commonly called "nitrous oxide gas" or "laughing gas." Its true scientific name should be *hyponitrous oxide.* N_2O_3 is a blue liquid. It is called "nitrogen trioxide," but its true scientific name should be *nitrous oxide.* It forms nitrous acid with water.

N_2O_5 is a white solid which forms nitric acid with water. It is called "nitrogen pentoxide." This is the only oxide of nitrogen that can be properly called *nitric oxide.*

[The proper nomenclature of these nitrogen compounds will be explained later on in the chapter on chemical nomenclature.]

279. Oxygen. The vast importance of oxygen may well be appreciated from the fact that it constitutes about one-half of the whole mass of the earth.

All of the well-known elements except fluorine form chemical compounds with oxygen, and the oxygen compounds are therefore the most numerous and abundant of all substances, whether mineral, vegetable or animal.

About one-fifth, by weight, of the air is oxygen.

Water is composed of eight-ninths, by weight, of oxygen and one-ninth of hydrogen.

The oxygen of the air is of vital importance to life. Animals inhale air and appropriate a part of its oxygen. They exhale the unused part of the oxygen together with the nitrogen and, with these, the carbon dioxide (CO_2) and water (H_2O) formed in the process of oxidation, which is the important object of respiration.

Oxygen is a colorless, odorless, tasteless, non-inflammable gas. It becomes liquid at –120° C. under a pressure of 50 atmospheres.

One cubic-decimeter of pure oxygen at 0° C. under 760 mm. barometric pressure weighs about 1.43 grams. Hence, 1 gram of oxygen under the conditions stated occupies a volume of about 699 cubic-centimeters.

Oxygen is commonly prepared by heating certain easily decomposed compounds containing it. The substances called potassium chlorate ($KOClO_2$), mercuric oxide (HgO), manganese dioxide (MnO_2), barium dioxide (BaO_2), and lead dioxide (PbO_2), may be used for this purpose. Potassium chlorate gives up all of its oxygen when heated, about two grams of oxygen being obtained from every five grams of the chlorate, and the residue is potassium chloride (KCl).

280. Whenever one atom of oxygen enters into chemical combination with hydrogen alone the oxygen atom unites with two hydrogen atoms. We, therefore, conclude that the combining value of one oxygen atom is twice that of one hydrogen atom.

No one atom of any other element can combine with more than four oxygen atoms unless the compound contains more than two elements.

At ordinary temperatures oxygen exhibits no great inclination to enter rapidly into combination with other elements except with phosphorus and with the elements called the alkali metals; but many elements are oxidized at higher temperatures and many are slowly oxidized by oxygen at the common temperature.

281. Ozone is a gas consisting of oxygen alone but differing decidedly from ordinary oxygen, ozone being much more active in causing oxidation. The difference between ordinary oxygen and ozone is due to the fact that each individual particle of common oxygen (O_2) consists of only two atoms, while each individual particle of ozone consists of three atoms (O_3).

282. Oxidation signifies, in the narrowest sense of the term, the chemical combination of any element with oxygen.

Fire is a violent or rapid chemical process by which the burning substances, or one or more of their component elements, enter into chemical combination with the oxygen of the air. This rapid oxidation is called *combustion* and produces heat, the intensity of which is in direct proportion to the velocity of the oxidation and dependent also upon the kind and quantity of the fuel "consumed." The elements of greatest importance as fuel are carbon and hydrogen in combination with each other and with other elements, or carbon alone. When carbon undergoes combustion it combines with oxygen to form oxides of carbon.

Respiration is attended with "slow combustion," by which certain substances contained in the venous blood entering the lungs are "oxidized" by the oxygen of the air inspired into those organs, and this process is a heat-producing chemical action.

Slow oxidation may be seen not only in the results of respiration but also in many other phenomena, as, for instance, in the tarnishing of iron and some other metals when exposed to moist air.

283. Oxides. Any compound consisting of only two elements, one of which is oxygen, is called an oxide. But a compound of a metal with oxygen is a salt if a part of the metal performs the basic function and another part the acidic function.

Silver oxide is a compound of silver and oxygen; the metal magnesium forms magnesium oxide; zinc forms zinc oxide.

But some elements have more than one oxide. Carbon has two, phosphorus has three, chlorine four, nitrogen five, and manganese seven different oxides; for the elements named, and also many other elements, can combine with oxygen in more than one proportion.

Whenever any oxide consists of but two elements, each individual particle or molecule of that oxide, if it contains more than four atoms of oxygen, must contain more than two atoms of the other element; and two atoms of one kind may hold in combination or be directly united to one, two, three, four, five or seven atoms of oxygen.

[Distinction may profitably be made between oxides composed of two elements in which all of the oxygen is directly combined with all of the other element, and the so-called oxides composed of two elements in which two oxygen atoms may be directly combined with each other. In HOH the oxygen is all combined with all of the hydrogen; but in HOOH each oxygen atom is directly combined with only one of the two hydrogen atoms.]

The oxides of the metals are all solids; but those of the non-metallic elements are some of them solids, others liquids, and others gases.

Many of the oxides can be produced by combustion, or by direct combination of oxygen with other elements.

284. Examples of Oxidation by Combustion. (*a*) *Sulphur* (S) burns with a blue flame, combining with the oxygen of the air to form that oxide of sulphur which constitutes the familiar, irritating, colorless gas produced when a sulphur match burns. No ash is formed. Each atom of the sulphur combines with two atoms of oxygen; hence the irritant sulphurous oxide is called a dioxide and it is represented by the symbolic formula SO_2, in which S stands for one atom of sulphur and O_2 for two atoms of oxygen.

As one atom of sulphur weighs twice as much as one atom of oxygen, it follows that the sulphur dioxide obtained weighs twice as much as the quantity of sulphur "consumed."

[Another oxide of sulphur exists which cannot be produced by combustion. It is a white solid and it is a trioxide, the composition of which is clearly indicated by its symbolic molecular formula, SO_3.]

(*b*) When charcoal, which is nearly pure *carbon* (C), is ignited and "consumed" by fire, or undergoes combustion, the carbon is oxidized. But if the supply of air or oxygen is insufficient the carbon does not combine with the maximum amount of oxygen it can hold in chemical combination, but with only one-half as much. A carbon atom weighs 12 times as much as an atom of hydrogen; but an oxygen atom weighs 16 times as much as a hydrogen atom. The carbon oxide formed by incomplete combustion of the carbon is composed of 12 parts of carbon and 16 parts of oxygen and it is in fact carbon monoxide, or CO. The oxide formed when the carbon undergoes complete combustion is composed of 12 parts of carbon and 32 parts of oxygen, and is in fact carbon dioxide, or CO_2.

Both of the oxides of carbon are colorless gases. They are the only two oxides carbon can form.

Carbon monoxide is *combustible.* It burns in the air with a blue flame, taking up from the air as much more oxygen as it already contains, being thus oxidized to carbon dioxide. This oxidation is represented symbolically as follows:

$$CO+O=CO_2.$$

But carbon dioxide is *not combustible*, because carbon cannot hold in combination with itself more than $2\frac{2}{3}$ times its own weight of oxygen, or, in other words, because one carbon atom cannot hold more than two oxygen atoms in direct combination if the compound contains no other element.

When pure carbon is thus oxidized no *ash* is formed. Twelve kilograms of carbon consume for complete oxidation thirty-two kilograms of oxygen, producing forty-four kilograms of carbon dioxide.

(*c*) *Alcohol* is composed of the three elements carbon, hydrogen and oxygen. When it is ignited and burns in a free supply of air the flame is smokeless, the combustion is complete, no ash or residue is left, and the products are carbon dioxide, CO_2, and water, H_2O. Each molecule of alcohol is composed of two atoms of carbon, six atoms of hydrogen and one atom of oxygen. Its molecular formula is, therefore, empirically written C_2H_6O. Hence, each molecule of alcohol weighs 46 times as much as one hydrogen atom. Each molecule of alcohol requires 6 additional atoms of oxygen for the formation of two molecules of carbon dioxide and three molecules of water. Accordingly, the combustion of alcohol is represented by the chemical equation,

$$C_2H_6O+6O=2CO_2+3H_2O.$$

Hence, 46 kilograms of alcohol will require 96 kilograms of oxygen for complete combustion and the products will be 88 kilograms of carbon dioxide and 54 kilograms of water vapor.

(*d*) *Wood* is a complex mixture of organic substances composed mainly of carbon, hydrogen and oxygen, but containing also some compounds of potassium, calcium and other elements. When wood is used as fuel the products of the combustion are chiefly the oxides of carbon and hydrogen, which we have already mentioned. These pass off, together with some "unconsumed" carbon and other matter, as smoke, while the compounds of potassium, calcium, aluminum, silicon and other "mineral matters" contained in the wood form the *ash.*

(*e*) When the soft white metal called *magnesium* (Mg) is ignited it burns rapidly, emitting an intense white light as it unites with the oxygen of the air to form a white solid, which is magnesium oxide, MgO. The "flash light" powder used by photographers consists of or contains powdered magnesium.

No gas is formed in the combustion of magnesium, for the only product is the oxide, which is a fine powder, forming a cloud of white dust but no smoke. Thus the only product here is the ash. Five grams of this white ash is produced out of every three grams of the metal, because a mass of 3 grams of magnesium unites with 2 grams of oxygen. Magnesium and oxygen unite with each other in no other proportions. Hence, we see that when magnesium is "consumed" by combustion it yields in fact a product weighing 66 per cent more than the metal consumed.

Magnesium oxide is commonly called "magnesia."

(*f*) When the black mineral called *antimonite*, or "black sulphide of antimony," which is composed of the elements antimony (Sb) and sulphur (S), is strongly heated or "roasted" in the air it decomposes. As one molecule of the black sulphide of antimony is composed of 2 atoms of antimony and three atoms of sulphur its symbolic formula is written Sb_2S_3. The antimony is oxidized by the oxygen of the air to antimony oxide, Sb_2O_3, which fuses and forms a glass-like solid, while the sulphur forms the gas SO_2. As the atomic weight of antimony is 120, because any given number of atoms of antimony weigh 120 times as much as the same number of atoms of hydrogen, it follows that when 336 grams of Sb_2S_3 is completely oxidized to Sb_2O_3 and SO_2, the quantity of oxygen required must be 144 grams, and that the combustion or oxidation is represented by the equation,

$$Sb_2S_3+9O=Sb_2O_3+3SO_2.$$

From these examples the student will learn that fire or combustion does not change the amount of matter in the universe; it simply alters the composition and form of matter by rearrangements of the atoms into other kinds of molecules; and that the weight of the product or products formed by a burning substance is greater than that of the substance burned by just the amount of oxygen taken up in combination to form the new substance or substances.

285. Water is one of the most plentiful oxygen compounds in nature. It is a most wonderful substance, composed of two of nature's most remarkable elements, hydrogen (H) and oxygen (O). In each molecule, or smallest possible individual particle of water, there are two hydrogen atoms and one atom of oxygen. Its molecular formula is, therefore, written H_2O; but it may also, and preferably, be represented by the formula HOH.

Water forms solutions of numerous kinds of matter and is indispenable to circulation and nutrition in plants and animals, rendering possible the chemical processes without which life in the world of matter must cease. It is the most neutral or chemically indifferent substance with regard to the vast majority of other kinds of matter, serving therefore as a medium in which other substances may be liquefied, whereby their molecules acquire greater freedom of motion, so that they can readily act upon each other. Its power to cause the dissociation of certain kinds of molecules into their component "ions" is referred to elsewhere. Molecules of water have a remarkable power and tendency to enter into some form of combination with other kinds of molecules, as "water of crystallization" and in other ways. Its uses in the economy of nature, in sanitation, and in the industries of civilization could not be subserved by any other substance known.

Water freezes at 0° C. (32° F.). Its boiling point is 100° C. (212° F.). It attains its maximum density at 4° C. (39.2° F.).

One liter of water at 4° C. *in vacuo* weighs 1 kilogram. One milliliter weighs 1 gram.

Six pints of water (96 fluid ounces) weighs approximately 100 avoirdupois ounces.

286. Hydrogen is a colorless, odorless, tasteless, highly inflammable gas. It is the lightest of all kinds of matter, occupying nearly 14½ times as much space as is taken up by an equal weight of air, and about 11,160 times as much space as is occupied by an equal weight of water at 0° C.

One cubic-decimeter of pure hydrogen at 0° C., bar. 760 mm., weighs about 0.09 gram.

Hydrogen has been obtained in liquid form at a temperature estimated to be below –200° C., and under a pressure of 40 atmospheres.

This element exists in nature in the free state only in extremely small quantities. In chemical combination it constitutes about 1 per cent by weight of the whole mass of the earth. Its most abundant compound is water. Hydrogen is a constituent of nearly all of the carbon compounds of the animal and vegetable kingdoms, and of coal oil, "natural gas" and other bituminous products.

287. Hydrogen is easily prepared by the action of zinc on diluted sulphuric acid. Ordinary sulphuric acid is a hydrogen sulphate composed of two hydrogen atoms, one atom of sulphur, and four oxygen atoms. Its molecular formula, representing its composition, is best written $(HO)_2SO_2$. When zinc (Zn) is added to a solution of sulphuric acid (or "diluted sulphuric acid") the zinc takes the place of the hydrogen, forming zinc sulphate, and the hydrogen is set free:

$$Zn+(HO)_2SO_2=ZnO_2SO_2+2H.$$

Hydrogen can also be made by passing steam (water vapor) over coal heated to a very high temperature. Carbon monoxide (CO) is formed at the same time, the reaction being $HOH+C=CO+2H$.

By the action of sodium hydroxide upon sodium formiate a perfectly pure hydrogen may be made:

$$NaOH+NaCHO_2=Na_2CO_3+2H.$$

288. Chemically considered, hydrogen is extremely important. Its properties place it between the metals and the non-metallic elements. It forms no true chemical compound with any true metal, but combines with all non-metallic elements. Its oxide or hydroxide, water, is neither a base nor an acid; but if one of the hydrogen atoms of the molecule of water, HOH, be replaced by a non-metallic element an acid is the result, whereas if a metal (of low combining value or valence) is substituted for one of the hydrogen atoms a base is formed. Hydrogen is contained in all acids.

Hydrogen does not at ordinary temperatures display any inclination to enter into chemical combination with other elements, but a mixture of hydrogen and chlorine, or of hydrogen and oxygen, may be exploded by an electric spark or by ignition.

The most intense heat that can be produced by combustion is that produced by igniting a mixture of hydrogen and oxygen in the proportions required to form water. Practical use is made of this in the "oxy-hydrogen blowpipe." By means of this, hydrogen burning in oxygen is thrown against a fragment of lime which quickly rises to an intense white heat and gives off the well-known powerful "lime light."

No one atom of any kind can unite directly with (or hold in combination) more than four hydrogen atoms.

Carbon and silicon can unite with four hydrogen atoms; boron, nitrogen, phosphorus, arsenic and antimony each with three; oxygen, sulphur, selenium and tellurium with two; and fluorine, chlorine, bromine and iodine each with only one hydrogen atom. No other elements unite directly with hydrogen under any circumstances.

Hydrogen forms alloys with a few of the metals, notably palladium.

Ammonia (H_3N) is the compound formed when one nitrogen atom is combined with all the hydrogen it can hold in combination.

289. As hydrogen of all elements has the lowest atomic weight, and of all substances the lowest specific weight, and as it has a uniform atomic combining value or valence as low as that of any other element, it has been adopted as the standard of comparison and unit of expression of all such values. Thus the atomic weight of hydrogen is 1, its vapor density is 1, and its valence is 1.

290. Hydrogen and oxygen are chemical opposites. Hydrogen is one of the positive elements; oxygen is always a negative element. Any element is oxidized whenever it combines with oxygen; it is reduced whenever it combines with hydrogen. An element is reduced whenever its oxygen compound exchanges its oxygen for hydrogen. An element is oxidized whenever its hydrogen compound exchanges its hydrogen for oxygen. Any element is positive whenever it is in direct combination with oxygen; it is negative whenever it is in direct combination with hydrogen.

Test Questions

1. What is the weight of one liter of pure dry air at 25° C. under the pressure of one atmosphere?

2. Is air a chemical compound?

3. Is water a chemical compound?

4. Why are nitrogen compounds generally unstable?

5. What is the proper technical name of so-called "laughing gas"?

6. Name one common nitrogen compound having a decided odor.

7. What is the algebraic combining number of nitrogen in H_4NCl and in N_2O_5?

8. Mention ten compounds containing oxygen.

9. Can oxygen be obtained from air?

10. How is oxygen generally produced?

11. What is the difference between oxygen and ozone?

12. Name several examples of simple oxidation.

13. What is the composition of calcium oxide?

14. What is the composition of potassium oxide?

15. What is the composition of aluminum oxide?

16. What is the percentage of oxygen in SO_3?

17. What are the products of the combustion of charcoal?

18. What are the products of the combustion of hydrocarbons?

19. What is the composition of the ash left on the combustion of magnesium?

20. How much antimonous oxide can be produced by roasting one kilogram of antimonous sulphide?

21. What is the algebraic combining number of the oxygen in water and what is it in "hydrogen dioxide"?

22. Is hydrogen dioxide really an oxide, or can you give a more scientific name for it?

23. What is the importance of hydrogen oxide to plants and animals?

24. What is meant by ionization?

25. How is hydrogen produced?

26. What products are formed when steam is passed over strongly heated coal?

27. Name four great classes of compounds containing hydrogen.

28. If you remove one hydrogen atom from each of two molecules of water and put one atom of sulphur in their place, what will be the compound formed?

29. If you put one atom of sulphur in the place of four hydrogen atoms removed from four molecules of water, what will be the resulting compound?

30. If you put a nitrogen atom in the place of five hydrogen atoms removed from five molecules of water, what will be the resulting compound?

31. If you put a sodium atom in the place of one hydrogen atom of a molecule of water, what will you have?

32. If you put a calcium atom in the place of two atoms of hydrogen removed from two molecules of water, what will be formed?

33. If you put one sulphur atom in the place of six hydrogen atoms taken from six molecules of water, what will be the compound formed?

34. If from that compound you remove two hydrogen atoms and one oxygen atom, what will remain?

35. If you remove from it four hydrogen atoms and two oxygen atoms, what will be the technical name of the residue?

36. If you take away three molecules of water from the compound formed by putting one sulphur atom in the place of six hydrogen atoms removed from six molecules of water, what will be left?

37. Why are acids, bases and salts said to be built on the water type?

38. In what way may the highest temperature be produced that can be obtained by chemical means ?

39. What is the composition of hydrogen telluride ?

40. Write the molecular formulas of hydrogen bromide, hydrogen nitride, hydrogen phosphide, hydrogen silicide, hydrogen carbide and hydrogen boride.

41. If the atomic weight of oxygen be set down as 100, what will be the corresponding atomic weight of hydrogen ?

42. Explain why an element is said to be reduced whenever it enters into combination with hydrogen, but oxidized whenever it enters into combination with oxygen.

LESSON FOURTEEN

XX

Fluorine, Chlorine, Bromine and Iodine

291. The four elements called respectively fluorine, chlorine, bromine and iodine form a natural group or family of elements closely resembling one another in their chemical properties and behavior.

292. One atom of either of these elements can hold in combination but one atom of hydrogen. The only possible hydrogen compounds of fluorine, chlorine, bromine and iodine are accordingly HF, HCl, HBr and HI. These four compounds are commonly called "acids," because they resemble the real acids in their power to neutralize alkalies; but they should instead be called the hydrogen halides, for they are binary compounds of the halogens, whereas all true acids contain more than two elements. The halides of hydrogen are often called the "hydrogen acids" or "hydracids," because they contain hydrogen without any oxygen, but as all acids contain hydrogen, the term "hydrogen acids" is ill chosen, since its employment to distinguish between these compounds and the true acids rests not upon what they contain (H) but upon what they do not contain (O).

The scientific names of HF, HCl, HBr and HI are hydrogen fluoride, hydrogen chloride, hydrogen bromide and hydrogen iodide.

293. All binary compounds of fluorine are fluorides; all binary compounds of chlorine except its compounds with fluorine or with oxygen are chlorides; all binary compounds of bromine are bromides, except its compounds with chlorine or fluorine (and its compounds with oxygen, did such compounds exist); and all binary compounds of iodine are iodides, except its compounds with bromine, chlorine, fluorine or oxygen.

294. A molecule of any fluoride, chloride, bromide or iodide may contain from one to six atoms of fluorine, chlorine, bromine or iodine, but never contains more than one atom of the positive element. A compound of fluorine and chlorine cannot contain more than one chlorine atom, but may contain one or more fluorine atoms. A chloride of bromine or iodine may contain one or three or five atoms of chlorine or bromine, but it cannot contain more than one iodine atom. This is because the combining value of any negative element in any true binary compound is unchangeable; the atomic combining value of the halogen in any halide is 1, and any member of the chlorine family of elements (the fluorine, chlorine, bromine and iodine are together called the "chlorine family") having a lower atomic weight is negative in its chemical relation to any other element of the same family having a higher atomic weight. The atomic weight of F is 19, that of Cl is 35.5, that of Br is 80 and that of I is 126.5.

295. Halogens. Fluorine, chlorine, bromine and iodine are called "halogens" (from *hals*, salt, and *gennao*, I generate), because their water-soluble binary compounds with the metals look like the water-soluble true salts (formed by true acids). But some metallic sulphides and many other compounds look like salts without being such. Common table salt is the chloride of sodium.

But positive chlorine, bromine or iodine cannot be called a halogen.

296. Halides are the binary compounds formed by the metals and by hydrogen with the halogens. Sodium chloride is therefore a halide (from *hals*, salt, and *eidos*, like).

297. Fluorine is a greenish-yellow gas. But very little is known concerning fluorine in its uncombined state, because the intensity of its chemical energy is so great that when it is set free from any one compound it cannot be prevented from entering at once into the formation of other compounds.

This element occurs in nature in the form of calcium fluoride or *fluorspar*, CaF_2, and as *cryolite*, which is a so-called "double fluoride" of aluminum and sodium.

Its most interesting compound is the hydrogen fluoride, commonly called "hydrofluoric acid," which is a colorless, fuming, highly corrosive liquid, very poisonous because of its destructive chemical action. It attacks glass and is used to produce etchings on glassware.

298. Chlorine is a yellowish-green gas of suffocating, characteristic odor, poisonous when inhaled. At 15° C. it can be compressed into a liquid under the pressure of four atmospheres.

One cubic-decimeter of chlorine at 0° C., bar. 760 mm., weighs about 3.17 grams.

One volume of water at 15° C. dissolves about 2½ volumes of chlorine. A water-solution saturated at 10° C. contains about 0.6 per cent of Cl. Such a solution is called "chlorine water."

299. Chlorine **occurs** most abundantly in the form of sodium chloride, or common *salt*, in sea-water and salt-springs, and in salt-beds or salt-mines as rock-salt.

300. Free chlorine is commonly **prepared** by heating manganese dioxide, MnO_2, with hydrogen chloride, HCl:

$$MnO_2+4HCl=MnCl_2+2H_2O+2Cl.$$

301. Chemical Properties. Chlorine displays great chemical energy, which fact is usually expressed by the statement that it strongly attacks many other substances or has a destructive effect upon them.

It unites with any one of all the other known elements (except those that form no compounds whatever, as is apparently the case with neon, argon, krypton and xenon). It displaces bromine and iodine from bromides and iodides.

No one atom of any other element can unite with more than six atoms of chlorine.

Noxious effluvia and other poisonous decomposition products of organic matter are frequently unstable hydrogen compounds, and they may generally be destroyed by chlorine, because of the great affinity of chlorine for hydrogen. This explains the great disinfectant power of chlorine.

302. Hydrogen chloride, HCl, is commonly called "hydrochloric acid." Being very unstable or easily decomposed when brought in contact with certain metals and other substances, it is described as highly corrosive or destructive. Iron, zinc, aluminum and several other metals readily attack hydrogen chloride, from which they appropriate to themselves the chlorine, thus liberating the hydrogen:

$$Zn+2HCl=ZnCl_2+2H.$$

303. Aqua regia is a mixture made of hydrogen chloride and nitric acid, and contains free Cl together with nitrosyl chloride, $ONCl$. This so-called "nitrohydrochloric acid" dissolves gold and platinum, forming the chlorides of these metals.

304. Chlorides are the compounds of negative chlorine with any other elements or with certain positive compound radicals. Among the most common chlorides are: Hydrogen chloride, HCl; sodium chloride, $NaCl$; ammonium chloride or "sal ammoniac" or "muriate of ammonia," H_4NCl; ferric chloride, $FeCl_3$; calomel, $HgCl$; and corrosive sublimate, $HgCl_2$.

305. Bromine is a dark-brownish-red, mobile, heavy liquid, which gives off suffocating yellowish-red vapors, intensely irritating to the eyes and the respiratory organs and extremely dangerous when inhaled. Its destructive action on organic substances, including clothing, wood, etc., render it imperative that bromine should be handled only with great caution.

Bromine occurs in sea-water and in salt-springs chiefly in the form of magnesium bromide, $MgBr_2$, from which the bromine is liberated by chlorine and in other ways.

Bromine exhibits intense chemical energy.

Potassium bromide, KBr, is the most common bromine compound. Hydrogen bromide is commonly called hydrobromic acid.

The binary compounds of the metals with bromine are called bromides.

306. Iodine consists of dry, brittle, purplish-black, rhombic crystal plates, having a shining appearance resembling metallic luster, a strong, characteristic, somewhat saffron-like odor, and an acrid taste.

The specific weight of iodine is 4.948 at 17° C. It melts at about 114° C. and boils at 200°. Its vapor is of a beautiful violet or purple color.

It is nearly insoluble in water but soluble in alcohol.

Iodine occurs together with chlorine and iodine in sea-salts and salt-springs. It also occurs in the form of sodium iodate in the residuary liquors obtained in separating sodium nitrate from the saltpetre deposits of Chili.

From sodium iodide leached out of the ashes of seaweeds the iodine is obtained in the same manner as chlorine and bromine may be liberated from chlorides and bromides:

$$2NaI+MnO_2+2H_2SO_4=MnSO_4+Na_2SO_4+H_2O+2I.$$

The most common iodide is that of potassium, KI.

XXI

Sulphur, Selenium and Tellurium, Phosphorus, Arsenic and Antimony, Carbon and Silicon, Boron

307. Sulphur is at ordinary temperatures a light yellow, hard, odorless and tasteless solid. Its specific weight varies from 1.96 to 2.07. It melts at about 114° C. to an amber-colored liquid. When carefully fused sulphur is allowed to cool slowly it crystallizes, and if the still liquid portion be poured off before the whole mass solidifies long crystals can be obtained. Molten sulphur heated beyond 150° C. darkens and thickens, and at nearly 200° it becomes almost black and so tough that it scarcely runs. Heated higher it gets thinner again, and if then poured into water and allowed to cool it forms a soft, tough, yellowish-brown solid. Sulphur boils at 446° C.

Brimstone is impure sulphur molded into cylindrical sticks.

Sublimed sulphur, or "flowers of sulphur," is a light yellow crystalline powder.

Precipitated sulphur is an extremely fine, pale, greenish-yellow powder, without odor and taste.

When sulphur is ignited it burns with a blue flame, forming sulphur dioxide, SO_2, which may be at once recognized by its pungent "sulphurous" odor and irritating effects upon the respiratory organs.

Sulphur is insoluble in water and in alcohol, but readily soluble in benzin, benzol, oil of turpentine and several other oils, and in ether and chloroform.

308. Occurrence in Nature. Sulphur is found in immense quantities in Italy, South America, California, Louisiana and elsewhere.

In combination with iron, copper, lead and zinc it occurs in great abundance. "Iron pyrites" is FeS_2; "copper pyrites" is $CuFeS_2$; "galena" is PbS; and "zinc blende" is ZnS.

309. **Chemical Properties.** Sulphur does not exhibit any great inclination to form compounds with other elements except at high temperatures.

Negative sulphur forms compounds whose structure is exactly analogous to that of the compounds of oxygen. These sulphur compounds are called *sulphides* when they correspond to the oxides; they are called "thio-salts" when analogous to oxygen salts.

Positive sulphur is sulphur in direct combination with either oxygen or with one of the four halogens (fluorine, chlorine, bromine or iodine). One sulphur atom can hold in combination either two or three oxygen atoms, forming the two oxides, SO_2 and SO_3.

SO_2 forms sulphurous acid with water; SO_3 forms sulphuric acid.

310. *Selenium* and *tellurium* are rare elements which form compounds exactly analogous to those formed by sulphur.

311. **Phosphorus** occurs chiefly in the form of a soft white, or slightly yellowish, semi-translucent solid of a peculiar odor and taste. It emits white fumes when exposed to the air and on longer exposure it ignites spontaneously and burns with a fierce flame, forming *phosphoric oxide*, P_2O_5, which is a snow-white solid. Owing to the intense inflammability of phosphorus it must be kept under water in strong glass-stoppered bottles in a cool, secure place. It is very poisonous.

Phosphorus is insoluble in water, but soluble in 350 parts of *absolute* alcohol at 15° C., in 80 parts of absolute ether, in about 50 parts of any fixed oil, and very freely in chloroform and carbon disulphide.

When the ordinary or waxy phosphorus is heated in a closed vessel to about 300° C. it is converted into *red phosphorus*, which is an amorphous dark-red powder, not poisonous nor self-inflammable.

312. Phosphorus *occurs* principally in the form of calcium phosphate in bones, and in the mineral called *apatite.* It is made from "bone-ash" or "calcined bone," which consists chiefly of calcium phosphate.

313. Arsenic is an element occurring chiefly in the form of sulphides. The so-called "cobaltum" of commerce is not cobalt but an impure arsenic.

Arsenic is a dark steel-gray, brittle solid of a somewhat metallic luster. It is not a metal, because it combines directly with hydrogen to form H_3As, and it does not perform the basic function, so that oxygen salts with arsenic as the basic element do not exist.

Chemically this element is closely related to nitrogen, phosphorus and antimony.

314. *Compounds of arsenic* are poisonous. Their structure is illustrated in the following examples:

As_2O_3 is arsenous oxide, commonly misnamed "arsenous acid."

H_2HAsO_3 is arsenous acid.

K_2HAsO_3 is potassium arsenite, contained in the medicinal preparation called "Fowler's Solution."

$Na_2HAsO_4 + 7H_2O$ is crystallized sodium arsenate.

$Na_4As_2O_7$ is sodium pyroarsenate.

315. Antimony occurs in nature chiefly as antimonous sulphide, called *antimonite.*

This element looks decidedly like a metal, having a high metallic luster. It is also very heavy, its specific weight being 6.8. But it combines with hydrogen to form H_3Sb, and it performs the basic function but feebly if at all.

The only water-soluble antimony compound is "tartar emetic," which has the composition $2OSbKC_4H_4O_6 + H_2O$.

Sb_2S_3 is antimonous sulphide. The "black sulphide of antimony" is crystallized antimonous sulphide. Precipitated antimonous sulphide is yellowish-red.

Sb_2O_3 is antimonous oxide.

Sb_2S_5 is antimonic sulphide.

$SbCl_3$ is antimonous chloride.

316. Carbon is an element common to all vegetable and animal substances. In its free state it exists in several forms, viz.: *diamond*, *graphite*, *soft coal*, *hard coal* and *peat*. Coke, wood charcoal, animal charcoal and lampblack are also carbon.

Combined carbon is contained not only in all vegetable and animal substances but also in limestone, chalk, marble, magnesite, etc.

In its ordinary forms carbon is a solid, inodorous, tasteless substance, insoluble in all liquids, infusible and non-volatile. When heated strongly in the air it ignites and burns, forming CO_2 if the supply of air or oxygen is abundant, but CO if the supply is deficient.

317. The **chemical properties** of carbon are extraordinary. At common temperatures it shows no chemical energy; but at a high heat it readily combines with oxygen, forming either CO_2 or CO, according to whether the supply of oxygen is liberal or deficient. It, therefore, has two combining values, 4 and 2. But the valence of the carbon atom in nearly all known carbon compounds is 4. The most remarkable characteristics of carbon are that its atoms can hold each other in combination to form chains or rings which give character to innumerable organic substances, and that the same carbon atom can hold in combination with itself both positive and negative elements at the same time. Thus hydrogen, which is positive, and oxygen, which is negative, can both be held in combination with the same carbon atom, as in H_3COH.

318. The compounds formed by carbon with hydrogen alone are called *hydrocarbons.* The simplest of these is H_4C, because it contains but one carbon atom. Hydrocarbons containing a small number of carbon atoms are gases; others, with a larger proportion of carbon, are liquid; and those containing much carbon are solids.

Coal oil is a mixture of hydrocarbons. Benzin, gasolin, petrolatum, paraffin, naphthaline, terebene and benzol are all hydrocarbons. Nearly all volatile oils contain one or more kinds of hydrocarbons. The coal gas used for illumination and for fuel is a mixture of gaseous hydrocarbons of which the chief is H_4C.

Carbon monoxide, or carbonous oxide, is CO—a colorless, odorless, tasteless gas which burns with a blue flame, forming CO_2. The CO is poisonous when inhaled. When steam is blown through incandescent coal or coke, the water (steam) is decomposed and the products are H and CO, which together constitute the gaseous mixture called *water gas.*

Carbon dioxide, CO_2, is present in the air because animals exhale it. CO_2 is also produced in the decay of certain organic substances and by combustion. The CO_2 is commonly called "carbonic acid gas," because when dissolved in water it forms a solution of carbonic acid, H_2CO_3. Carbonic acid water is a refreshing and not unwholesome drink; but *when inhaled* the gas CO_2 is poisonous, and even a small proportion of it renders air unfit to be breathed. Effective ventilation is necessary to remove the air contaminated with the CO_2 injected into it by respiration. Men and animals inhale air and exhale carbon dioxide. Plants decompose the carbon dioxide, appropriating the carbon and restoring the oxygen to the air.

Cyanogen, $(CN)_2$, is a colorless gas of irritating odor and very poisonous. HCN is the fearfully poisonous hydrogen cyanide, commonly called "hydrocyanic acid," or "prussic acid."

319. Silicon is, next to oxygen, the most abundant of all elements. *Silica*, SiO_2, and *silicates* of several kinds, constitute a large proportion of the rock, sand and clay formations of the earth's surface. Quartz, flint, sand and agate are different forms of silicon dioxide or silica.

Brick, earthenware, porcelain and glass are mixtures of silicon compounds. The chief constituents of *glass* are the silicates of potassium, sodium, calcium and lead. The pure silicates of potassium and sodium are water-soluble, but mixtures of them with the silicates of calcium and lead are not only insoluble in water but even resist the action of strong acids and alkalies to a remarkable degree.

320. Boron is an element that occurs chiefly in the compound called *borax*, which is sodium tetraborate, $Na_2B_4O_7$. *Boric acid* is H_3BO_3, or, rather, $(HO)_3B$.

Boric acid is a remarkable antiseptic and hence used in large quantities as a preservative of meats and other perishable organic substances and also as a harmless and yet effective constituent of antiseptic lotions, dressings and powders.

Test Questions

1. Name the halogens.

2. What is the correct scientific name for hydrobromic acid?

3. What is the maximum number of chlorine atoms that can be contained in a chloride?

4. What is the maximum number of atoms of the positive element in any true iodide?

5. How can tri-iodide of chlorine be made?

6. What is the most common fluorine compound in nature?

7. What is the most abundant chloride?

8. How is chlorine produced?

9. How is the great power of chlorine as a disinfectant explained?

10. What is formed when iron is dissolved in a solution of hydrogen chloride? Write the equation representing the chemical reaction.

11. What is the algebraic combining number of the nitrogen in nitrosyl chloride?

12. Write the formulas for mercurous chloride and mercuric chloride; for ferrous chloride and ferric chloride.

13. What is the action of chlorine on water?

14. Why is chlorine recognized as a powerful oxidizing agent?

15. Write the formula for ammonium bromide.

16. How is bromine liberated from a bromide?

17. Describe bromine.

18. How does it differ from chlorine and iodine?

19. What are the sources of iodine?

20. What is the chemical action of bromine on potassium iodide?

21. What is the percentage of bromine in a 10 per cent solution of hydrogen bromide?

22. What is the percentage of bromine in potassium bromide?

23. Which contains the greater amount of iodine, a syrup containing 10 per cent of hydrogen iodide or the compound known as potassium iodide?

24. Which of the two compounds, potassium chloride and potassium chlorate, is best able to resist decomposition when exposed to strong heat?

25. Describe SO_2 and state how it is produced.

26. What is the difference between a carbonate and a thio-carbonate?

27. What is the difference between positive sulphur and negative sulphur?

28. What is the difference between sulphuric sulphur and hyposulphurous sulphur?

29. What is formed when SO_3 is added to water?

30. Write the chemical reaction occurring when SO_2 is dissolved in water.

31. Name the several possible products formed from SO_3 and water.

32. Can you name any compound containing both positive sulphur and negative sulphur?

33. Describe phosphorus.

34. What are the differences between the two allotropic modifications of phosphorus?

35. What is the most common source of phosphorus?

36. How many bonds has the phosphorus atom in HPH_2O_2?

37. How many bonds has the phosphorus in H_3PO_2?

38. How many bonds does the phosphorus have in $HOPO_2$?

39. How many bonds does the phosphorus have in H_2PHO_3? How many in H_3PO_3?

40. How many bonds does the phosphorus have in H_5PO_5? In H_3PO_4? In HPO_3?

41. Give the technical names of all the phosphorus compounds represented by the formulas in questions 36-40.

42. What is the difference between the phosphorus in a metaphosphite and the phosphorus in any phosphate?

43. Write the molecular formula for nitrate of arsenic.

44. Write the molecular formula for arsenous hydroxide.

45. If hydrogen arsenide is H_3As, what possible combining values can the arsenic have when united to oxygen?

46. Why is the formula for arsenous acid written H_2HAsO_3 instead of H_3AsO_3?

47. Can that formula be written more scientifically than it is in either of the forms given in the preceding question?

48. Why is As_2O_3 not an acid?

49. Antimony is a very heavy, brilliantly metallic looking

substance and forms several useful alloys. Why, then, is it not a metal, chemically as well as physically?

50. What is an antimonide?

51. What is the difference between antimonous oxide and antimonic oxide?

52. Name several carbon compounds contained in the mineral world.

53. Mention several forms of free carbon found in nature.

54. What is the algebraic combining number of the carbon atom in H_3COH?

55. Why are the hydrocarbons so useful as fuel?

56. What is carbonic acid?

57. What is carbonic acid gas?

58. How is the CO_2 exhaled by men and animals removed from the atmosphere?

59. What is hydrocyanic acid?

60. What is the algebraic combining number of the carbon in a molecule of the so-called hydrocyanic acid?

61. What is silica?

62. What is the composition of glass?

63. What are the principal uses of boric acid?

64. What is the algebraic combining number of each boron atom in borax?

LESSON FIFTEEN

To the Student:

The section numbered XXIV, which treats of the solubilities of common inorganic chemical compounds in water and in alcohol, is included in this lesson principally because of its value as a matter of reference for students. It is full of facts a knowledge of which the student should have, but as the mastering of it is a pure matter of memory, no questions are given upon it. It is not expected, moreover, that the student will memorize the chapter, but will keep it available for frequent reference in subsequent lessons, and it is certain that he will find the matter useful in examinations and in future work.

XXII

The Light Metals

321. The **light metals** are those whose specific weights are less than 5 and lower than the specific weights of their own oxides. The most important light metals are lithium, sodium, potassium, magnesium, calcium, strontium, barium and aluminum.

All of these metals have a constant valence.

322. The **alkali metals** are lithium, sodium, potassium, rubidium and cæsium. The two last mentioned are rare. Potassium and sodium are abundant.

All of them are monads or have an atomic combining value of 1, for their oxides are Li_2O, Na_2O, K_2O, Rb_2O and Cs_2O. Their hydroxides are the true *alkalies*, which are freely water-soluble. The alkali metals have such an intense affinity for oxygen that they must be excluded from contact with air, and this is effected by keeping them immersed in kerosene or benzin. When put in water they decompose it, combining with hydroxyl and liberating one hydrogen atom from each molecule of water decomposed:

$$HOH + K = KOH + H.$$

323. **Potassium** is a soft silver-white metal, lustrous when freshly cut but tarnishing rapidly in the air. It is kept immersed in benzin to prevent its oxidation. The specific weight of K is 0.86.

324. **Occurrence.** Potassium is a widely distributed metal. Potassium silicate occurs in granite rocks, and plants growing in the soils derived from such rocks yield an ash containing potassium carbonate. This is leached out from wood ashes with water and the solution boiled down to get the crude potassium carbonate which is called "potash." The metal itself derives its name from the potash. Potassium is also contained in "argols" or crude "tartar," which is the bitartrate of potassium deposited from the fermenting grape juice in the process of making wine. Purified by recrystallization, the crude tartar is called "cream of tartar." But the present source of potassium is the potassium chloride associated with other salts in the salt beds at Stassfurt, Germany.

325. **Potassium compounds** are white or colorless unless they contain other elements which impart color. They are nearly all very readily water-soluble, and several common potassium compounds are, in fact, deliquescent.

Among the most common compounds of potassium are:
KOH, potassium hydroxide, called "caustic potash."
K_2CO_3, the carbonate of potassium, or "potash."
$KHCO_3$, bicarbonate of potassium.
KBr, potassium bromide.
KI, potassium iodide.

KNO_3, potassium nitrate, or "niter," or "saltpetre."

$KClO_3$, potassium chlorate.

326. **Sodium** is very like potassium, but does not decompose water so violently. Its specific weight is 0.97.

It occurs abundantly in the form of common "salt," which is sodium chloride, in sea-water and in salt-springs and salt-beds. Sodium nitrate is found in Chili in the form called "Chili saltpetre."

Common "washing soda" is sodium carbonate, which is manufactured on an immense scale from sodium sulphate made out of sodium chloride, or the carbonate may be made direct from sodium chloride.

327. **Sodium compounds** are white or colorless and generally very readily water-soluble.

The most common include:

$NaOH$, sodium hydroxide, or "caustic soda."

$Na_2CO_3 + 10H_2O$, sodium carbonate, which constitutes "sal sodæ" or washing soda.

$NaHCO_3$, sodium bicarbonate, or "baking soda."

$NaCl$, "common salt."

$Na_2SO_4 + 10H_2O$, sodium sulphate, or "Glauber's salt."

$Na_2SO_3S + 5H_2O$, sodium thio-sulphate, commonly but erroneously called "hyposulphite of sodium" (which is Na_2SO_2—quite another substance).

$NaNO_3$, sodium nitrate, or "Chili saltpetre."

$Na_2HPO_4 + 12H_2O$, sodium phosphate.

$Na_2B_4O_7 + 10H_2O$, sodium tetraborate, or "borax."

$NaC_{18}H_{33}O_2$, sodium oleate, the chief constituent of common hard soap, such as "Castile soap."

328. **Lithium** is, like potassium and sodium, a soft silver-white metal. It is comparatively rare and costly. Its specific weight is 0.589.

Its compounds are white or colorless. They are not as generally or freely soluble as the compounds of potassium and sodium. One of the most striking properties of lithium salts is the beautiful crimson color they impart to flame.

329. **The Alkaline Earth Metals.** These are barium, strontium and calcium. They have an atomic combining value of 2, for their oxides are BaO, SrO and CaO.

The hydroxides of these metals are sparingly water-soluble, but the solutions have a strongly alkaline character.

Like the alkali metals, they decompose water, but much more quietly.

330. **Barium** is a soft, yellowish metal of the specific weight 4. It occurs in "heavy spar," which is barium sulphate, in caves on Put-in-Bay Island, Ohio.

The most common compounds of barium are:

BaO, barium oxide, or "baryta."

$BaCO_3$, barium carbonate.

$BaCl_2 + 2H_2O$, barium chloride.

$Ba(NO_3)_2$, barium nitrate.

$BaSO_4$, barium sulphate.

331. **Strontium** is comparatively rare. It is a soft, yellowish metal having the specific weight 2.5. Its compounds are analogous to those of calcium and barium.

332. **Calcium** is a soft, yellowish metal of the specific weight 1.6. It may be kept in dry air without oxidation, but decomposes water rapidly:

$$2H_2O + Ca = Ca(OH)_2 + 2H.$$

It occurs abundantly in the form of limestone, chalk and marble, all of which are calcium carbonate. Igneous rocks contain calcium silicate and other calcium compounds. "Gypsum" is calcium sulphate, and dried gypsum is nearly anhydrous or water-free calcium sulphate, which, when mixed with the proper amount of water, forms normal calcium sulphate, commonly called crystallized calcium sulphate or "plaster of Paris." Quick lime, or building lime, is calcium oxide, and slaked lime is calcium hydroxide. Hydraulic *cement* is made by calcining limestone containing clay and silica; this cement hardens when mixed with water, forming calcium silicate and carbonate.

333. Calcium compounds are white or colorless. The carbonate, phosphate and oxalate are insoluble; hydroxide and sulphate are sparingly soluble.

Among the most common calcium compounds are:

CaO, calcium oxide, calx, or "lime."

$Ca(OH)_2$, calcium hydroxide, "slaked lime." "Lime water" is a solution of calcium hydroxide.

$CaCl_2$, calcium chloride.

$CaCO_3$, calcium carbonate, marble, chalk, limestone.

CaH_4SO_6 (or $CaSO_4 + 2H_2O$), calcium sulphate or "gypsum."

$CaSO_4$, dried calcium sulphate, used for making "plaster of Paris" by mixing the dry powder with water.

$Ca_3(PO_4)_2$, calcium phosphate, which is the chief inorganic constituent of bone.

$Ca(ClO)_2$, calcium hypochlorite, the valuable constituent of the so-called "chloride of lime" or "bleaching powder," which also contains $CaCl_2$.

334. Magnesium is a white metal which oxidizes but slowly in moist air. Can be made into wire and ribbons, and converted into coarse powder. Its specific weight is 1.74. It does not decompose water at the ordinary temperatures, but does so at the boiling point of the water.

The "flash-light" of photographers is produced by burning powdered magnesium.

Magnesium occurs in large quantities, chiefly in the form of carbonate and silicate.

Magnesite is magnesium carbonate. "French chalk" or "talcum," and also "asbestos" and "meerschaum," are magnesium silicate.

335. *Magnesium compounds* are white or colorless. The oxide, hydroxide, carbonate, phosphate and oxalate are insoluble in water. The citrate is also practically insoluble in water, but the "solution of citrate of magnesium" of the drug stores is made by adding a large excess of citric acid, which holds the magnesium citrate in solution in the water.

Among the most common magnesium compounds are:

MgO, magnesium oxide, commonly called "calcined magnesia."

$MgH_2SO_5 + 6H_2O$ (commonly represented as $MgSO_4 + 7H_2O$) is magnesium sulphate, or "Epsom salt."

$Mg_5(OH)_2(CO_3)_4 + 5H_2O$ is the common carbonate of magnesium.

336. **Aluminum** is a silver-white metal which is malleable, ductile and capable of high polish. It is not tarnished in dry, pure air. Its specific weight is 2.5. It is strong, tough, durable and light, and as it does not corrode in the air and is not easily affected by other substances except chlorides, it is an extremely useful metal.

This metal occurs abundantly in combination with oxygen and silicon. *Clay* consists of aluminum silicate. *Cryolite* is $3NaF.AlF_3$. *Beauxite* is $Al_2O_3 + H_2O$. Aluminum oxide, commonly called "alumina," occurs as emery, corundum, sapphire and ruby Feldspar and mica contain aluminum, and "china clay" or "pipe clay" or "kaolin" are also aluminum compounds. The metal is named after "alum."

337. *Aluminum salts* are white or colorless. Those soluble in water are astringent.

The *structure* of aluminum compounds is illustrated by the following common compounds:

Al_2O_3, aluminum oxide.

$Al(OH)_3$, aluminum hydroxide, commonly misnamed "aluminum hydrate."

$AlCl_3$, aluminum chloride.

$AlK(SO_4)_2 + 12H_2O$, aluminum and potassium sulphate, or alum, or "potash-alum."

$AlH_4N(SO_4)_2 + 12H_2O$, aluminum and ammonium sulphate, or "ammonia alum," the now *common alum.*

XXIII

The Heavy Metals

338. The **heavy metals** are those whose specific weights exceed 5 and are higher than those of their oxides. The heavy metals of great importance include zinc, iron, nickel, chromium, manganese, lead, copper, mercury, silver, gold, platinum, bismuth and tin.

The compounds of the heavy metals are not as generally water-soluble as are the compounds of the light metals, and the compounds of metals of very high atomic weights as well as specific weights form very few water-soluble compounds.

The light metals form more powerful bases than the heavy metals.

339. **Zinc** is a bluish-white, crystalline, lustrous, brittle metal of the specific weight 7.2. It melts at 412° C. It readily decomposes dilute acids, and also the alkalies in hot solutions.

Zinc *occurs* as *zinc blende*, which is sulphide of zinc, and also as *calamine*, which is composed of carbonate and silicate.

340. **Zinc compounds** are generally white or colorless. The water-soluble salts of zinc have a disagreeable, bitter, astringent, metallic taste, and are poisonous.

Among the most common zinc compounds we have:

ZnO, zinc oxide.

$ZnCl_2$, zinc chloride.

$ZnH_2SO_5 + 6H_2O$ (commonly represented as $ZnSO_4 + 7H_2O$), zinc sulphate, or "white vitriol."

341. Iron is light grayish, lustrous, hard, malleable, ductile, tenacious. Its specific weight is from 7.3 to 7.9. It melts at about 2000° C.

Wrought iron, *steel* and *cast iron* all contain carbon and minute amounts of other elements. Wrought iron contains the smallest proportion of carbon; cast iron the greatest.

Iron occurs in very large quantities in the form of oxides, hydroxides, carbonates and sulphides. The best iron ore is "magnetic iron ore," which has a composition represented by Fe_3O_4.

342. Iron compounds are of various colors—white, gray, green, yellow, red, brown, blue, black, purple and rose.

Ferrous compounds contain iron with a valence of 2. They are generally white or grayish-white when anhydrous, but green or greenish-blue when hydrous or in water solution.

Ferric compounds contain iron with a valence of 3. They are usually nearly white or pale yellow when anhydrous, but red-brown when associated with water.

The iron preparations used in medicine are numerous. Among the most common compounds of iron are the following:

$FeCl_2$, ferrous chloride.

FeI_2, ferrous iodide.

$FeH_2SO_5 + 6H_2O$ (commonly written $FeSO_4 + 7H_2O$), ferrous sulphate, or "green vitriol."

FeH_2SO_5, dried or anhydrous ferrous sulphate.

Fe_2O_3, ferric oxide.

$FeCl_3$, ferric chloride.

$Fe(OH)_3$, ferric hydroxide, commonly misnamed "ferric hydrate."

$Fe_2(SO_4)_3$, ferric sulphate.

343. Nickel is a hard silver-white metal, tough, capable of high polish. Its specific weight is 8.9.

The principal nickel ore is nickelic arsenide, NiAs.

344. Chromium is a hard, gray, crystalline, infusible powder of the specific weight 7.3.

Chromous compounds contain the metal with a valence of 2, as in $CrCl_2$. In chromic compounds the element has a valence of 3, as in Cr_2O_3. But potassium dichromate (commonly misnamed "bichromate") has the composition $K_2Cr_2O_7$, and "chromic anhydride" is CrO_3, which is commonly misnamed chromic acid.

345. Manganese is a hard, brittle metal, fusible with difficulty. It occurs in nature in combination with oxygen. Its specific weight is about 7.5.

Manganese is remarkable because of its many different valences. It can apparently have a valence of either 2, 3, 4, 6 or 7.

MnO is manganous oxide.
Mn_2O_3 is manganic oxide.
MnO_2 is manganese dioxide.
$MnSO_4$ is manganous sulphate.
K_2MnO_4 is potassium manganate.
$KMnO_4$ is potassium permanganate.

346. Lead is a soft, gray or bluish-white metal of bright luster when untarnished. Its specific weight is 11.4, and its melting point 330° C.

The principal lead ore is *galena*, which is PbS.

The only water-soluble lead compounds are the acetate and the nitrate.

PbO is oxide of lead, familiar in the form of the red "litharge" and the yellow "massicot."

"White lead" is a "basic carbonate of lead."

"Red lead" or "minium" is Pb_3O_4.

Lead compounds are poisonous.

347. Copper is reddish, softer than iron but harder than silver, malleable and ductile, capable of high polish. Its specific weight is 8.9, and its melting point about 1090°.

It is found in large quantities, uncombined, in the great copper mines of the Lake Superior regions and in other places. Copper pyrites is represented by the formula $CuFeS_2$ and is common.

Brass is an alloy of copper and zinc.

348. **Copper compounds** are generally green or blue, but some are white, red, brown or black.

Cuprous copper is a monad; cupric copper a dyad.

Soluble copper compounds have a nauseous, strongly "metallic" or "brassy," persistent taste, and are poisonous.

Among the very common copper compounds are the following:

Cu_2O, cuprous oxide.

CuO, cupric oxide.

Cu_2S, cuprous sulphide.

CuS, cupric sulphide.

$Cu(NO_3)_2$, cupric nitrate.

$CuSO_4$, anhydrous cupric sulphate.

$CuSO_4 + 5H_2O$, crystallized cupric sulphate, or "blue vitriol."

349. **Mercury** is the only metal which is liquid at the ordinary temperatures. It is silver-white, lustrous, and so mobile that it is called "quick silver." Its specific weight is 13.6, and its boiling point 360° C. It freezes at about –40° C.

Cinnabar is the crystallized mercuric sulphide found in nature and this constitutes the ore from which the metal is obtained.

350. **Mercury compounds** are of two classes, according to the valence of the element. Mercurous mercury is a monad, forming mercurous compounds; mercuric mercury is the metal with a valence of 2, forming mercuric compounds.

The only water-soluble mercury compounds are mercuric chloride and mercuric cyanide; but the nitrates, both mercurous and mercuric, can be dissolved in a mixture of nitric acid and water.

Mercury compounds have a great variety of colors: colorless, white, scarlet, crimson, gray, yellow, orange red, black and brown.

They are poisonous, except when absolutely insoluble.

Among the most common mercury compounds are:

$HgCl$, mercurous chloride or "calomel."

HgI, mercurous iodide.

HgO, mercuric oxide, which is red if produced "in the dry way," but yellow if made by precipitation. Red oxide of mercury is often called "red precipitate," but cannot be made by "precipitation" as we now understand that term.

$HgCl_2$, mercuric chloride or "corrosive sublimate."

HgI_2, mercuric iodide, or "red iodide of mercury."

HgS, mercuric sulphide, which is red when crystallized, but black when precipitated, although the black precipitated mercuric sulphide can be converted into a red powder called "vermilion."

H_2NHgCl is mercuric chloramide, commonly called "white precipitate."

351. Silver is a beautiful white metal, harder than gold, capable of very high polish, malleable and ductile. Its specific weight is 10.6, and its melting point about 916° C. It is the best known conductor of heat and of electricity.

Pure silver is called "sterling silver."

This metal occurs in nature in the free state, but more freely in the form of sulphide associated with the sulphides of lead and copper.

352. Silver compounds are colorless, white, black, yellow or brown. As silver is univalent, the structure of its compounds is simple:

Ag_2O is silver oxide.

$AgCl$, silver chloride.

$AgNO_3$, silver nitrate, which, when molded into pencils, is called "lunar caustic."

353. **Gold** is soft, yellow, capable of extremely high polish, remarkably malleable and ductile. Its specific weight is 19.3. It melts at about 1037° C.

Pure gold does not decompose acids, but it dissolves in the mixture called "aqua regia," which is made of nitric acid and hydrochloric acid, because that mixture contains free chlorine, with which the gold forms a soluble chloride.

Gold occurs in nature almost exclusively in the uncombined state.

The most common gold compound is the chloride, $AuCl_3$, which is a light yellow, transparent, water-soluble, crystalline solid.

354. **Platinum** is a grayish-white, lustrous, hard, tough metal, fusible only at a strong white heat. Its specific weight is 21.46. It occurs in nature only in the free state. It dissolves in "aqua regia" to form platinic chloride, $PtCl_4$.

355. **Bismuth** occurs in nature only in the uncombined state. It is a reddish-white, brittle metal of high luster and well defined crystalline structure. It is not malleable nor ductile. It has the specific weight 9.74. It is easily fused, its melting point being 270° C. It readily decomposes nitric acid, forming nitrate of bismuth, which is soluble in water mixed with nitric acid, but converted into subnitrate of bismuth by water alone.

Bi_2O_3 is bismuth oxide.

$OBiCl$ is bismuthyl chloride.

$Bi(NO_3)_3$, bismuth nitrate.

$OBiNO_3$, bismuthyl nitrate, or "subnitrate of bismuth."

$(OBi)_2CO_3+H_2O$, "subcarbonate of bismuth," or bismuthyl carbonate.

356. **Tin** is a silver-white, lustrous, soft, malleable metal, of the specific weight 7.3, fusible at 228° C. It occurs in

nature in the form of "tin ore" or "tin-stone," which is stannic oxide, SnO_2.

Tin is not easily oxidized, nor is it affected by organic substances which attack iron, copper, lead, zinc, etc. Hence its great usefulness.

"Tin salt" is stannous chloride, $SnCl_2 + 2H_2O$.

XXIV

Solubilities of Common Inorganic Chemical Compounds in Water and in Alcohol

WATER SOLUBILITIES

357. Potassium Compounds. All are water-soluble and most of them are readily soluble.

Deliquescent are the hydroxide, carbonate, cyanate, phosphate, hypophosphite, acetate and the sulphated potassa.

Readily soluble are the bicarbonate, chloride, bromide, iodide, ferricyanide, ferrocyanide, nitrate, tartrate, citrate, salicylate, benzoate and Rochelle salt.

Less readily soluble are sulphate in 9.5 parts of water, dichromate in 10 parts of water, permanganate in 16 parts of water and chlorate in 16.7 parts of water.

Very sparingly soluble is cream of tartar in 201 parts of water.

Nearly insoluble is potassium-platinum chloride.

358. Sodium Compounds. All are soluble except antimonite, which is nearly insoluble.

Very freely soluble are the hydroxide, carbonate, chloride, bromide, iodide, chlorate, sulphate, sulphite, bisulphite, thio-sulphate, nitrate, nitrite, phosphate, hypophosphite, arsenate, acetate, tartrate, citrate, valerate, salicylate and benzoate and Rochelle salt.

Less readily soluble are bicarbonate in 11.3 parts of water, pyrophosphate in 12 parts of water, borax in 16 parts of water and bitartrate sparingly.

359. **Lithium Compounds.** All freely soluble in water except the carbonate, which dissolves in 80 parts of water, and the phosphate, which is nearly insoluble.

360. **Ammonium Compounds.** All officinal ammonium compounds are readily water-soluble, the least soluble being the benzoate and the carbonate, which are soluble in 5 parts of water.

361. **Barium Compounds.** The nitrate, chloride, bromide, iodide, sulphide and acetate are readily soluble. The hydroxide is soluble in 20 parts of water.

Insoluble are the carbonate, phosphate, sulphate and oxalate.

362. **Strontium Compounds.** The chloride, bromide and iodide are deliquescent. The acetate, lactate and nitrate are readily soluble. The hydroxide is comparatively sparingly soluble.

Insoluble are the carbonate, phosphate, sulphate and oxalate.

363. **Calcium Compounds.** Deliquescent are the chloride, bromide and iodide. Readily soluble are the nitrate, hypophosphite, sulphite, acetate, lactate and the sulphurated lime. Sparingly soluble is the hydroxide, which requires from 600 to 700 parts of water for solution, and the sulphate, which is soluble in from 300 to 400 parts of water. Insoluble are the carbonate, oxalate and phosphate.

364. **Magnesium Compounds.** Readily soluble are the chloride, bromide, iodide, nitrate, sulphate, acetate, lactate and the acid citrate. Insoluble are the oxide, hydroxide, carbonate, oxalate and phosphate.

365. **Zinc Compounds.** Deliquescent are the chloride, bromide and iodide. Readily soluble are the sulphate,

nitrate, acetate, lactate and paraphenolsulphonate. Less readily soluble is the valerate. Insoluble are the oxide, sulphide, phosphide, hydroxide, carbonate, oxalate, phosphate and oleate.

366. Cadmium Compounds. Soluble are the chloride, bromide, iodide, nitrate and sulphate. Insoluble are the oxide, hydroxide, sulphide, carbonate, oxalate and phosphate.

367. Aluminum Compounds. Readily soluble are the chloride, bromide, iodide, nitrate, sulphate, acetate, potash alum and ammonia alum. Insoluble are the oxide and hydroxide.

368. Cerium Compounds. Soluble are the chloride, nitrate and sulphate. Insoluble are the oxide, hydroxide, carbonate and oxalate.

369. Cobalt Compounds. The cobaltous salts and halides are deliquescent. Insoluble are the oxides, hydroxides and sulphides.

370. Nickel Compounds. Nickelous sulphate and nickelous chloride are soluble. The oxides, hydroxides and sulphide of nickel are insoluble.

371. Iron Compounds. Very readily water-soluble are ferrous chloride, bromide and iodide, ferrous sulphate and nitrate, ferric chloride and bromide, ferric nitrate, subsulphate, sulphate, acetate and citrate, and iron alum. The scale-salts of iron are all freely soluble.

Less soluble is ferrous lactate, requiring 40 parts of water for solution.

The insoluble iron compounds are ferrous and ferric oxides, hydroxides, sulphides, carbonates, oxalates, phosphates, pyrophosphates, metaphosphates and hypophosphites.

372. Chromium Compounds. Water-soluble are the chlorides, chromium sulphate, chromic anhydride, commonly called chromic acid, potassium chromate, potassium dichromate and chrome alum.

373. Manganese Compounds. Soluble are manganous chloride, bromide, iodide, nitrate and sulphate; also potassium manganate and permanganate and sodium permanganate. Insoluble are the oxides, hydroxide, carbonate, oxalate, phosphate and sulphide.

374. Lead Compounds. The only readily water-soluble lead compounds are the nitrate, acetate and subacetate. Lead chloride is sparingly soluble.

375. Copper Compounds. The only water-soluble cupric compounds are the chloride, nitrate, sulphate and acetate.

376. Mercury Compounds. All mercurous compounds are insoluble in water, but mercurous nitrate is soluble in a mixture of water and nitric acid.

The only water-soluble mercuric compounds are the chloride, which is soluble in 16 parts of water, and the acetate and cyanide. The bromide is soluble in about 200 parts of water, but mercuric nitrate is soluble in a mixture of nitric acid and water.

377. Silver Compounds. The only water-soluble salts are the nitrate and acetate.

378. Gold Compounds. The only water-soluble gold compound much in use is the trichloride.

379. Bismuth Compounds. The only water-soluble bismuth compound is citrate of bismuth and ammonium. But the normal bismuth nitrate which is decomposed by water is soluble in glycerin and also in glacial acetic acid without decomposition. It is also soluble in a mixture of nitric acid and water.

380. Antimony Compounds. The only water-soluble antimony compound is tartrate of antimonyl and potassium, commonly called tartar emetic. But chloride of antimony is soluble in a mixture of hydrogen chloride and water.

381. Arsenical Compounds. Sodium arsenate is readily soluble. Potassium arsenite is also soluble, as is iodide of arsenic. Arsenous acid is only sparingly soluble.

382. Oxides. No metallic oxides are water-soluble, except chromic anhydride and other oxides that react with the water to form either acids or bases. These dissolve by "chemical solution."

383. Hydroxides. The only freely water-soluble metallic hydroxides are those of the alkali metals. The hydroxides of barium, strontium and calcium are comparatively sparingly or very sparingly soluble. All other metallic hydroxides are insoluble.

384. Chlorides. All metallic chlorides are water-soluble except those of silver and lead, mercurous chloride and the chloride of antimony (which is decomposed by water, but soluble in a mixture of hydrochloric acid and water).

Deliquescent chlorides are those of calcium, zinc, ferric chloride and platinic chloride.

Readily soluble are the chlorides of potassium, sodium, lithium, ammonium, barium, strontium, magnesium, aluminum and gold.

Less readily soluble is mercuric chloride, soluble in 16 parts of water.

Nearly insoluble is lead chloride.

Insoluble are silver chloride and mercurous chloride.

Decomposed by water is antimony trichloride.

385. Bromides. Readily soluble are the bromides of potassium, sodium, lithium, ammonium, barium, strontium, calcium, magnesium, zinc, aluminum and ferrous and ferric bromide.

Soluble, though rather sparingly, are mercuric bromide and bromide of gold.

Insoluble are the bromides of silver, lead, and mercurous bromide.

386. Iodides. Freely soluble are the iodides of potassium, sodium, lithium, ammonium, barium, strontium, calcium, magnesium, zinc, cadmium, ferrous iodide, manganous iodide and arsenous iodide.

Insoluble are the iodides of silver, lead and mercury.

387. **Cyanides.** Those of the alkali metals are freely soluble. Mercury cyanide is soluble. Silver cyanide is insoluble.

388. **Ferrocyanides** and **Ferricyanides** of the alkali metals are water-soluble.

389. **Sulphides.** Those of the alkali metals and the alkaline earth metals are freely water-soluble. All sulphides of the heavy metals are insoluble.

390. **Hypochlorites** of the alkali metals and alkaline earth metals are soluble.

391. **Chlorates** of potassium and sodium are soluble.

392. **Sulphites** of potassium and sodium are readily soluble. Those of calcium and magnesium are soluble.

393. **Sulphates.** All metallic sulphates are soluble, except those of barium, strontium, calcium, lead and mercury. Readily soluble sulphates are those of sodium, ammonium, aluminum and ferric sulphate, also the alums. Soluble are the sulphates of potassium, lithium, magnesium, zinc, ferrous sulphate, manganous sulphate and copper sulphate. Very sparingly soluble is calcium sulphate. Insoluble are the sulphates of barium, strontium and lead. Decomposed by water is sulphate of mercury.

394. **Thio-sulphates** of potassium and sodium are freely soluble.

395. Sulphated potassa and sulphurated lime are freely soluble.

396. **Nitrates.** All are water-soluble except those of mercury and bismuth, which are decomposed by water.

397. **Nitrites** of the alkali metals are soluble.

398. **Phosphates, Pyrophosphates and Metaphosphates.** The only water-soluble phosphates are those of potassium,

sodium and ammonium, but some phosphates of the heavy metals, also the phosphates of the alkaline earth metals and magnesium, are soluble in phosphoric acid.

399. **Orthophosphates** of iron are soluble in orthophosphoric acid, but insoluble in pyrophosphoric or metaphosphoric acid. Pyrophosphates and metaphosphates of iron are insoluble in orthophosphoric acid, but soluble in metaphosphoric acid.

400. **Hypophosphites.** Those of the alkali metals and of calcium are water-soluble. Those of the heavy metals are insoluble, or nearly so.

401. **Carbonates.** The only water-soluble carbonates are those of potassium, sodium and ammonium. That of lithium is but sparingly soluble.

402. **Borates.** Borax is soluble.

403. **Acetates** of the metals are all water-soluble.

404. **Valerates.** Those of potassium, sodium, lithium and ammonium are soluble. Valerate of zinc is sparingly so.

405. **Oxalates.** Only those of the alkali metals and ammonium are soluble.

406. **Tartrates.** The normal tartrates of the alkali metals and ammonium are soluble. Their bitartrates are sparingly soluble. The tartrates of ferryl and potassium, and ferryl and ammonium, and antimonyl and potassium are soluble.

407. **Citrates.** Those of the alkali metals, ammonium and iron are soluble. Magnesium citrate is soluble in water containing much citric acid. Bismuth citrate is insoluble, but citrate of bismuth and ammonium is soluble.

408. **Lactates** of the alkali metals, calcium, strontium, magnesium, zinc and iron are water-soluble.

409. **Salicylates.** Those of the alkali metals are alone water-soluble.

410. **Phenol Sulphonates.** Those of the alkali metals and of barium, calcium and zinc are water-soluble.

411. **Benzoates.** Those of the alkali metals and of ammonium and calcium are water-soluble.

412. **Oleates.** Only the soaps are water-soluble.

413. The student will find it very useful carefully to memorize the following:

All of the officinal compounds of potassium, sodium and ammonium are water-soluble, but cream of tartar is only very sparingly soluble.

The hydroxides of potassium, sodium and ammonium are freely soluble.

The oxides, hydroxides, sulphides, carbonates, oxalates, phosphates (including pyrophosphates, metaphosphates and orthophosphates), hypophosphites, arsenates, arsenites, salicylates, benzoates and oleates of the heavy metals are all insoluble.

ALCOHOL SOLUBILITIES

414. A very large proportion of the inorganic chemical compounds are insoluble in alcohol, and especially those that contain much water. Inorganic chemical compounds which are insoluble in water are also, with scarcely any exception, insoluble in alcohol, but even a large number of the water-soluble inorganic chemicals are insoluble in alcohol.

415. Very soluble (in less than 5 parts of alcohol) are:

Hydroxides of potassium, sodium and ammonium.

Chlorides of magnesium, zinc, iron and mercuric chloride.

Bromides of lithium, barium, strontium, calcium, magnesium and zinc.

Iodides of lithium, sodium, barium, calcium, magnesium and zinc.

Acetate of potassium.

Valerates of potassium, sodium, ammonium and iron (ferric).

Salicylates of potassium, sodium, lithium and ammonium.

Ferric sulphate.

416. Soluble in from 6 to 30 parts of alcohol:

Iodine, 1 in 10.

Boric acid, 1 in 15.

Chloride of lithium, 1 in 10; of strontium, 1 in 6; of calcium, 1 in 8.

Bromide of sodium, 1 in 13; of ammonium, 1 in 30.

Iodide of potassium, 1 in 18; of ammonium, 1 in 9.

Mercuric cyanide, 1 in 15.

Nitrate of ammonium, 1 in 20.

Hypophosphite of potassium, 1 in 7.3; sodium, 1 in 30.

Acetate of sodium, 1 in 30; lead, 1 in 21.

Lactate of strontium.

Benzoate of lithium, 1 in 12, and ammonium, 1 in 28.

417. Sparingly soluble (in from 36 to 200 parts of alcohol):

Bromide of potassium, 1 in 200.

Iodide, mercuric, 1 in 130.

Chlorate of sodium, 1 in 100.

Nitrate of sodium, 1 in 100.

Phenolsulphonate of sodium, 1 in 132.

Acetate of zinc, 1 in 36.

Valerate of zinc, 1 in 40.

Benzoate of sodium, 1 in 45.

418. Insoluble, or nearly so, in alcohol are:

All metallic carbonates, oxalates, phosphates, pyrophosphates, metaphosphates, arsenates, arsenites, citrates and tartrates.

All metallic sulphates except ferric sulphate.

All the scale-salts of iron.

Chlorides of potassium, sodium and ammonium and mercurous chloride.

Iodide of lead and mercurous iodide.

Cyanide of potassium.

Nitrates of potassium, lead, copper and mercury.

Chlorate of potassium.

Nitrate of sodium.
Sulphite of potassium.
Thio-sulphate of sodium.
Borax.
Potassium dichromate.
All the ferrocyanides and ferricyanides.
Ammoniated mercury.
Ferrous lactate.

Test Questions

1. Write the chemical reaction which takes place when sodium is placed in water.

2. What is the most common potassium compound with which you are acquainted? Give the molecular formula for that compound.

3. What is the difference between washing soda and baking soda? Give the molecular formulas of both.

4. What is cream of tartar?

5. What is the color of sodium thio-sulphate?

6. What kind of a salt is Castile soap?

7. What is the percentage of bromine in potassium bromide and in lithium bromide?

8. Give the molecular formula of strontium sulphate.

9. Give the molecular formula of barium hydroxide.

10. Describe calcium.

11. What is the difference between $CaSO_4 + 2H_2O$ and CaH_4SO_6?

12. What is the difference between quick lime and slaked lime?

13. What is chloride of lime?

14. What is talcum?

15. Give the molecular formula of magnesium hydroxide.

16. What is the difference between $MgSO_4 + H_2O$ and MgH_2SO_5?

17. What kind of a sulphate is $MgSO_4$ and what kind of a sulphate is MgH_2SO_5?

18. How many aluminum atoms are contained in $3NaF.AlF_3$?

19. How many different systems of atomic linking do you find in the foregoing formula?

20. What is the molecular formula for alum?

21. Write the molecular formula for aluminum and sodium sulphate.

22. What is the most common source of aluminum?

23. Can you mention any property by which the light metals differ chemically from the heavy metals?

24. What is zinc blende?

25. What is formed when zinc is dissolved in diluted sulphuric acid? Write the reaction.

26. What is formed when zinc is dissolved in so-called hydrochloric acid? Write the reaction.

27. What is the difference between ferrous phosphate and ferric phosphate?

28. What is the difference in color between a solution of ferric chloride and a solution of ferrous chloride?

29. Can you trace the atomic linking in the substance represented as Fe_3O_4?

30. What is the difference between $FeO + Fe_2O_3$ and Fe_2FeO_4?

31. What is FeH_2SO_5?

32. What is $Fe(NO_3)_2$?

33. What is $Fe(NO_3)_3$?

34. What is FeO?

35. What is the algebraic combining number of each of the two elements in nickelic arsenide?

36. What is the difference between chromic anhydride and chromic acid? Write the molecular formulas for both.

37. What is the difference between potassium dichromate

and potassium bichromate? Write the molecular formulas for both.

38. What is MnO_2?

39. If such a compound as $MnMnO_4$ exists, what is it, and how does it differ from MnO_2?

40. What is the difference between basic manganese and acidic manganese as to valence?

41. What is galena?

42. What is PbO_2?

43. Can you trace the atomic linking in Pb_3O_4?

44. Can you trace the atomic linking in Pb_2PbO_4?

45. If Pb_2PbO_4 exists, what is its technical title?

46. What is the highest valence possible to lead, as indicated by its position in the periodic system?

47. Give the molecular formula for sulphate of copper.

48. What are the differences between mercurous compounds and mercuric compounds?

49. How can you distinguish between them when you see their molecular formulas?

50. How is mercury obtained?

51. What is the difference between calomel and corrosive sublimate?

52. Silver nitrate being soluble in water, how would you make it?

53. Silver chloride being insoluble in water, how would you make it?

54. What is the combining value of silver?

55. Why is it that aqua regia dissolves gold but does not dissolve silver?

56. What is the algebraic combining number of the bismuth in OBiCl?

57. Write the formula for bismuthic oxide.

58. Write the formula for bismuthous sulphide.

59. Write the formula for stannic chloride.

LESSON SIXTEEN

XXV

Weights and Measures

419. Three different systems of weights and measures are at the present time in use in medicine and pharmacy, although the metric system is exclusively employed in all pharmacopœias except the British, and the British pharmacopœia uses both the metric system and the imperial system.

Physicians who write prescriptions employ the metric system exclusively in all countries except Great Britain and America. In Great Britain they use partly the imperial system and partly the old apothecaries' system, while in the United States the apothecaries' system is generally used. Pharmacists in this country must therefore understand all the three systems—the imperial system, the apothecaries' system and the metric system. It is also necessary that pharmaceutical students understand the relations of weight and volume to each other and the principles of metrology.

420. The **metric system** is the most scientific and simple system of weights and measures in use.

Its chief merit is that it is decimal, and therefore in perfect harmony with our arithmetical notation. We count from 1 to 10 and the number 10 is expressed by two numerals. When we reach 100 we use three numerals, and for 1000 we use four. In other words, the periodic number of our arithmetic is 10.

No mathematician believes that 10 is the most convenient periodic number; on the contrary, either 8 or 12 would be far superior to 10, because 8 can be subdivided successively by 2 until unity is reached, and, moreover, the number 8 contains the cube of the smallest number that can be cubed. It is evidently most natural to men to divide numbers into halves and quarters, eighths, sixteenths, thirty-seconds, etc. It is not natural to divide by 10 and 5. The number 12 can be divided by either 6, 4, 3 or 2, but cannot be divided successively by 2 without striking fractions. Hence, although 12 is preferable to 10, it is probably not so convenient as 8.

The only reason advanced against the introduction of the metric system which has any weight or deserves any attention is the argument that our system of arithmetic is unnatural and will probably be changed in the course of time; but it has been admitted by those who advance this argument against the metric system that probably centuries will elapse before a more natural system of arithmetical notation is adopted. Every one competent to express an opinion will readily admit that whatever our system of arithmetic may be, our weights, measures and money ought to agree with it. Since, therefore, our arithmetical notation is decimal, it follows that our weights, measures and money should also be decimal, in order that computations may be rendered as simple as possible; and if we are going to continue to use decimal arithmetic for centuries, we certainly should in the meantime use decimal weights, measures and money instead of waiting for reform in weights and measures until a new system of arithmetic has been introduced.

421. The metric system was devised a little over one hundred years ago. Many of the world's scientific men were concerned in constructing it. It was first decided that it should be decimal. Next, it was decided that it should be based upon some linear unit, and that measures of surface, volume and weight should be based upon the linear unit primarily.

Next, it was decided that the linear unit chosen should be an aliquot part of some physical constant. The physical constants that have been thought of are the length of the polar axis, the length of the equator and the length of the meridian, also the length of the seconds pendulum—a pendulum of such length that it swings in seconds of time at a given latitude—or the length of the seconds rod, which is exactly 50 per cent longer than the seconds pendulum. The idea involved in the selection of a physical constant as the natural basis of a universal system of weights and measures was that the dimensions and movements of the earth can be measured at any time, so that if the material standard made to represent the natural standard should ever be lost, it could be replaced with absolute certainty of perfect sameness. In devising the metric system, the length of the meridian was chosen as the primary natural standard, and the length of the seconds pendulum was chosen as a secondary standard to serve as a check upon the other. But the length of the seconds pendulum is hardly ever mentioned in connection with the metric system any longer, and the length of the meridian has now but a theoretical and sentimental connection with the metric system based upon the meter. The original meter was intended to be identical with the forty-millionth part of the length of the meridian, or the ten-millionth part of the quadrant, and in order to arrive at this unit of length an arc of the meridian was measured from Dunkirk to Barcelona, and a platinum bar was constructed and called the meter. Upon the length of this meter the whole metric system was based. It has since been held by some that the platinum meter is not exactly identical with the ten-millionth part of the quadrant. At all events, the question is a disputed one.

Whether the theoretical meter, which is the forty-millionth part of the meridian, and the actual meter made of platinum are identical is of no consequence whatever, for there are now extant in the world a large number of meter bars made of platinum alloyed with 10 per cent of iridium which are microscopically accurate, and as these several meter bars are kept in various parts of the world and are so constructed that they will resist any injury, we shall never lose all of them. Any meter bar lost can be readily replaced with the absolute certainty that the new one will have precisely the same value as the one lost. Hence, there will never be any occasion for measuring the meridian again for the purpose of constructing a new meter bar.

422. The original platinum meter is preserved in the archives of France, and is universally called the "Mètre des Archives." It is believed to be porous and inferior in other ways to the irido-platinum meter bars now used, so that the Mètre des Archives is merely an interesting historical relic. It is never used.

423. The modern meter bars are constructed by the **International Metric Bureau**, an institution established by the civilized nations of the world, who all contribute toward its maintenance. The International Metric Bureau is located near Paris. It has supplied standard meter bars and standard kilogram weights to all countries, and is engaged in investigations and scientific determinations connected with weights and measures for the benefit of the civilized world.

424. The **units** employed in the metric system for the measurement of surfaces are simply the squares upon the meter and upon decimal multiples and subdivisions of the meter. For the measurement of bulk the cubes upon the meter and its decimal multiples and subdivisions are used. In order to obtain a unit of mass, the scientific men who devised the metric system decided that the mass of a given volume of water at the temperature of the maximum density of that liquid should constitute that unit. Hence, the weight of a cubic centimeter of water at 4° C., weighed *in vacuo*, was called a gram, and that gram is the unit of weight of the metric system. In France there is, further, a simple relationship between the metric unit of weight and the weight of the silver coinage.

425. The important units of the metric system for the measurement of linear measure, square measure, cubic measure and weight are the meter, the are, the stère, the liter and the gram; the meter for long measure, the are for land measure, the stère for the measurement of large bulks, the liter, or cubic decimeter, for capacity measure for smaller volumes, and for weight the gram, and one thousand grams make the so-called kilogram represented by the mass standards of metric countries.

426. One of the defects of the metric system is the redundance of units it provides. A new unit with a new name has been provided for each successive decimal multiple and for each successive decimal subdivision of each of the principal units.

The multiples are indicated by Greek **prefixes**; namely, the word *deka*, which means ten; the word *hekto*, which means one hundred; *kilo*, which means one thousand; and *myria*, which means ten thousand. A dekagram, therefore, means a ten-gram, and hektometer means a one-hundred-meter; three kiloliters means three thousand-liters, and a myriagram means one ten-thousand-gram.

The subdivisions are named with the aid of Latin prefixes; namely, *deci*, which means one-tenth; *centi*, which means the one-hundredth part; and *milli*, which means a one-thousandth. A milliliter, therefore, is a one-thousandth-liter; a centigram is a one-hundredth-gram, and a decimeter is a one-tenth-meter.

It is not only unnecessary but burdensome to use so many different units. The superfluity of these many units is well exemplified by the following illustration: In America the monetary unit is called the dollar. In common speech we speak of ten dollars as an eagle, of the tenth of a dollar as a dime, the one-hundredth part of a dollar as a cent, and the one-thousandth part of the dollar as a mill. But no sensible person would count money in eagles, dollars, dimes, cents and mills. We find the dollar and the cent amply sufficient for all purposes.

In the metric system the only necessary linear units are the kilometer, the meter and the millimeter. For capacity measures the liter and the milliliter are sufficient, and for weights, the kilogram, the gram and the milligram.

427. The following tables of the weights and measures of the metric system are sufficient for purposes of study:

Linear Measure

1 kilometer = 1,000 meters
1 hektometer = 100 meters
1 dekameter = 10 meters
1 meter = 1 meter
1 decimeter = 0.1 meter
1 centimeter = 0.01 meter
1 millimeter = 0.001 meter

1 meter is equal to 39.37 inches, and 25 millimeters nearly equal 1 inch.

Square Measure

1 square kilometer = 1,000,000 square meters
1 square meter = 100 square decimeters
1 square meter = 10,000 square centimeters
1 square meter = 1,000,000 square millimeters

Land Measure

1 square meter is called a centiare
100 square meters is an are
10,000 square meters is a hektare.

CUBIC MEASURE

1 cubic meter = 1,000 cubic decimeters
1 cubic decimeter = 1,000 cubic centimeters

The cubic meter is called a STÈRE.

CAPACITY MEASURES

1 kiloliter = 1,000 liters
1 hektoliter = 100 liters
1 dekaliter = 10 liters
1 liter = 1 cubic decimeter
1 deciliter = 0.1 liter
1 centiliter = 0.01 liter
1 milliliter = 0.001 liter

One liter is equivalent to about 33.8 U. S. fluid ounces.

WEIGHT UNITS

1 kilogram = 1,000 grams
1 hektogram = 100 grams
1 dekagram = 10 grams
1 gram = 1 gram
1 decigram = 0.1 gram
1 centigram = 0.01 gram
1 milligram = 0.001 gram

One gram is equivalent to 15.432 grains (nearly).

428. The system of weights and measures in the United States is an incongruous mixture of old standards which were introduced into this country during colonial times. Several of the units we employ have been abolished in Great Britain, and the values of our customary weights and measures are probably not absolutely identical with the original English values, which they are supposed to represent.

Our linear units are squared and cubed, but our unit of land measure, the acre, does not bear a simple relationship to the standard yard; nor do the bushel and gallon measures bear a simple relationship either to the yard or the pound. We have several kinds of gallons and several kinds of pounds, although only two of the gallons are actually used.

429. The original theoretical yard was of such length that the length of the seconds pendulum at Greenwich, England, was expressed by 39.1393 inches, each inch being the thirty-sixth part of the standard yard; but it is not absolutely certain that either the British yard or the American yard is now identical with the value just stated, for when the original British standard yard was lost and a commission was appointed to remeasure the length of the seconds pendulum and to construct a new standard yard from the results, the task was abandoned as impracticable and an extant copy of the old standard yard was chosen and adopted as the new standard, and in our country the length of the yard is now $\frac{3600}{3937}$ of the length of the meter. The present American yard may or may not be absolutely identical with the present British yard.

430. Our customary capacity measures are not based upon the linear unit, but upon weight. Our bushel measures, gallon measures and their subdivisions are, in other words, constructed and verified by weight. Originally the gallon employed for the measurement of liquids (the Old English wine gallon) was 231 cubic inches, but the American gallon of to-day is the volume of 3785.434 grams of water at 4° C., weighed *in vacuo.* Whether or not that volume is 231 cubic inches is doubtful.

The National Bureau of Standards of America adjusts the liquid gallon by weight, on the assumption that 252.892 grains of water at its maximum density, weighed *in vacuo*, measures one cubic inch. If the theoretical kilogram, which is the weight of one cubic decimeter of water at its maximum density *in vacuo*, is identical with the actual international standard kilogram, which is assumed to be equivalent to 15432.35639 grains, then, as 39.37 inches is equal to one meter, the weight of a cubic inch of water at its maximum density *in vacuo* is 252.892 grains, and from this value the weight of 231 cubic inches of water at its maximum density *in vacuo* must be 3785.434 grams. But many authorities declare that the weight of one cubic inch of water at its maximum density, weighed *in vacuo*, is not 252.892 grains. If so, our liquid gallon is not 231 cubic inches.

The gallon for dry measure in America is supposed to be the old English Winchester gallon of 268 cubic inches.

431. The commercial pound of this country is assumed to be identical with the British imperial pound, but we also employ in America the old English Troy pound, and a copy of the old British Troy pound is kept in the custody of the United States Mint at Philadelphia for the purpose of regulating the coinage of the United States, in accordance with a resolution of Congress. The Troy weight is used also for weighing gold and silver bullion, gold and silver ware and jewelry.

The Troy pound is subdivided into 12 Troy ounces, and each Troy ounce is subdivided into 20 pennyweights, and each pennyweight into 24 grains. It will be seen, therefore, that the subdivisions of the Troy pound are not identical with the subdivisions of the commercial pound, called the avoirdupois pound, nor is it identical with the subdivision of the apothecaries' pound.

The value of the Troy ounce is not identical with the value of the avoirdupois ounce, but it is identical with the value of the apothecaries' or medicinal ounce. The only unit of avoirdupois weight, Troy weight and apothecaries' weight having the same value is the grain.

432. The customary weights and measures of America are as follows:

Linear Measure

1 league = 3 miles, or 5,280 yards
1 mile = 8 furlongs, or 1,760 yards
1 furlong = 40 poles or rods
1 pole or rod = 5½ yards
1 yard = 3 feet, or 36 inches
1 foot = 12 inches

SURFACE MEASURE

1 square mile = 640 acres
1 acre = 4 roods, or 4,840 square yards
1 rood = 40 square poles
1 square pole = $30\frac{1}{4}$ square yards
1 square yard = 9 square feet
1 square foot = 144 square inches

CUBIC MEASURE

1 cubic yard = 27 cubic feet
1 cubic foot = 1,728 cubic inches

CAPACITY MEASURE

Dry Measures

1 bushel = 4 pecks, or 32 dry quarts
1 peck = 2 dry gallons, or 8 dry quarts
1 dry gallon = 4 dry quarts, or 8 dry pints
1 dry quart = 2 dry pints

Liquid Measures

1 liquid gallon (wine gallon) = 4 liquid quarts
1 liquid quart = 2 liquid pints
1 liquid pint = 4 gills

American Medicinal Fluid Measures

1 liquid gallon = 4 liquid quarts
1 quart = 2 pints
1 pint = 16 fluid ounces
1 fluid ounce = 8 fluid drams
1 fluid dram = 60 minims

WEIGHTS

Commercial or Avoirdupois Weights

1 ton = 20 hundredweights, or 2,000 pounds
1 hundredweight = 100 pounds
1 pound = 16 ounces, or 7,000 grains
1 ounce = 16 drams, or $437\frac{1}{2}$ grains
1 dram (now obsolete) = $27\frac{11}{32}$ grains

Troy Weights

1 troy pound = 12 troy ounces, or 5,760 grains
1 troy ounce = 20 pennyweights, or 480 grains
1 pennyweight = 24 grains

Apothecaries' Weights

1 pound = 12 ounces, or 5,760 grains
1 ounce = 8 drams, or 480 grains
1 dram = 3 scruples, or 60 grains
1 scruple = 20 grains

433. The imperial system of Great Britain was adopted in 1824, to take effect January 1, 1825.

The imperial gallon is the volume of 10 imperial pounds of pure water at 62° F., weighed in air of the same temperature. Therefore the imperial gallon is based upon weight and not upon any linear unit. It is true that the British Parliament has also declared that the imperial gallon is equal to 277.274 cubic inches, but the volume of 10 pounds of water under the British standard conditions must depend upon natural laws, without reference to legislation by Parliament. If 277.274 cubic inches of water at 62° F., weighed in air, does not weigh 10 pounds, Parliament cannot alter the fact.

As the British pound is subdivided into 7000 grains and into 16 ounces, each equivalent to 437.5 grains, and as the imperial gallon is subdivided into 8 pints, and each pint into 20 fluid ounces, it follows that the imperial weight ounce and the imperial fluid ounce are commensurate units, with regard to water, under the British standard conditions. In other words, an imperial fluid ounce of water weighs one imperial ounce, or one imperial ounce of water measures an imperial fluid ounce. But the imperial minim of water does not weigh one grain.

434. The capacity measures of the imperial system are shown in the following table:

1 bushel = 4 pecks, or 32 quarts
1 peck = 2 gallons, or 8 quarts
1 gallon = 4 quarts, or 8 pints, or 160 fluid ounces
1 quart = 2 pints, or 40 fluid ounces
1 pint = 20 fluid ounces
1 fluid ounce = 8 fluid drams
1 fluid dram = 60 minims

435. The linear measure of the British imperial system is the same as prior to 1825 and practically identical with the American customary long measure. The surface measures are the same as those used in this country The only weights which may be legally used in Great Britain are the avoirdupois weights, and the only liquid measures are the imperial measures referred to in the preceding paragraph.

436. From the foregoing, the student will see that the *theoretical meter* is the forty-millionth part of the length of the meridian, while the *actual meter* is the length of the material prototype meter of the International Metric Bureau.

The *theoretical liter* is one cubic decimeter, but the *actual liter* is the volume of one kilogram of water at 4° C., weighed *in vacuo*, because capacity measures must of necessity be constructed by and based upon weight and not upon linear measure.

The *theoretical kilogram* is the mass of one cubic decimeter of water at 4° C., but the *actual kilogram* is the mass of the piece of irido-platinum of the International Metric Bureau, called the standard kilogram.

The standard kilogram of the International Metric Bureau is probably too light. In other words, the true mass of one cubic decimeter of water at 4° C. is probably more than one standard kilogram.

437. In the metric system the liter is subdivided into 1000 milliliters, but the milliliter is very generally referred to as a cubic centimeter, and in tables of weights and measures it is stated that one liter is equivalent to 1000 cubic centimeters. But the student should observe that the one-thousandth part of one cubic decimeter, which is of course one cubic centimeter, cannot be one milliliter unless the liter is exactly equivalent to one cubic decimeter. The actual liter in use is the volume of one kilogram of water at 4° C., weighed *in vacuo*, and as the kilogram upon which the liter is based and by which it is standardized cannot be the theoretical kilogram but is instead the actual kilogram, which is too light, the actual liter must be less than one cubic decimeter.

438. The relations between the various units of weight and measure in use by civilized nations are shown in the following tables:

Long Measure

1 league = 4,828 meters
1 mile = 1,609.3 meters
1 furlong = 201.2 meters
1 rod = 5.03 meters
1 yard = 36 inches = 0.914 meters
1 foot = 30.48 centimeters
1 inch = 25.4 millimeters

1 kilometer = 0.6213 mile
1 meter = 1.0936 yards
1 meter = 3.28 feet
1 meter = 39.37 inches

Surface Measure

1 square mile = 259 hektares
1 acre = 40.47 square meters
1 square yard = 0.8361 square meter
1 square foot = 9.29 square decimeters
1 square inch = 6.452 square centimeters

1 square meter = 1.196 square yards
1 square meter = 10.764 square feet
1 hektare = 2.471 acres

Measures of Capacity

1 bushel = 35.24 liters
1 peck = 8.81 liters
1 dry gallon = 4.40 liters
1 dry quart = 1.10 liters

1 American liquid gallon = 3,785.4 liters
1 American liquid quart = 0.946 liter
1 American liquid pint = 473 milliliters

1 American fluid ounce = 29.57 milliliters
1 American fluid dram = 3.697 milliliters
1 American minim = 0.0616 milliliter

1 British Imperial gallon = 4.543 liters
1 British Imperial quart = 1.136 liters
1 British Imperial pint = 0.568 liter

1 British Imperial fluid ounce = 28.39 milliliters
1 British Imperial fluid dram = 3.55 milliliters
1 British Imperial minim = 0.059 milliliter

1 American liquid gallon = 0.833 British Imperial gallon
1 American liquid quart = 0.833 British Imperial quart
1 American liquid pint = 0.833 British Imperial pint

1 American fluid ounce = 1.04 British Imper'l fluid ounces
1 American fluid ounce = 500 British Imperial minims

1 British Imperial gallon = 1.200 American liquid gallons
1 British Imperial gallon = 9.601 American liquid pints
1 British Imperial pint = 1.200 American liquid pints

1 British Imperial fluid ounce = 0.96 American fluid ounce
1 British Imperial fluid ounce = 461 American minims

1 liter = 0.2642 American liquid gallon
1 liter = 1.0567 American liquid quarts
1 liter = 33.81 American fluid ounces

1 liter = 0.220 British Imperial gallon
1 liter = 0.881 British Imperial quart
1 liter = 35.23 British Imperial fluid ounces

Measures of Weight

1 kilogram = 2.205 avoirdupois pounds
1 gram = 15.432 grains
1 milligram = $\frac{10}{648}$ grain

1 avoirdupois pound = 453.6 grams
1 avoirdupois ounce = 28.35 grams
1 grain = 64.8 milligrams

1 American medicinal pound = 373.243 grams
1 American medicinal ounce = 31.10 grams

1 avoirdupois pound = 1.215 Troy pounds
1 avoirdupois ounce = 0.911 American medicinal ounce

1 American medicinal pound = 0.823 avoirdupois pound
1 American medicinal ounce = 1.097 avoirdupois ounces

Convenient Approximate Equivalents

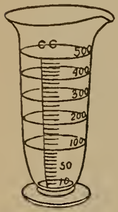
1 kilogram = 32 medicinal ounces
1 milligram = $\frac{1}{64}$ grain

1 grain = 64 milligrams

480 American minims = 500 Imperial minims

The weight of 96 American medicinal fluid ounces of water is 100 avoirdupois ounces.

439. The differences between the values of the theoretical and the actual units of the metric system and the differences between the actual and theoretical values of some of the customary units of weights and measures are so insignificant that in actual practice they are ignored. In fact, it is sufficient in all ordinary operations to employ approximate equivalents. For example, it is sufficient to consider one meter as equivalent to 40 inches and one inch as equivalent to 25 millimeters. It is quite sufficient to consider one liter as equivalent to 34 apothecaries' fluid ounces. It is even perfectly allowable to consider one apothecaries' fluid ounce as equivalent to 32 cubic centimeters, although it is more nearly 30 cubic centimeters. If one fluid ounce be considered as equivalent to 32 cubic centimeters, then one fluid dram is equivalent to 4 cubic centimeters, and one cubic centimeter is equivalent to 15 American minims. It is sufficient to consider one apothecaries' ounce as equivalent to 32 grams, although it is a little over 31 grams. If the apothecaries' ounce be considered as equivalent to 32 grams, then one dram is equivalent to 4 grams, and one gram is equivalent to 15 grains. But in the pharmaceutical laboratory and at the dispensing table it matters little whether one gram be considered equivalent to 15 grains or 15.432 grains or 16 grains, and it is immaterial whether the cubic centimeter be considered as equivalent to 15 minims or 16 minims. It makes no difference whether a certain amount of medicine be divided into 31 equal doses or into 32 equal parts, for a dose of medicine of any kind is of necessity an arbitrary one, representing simply the best judgment of the medical man in each instance. It would be impossible to observe any difference between the medicinal action of 30 grains and the medicinal action of 31 grains of the same substance. In chemical analysis the conditions are of course altogether different. The most accurate balances and weights are necessary in chemical determinations, while in the weighings at the dispensing table a balance sensitive to two or three milligrams is sufficient, and more durable than a balance sensitive to the fraction of one milligram.



A GRADUATED GLASS MEASURE

Thirty-two Troy ounces or apothecaries' ounces of water at ordinary room temperatures is equal to one liter, and 32 apothecaries' ounces is equal to one kilogram. One grain is equal to 64 milligrams, or, in other words, $\frac{1}{64}$ of a grain is equal to one milligram. As 6 American liquid pints of water weighs 100 avoirdupois ounces, it follows that the weight of 6 pints of anything else in avoirdupois ounces must be 100 times its specific gravity.

To convert any number of kilograms into the corresponding number of avoirdupois pounds, multiply by 2.2. To find the weight in grams of any number of cubic centimeters, multiply the cubic centimeters by the specific weight. To find the volume in cubic centimeters of any number of grams, divide by the specific weight or multiply by the specific volume. To find the volume of any number of apothecaries' ounces in American fluid ounces, divide by the specific weight, or multiply by the specific volume, and then add 5 per cent. To find the weight in apothecaries' ounces of any number of fluid ounces of any liquid, multiply by the specific weight and deduct 5 per cent. This is because one fluid ounce of water weighs .95 of an ounce.

Test Questions

1. In what countries are the weights and measures of the imperial system used?
2. In what countries are the weights and measures of the apothecaries' system used?
3. In what countries is the metric system employed?
4. Why is a decimal system of weights and measures preferable to any other?
5. What was the object of making the length of the meridian the basis of the metric system?
6. What is the length of the quadrant?
7. What is the difference between the theoretical meter and the actual meter?
8. What is the difference between the theoretical liter and the actual liter?
9. What is the difference between the theoretical kilogram and the actual kilogram?
10. Where are all the standard prototypes of weights and measures made and adjusted?
11. How is the permanent loss of the metric standards prevented?
12. How many cubic millimeters are contained in one cubic decimeter?

13. How many cubic centimeters in one cubic meter?

14. How many square centimeters in one square decimeter?

15. Do you know any other name for the cubic centimeter?

16. Do you know any other name for the liter?

17. What is a myriameter?

18. What is a decigram?

19. What one name is given to ten liters? to one hundred grams? to one thousand liters? to the tenth of a gram? to the hundredth part of a liter? to the thousandth part of a kilogram? to the thousandth part of a gram?

20. What is the difference between a milliliter and a cubic centimeter?

21. What is the difference between a liter and a cubic decimeter?

22. What is the exact value of the American yard?

23. What is the exact value of the wine gallon now in use for commercial purposes?

24. Is any other gallon used for commercial purposes than the wine gallon?

25. What is the difference between the old English wine gallon and the American wine gallon?

26. What is the ultimate standard for the adjustment of our bushel measures and gallon measures in America?

27. What is the ultimate standard which fixes the present value or size of an acre?

28. What is the weight of a cubic inch of water at 4° C. *in vacuo*, according to the Government authorities of the United States?

29. What is the difference between a Troy ounce and an apothecaries' ounce?

30. What is the difference between an avoirdupois ounce and an imperial ounce?

31. What is the difference between an apothecaries' grain and an imperial grain?

32. What is an imperial gallon?

33. What is the origin of the American liquid gallon?

34. Has the American liquid gallon ever been used in any other country, and is it now in use in any other country?

35. What is the volume of ten pounds of water at 62° F. in air, measured in cubic inches?

36. What is the equivalent of the apothecaries' pound in grains?

37. What is the equivalent of the English commercial pound in grains?

38. Into how many drams is the Troy ounce subdivided, and into how many scruples is the Troy dram divided?

39. How many drams are there in an avoirdupois ounce?

40. Which has the greater mass, the actual kilogram or the theoretical kilogram?

41. Which is greater, the actual liter or the theoretical liter?

42. What is approximately the equivalent of one kilogram in apothecaries' ounces?

43. How many milligrams equal one-half grain?

44. How many grams approximately equal one dram?

45. If you had a prescription for one powder with the quantities of the ingredients for that powder stated in grains, how would you convert that prescription into metric terms and increase the quantities so that fifteen powders can be made, each containing the same dose as in the original prescription?

46. An average adult dose of opium is considered to be one grain. What would it be set down to be in an ordinary dose table if our grain were 10 per cent larger than it is, and how much would it be set down to be if our grain were 10 per cent lighter than it is?

47. What is the equivalent of two American fluid ounces in British minims?

48. What is the weight of one quart of a liquid having the specific weight 1.800 ?

49. What is the equivalent of an American fluid ounce in cubic centimeters and what is its equivalent in milliliters ?

50. Which is larger, an imperial pint or an American pint ?

51. Which is larger, an imperial fluid ounce or an American fluid ounce ?

52. Which is larger, an imperial minim or an American minim ?

53. Which is larger, an imperial grain or an American grain ?

54. What is the ultimate standard by which the weight of American coins is regulated ?

LESSON SEVENTEEN

XXVI

Specific Weight and Specific Volume

440. The **specific weight** of any substance is the relation of its mass to its volume.

A substance having great weight in proportion to its volume is said to have a large specific weight, and a substance of which the same volume weighs less has a smaller specific weight.

The specific weight of different substances must be conveniently and intelligently expressed, and this is accomplished by stating specific weights in numbers referring to the specific weight of water as the unit. In other words, the relation of the weight of water to its volume under standard conditions is arbitrarily called 1, and the specific weight of any substance a given volume of which is heavier than the same volume of water is expressed by a number greater than 1, while the specific weight of any substance a given volume of which weighs less than the same volume of water is expressed by a number less than 1. The number expressing the specific weight of any solid or liquid is the number of times the weight of that solid or liquid contains the weight of the same volume of water. In other words, it is expressed by the number obtained by dividing the weight of a given volume of that solid or liquid by the weight of the same volume of water expressed in the same kind of weight units. The specific weight of chloroform is

1.5, because a liter of chloroform weighs 1.5 kilograms; and the specific weight of ether of a certain strength is .750 if 1000 cubic centimeters of it weighs 750 grams, for 1000 cubic centimeters of water weighs 1000 grams, and 750 ÷ 1000 is .750.

In the pharmacopœia and most of the technical works specific weights are expressed to the third decimal. Hence, the specific weight of chloroform is given as 1.500 and not as 1.5.

441. **Specific volume** is the relation of the volume of a substance to its mass. Accordingly, the specific volume of any substance is expressed by a number which is the reciprocal of the number expressing its specific weight. In other words, if the specific weight is 2, the specific volume must be $\frac{1}{2}$. If the specific weight is $\frac{2}{3}$, the specific volume must be $\frac{3}{2}$. If the specific volume of any substance is $\frac{4}{5}$, then the specific weight must be $\frac{5}{4}$.

Specific weights and specific volumes, when expressed by numbers with fractions, are expressed decimally, but if the specific weight is expressed by a common fraction, then the corresponding specific volume is found by simply inverting the fraction. For example, as the specific weight of chloroform is 1.500, or stated in the form of a common fraction, $\frac{1500}{1000}$, it follows that the specific volume of chloroform is $\frac{1000}{1500}$. As the specific weight of glycerin is 1.250, its specific volume must be 0.800, for 1.250 multiplied by 0.800 gives the product 1. The specific volume is found from the specific weight by dividing 1 by the specific weight, and the specific weight can be found from the specific volume by dividing 1 by the specific volume.

The specific volume of any liquid is found also by dividing the volume of a given weight of the liquid by the volume of the same weight of water, expressed in the same units.

The use of the term specific volume to indicate the relation of the volume of a liquid to its weight as here explained was first proposed by the writer of this book in 1883. Its practical value depends upon the fact that multiplication is an easier operation than division. In converting weight into volume we multiply the weight by the specific volume, if the weight units and the volume units are commensurate.

442. Several pairs of **commensurate units** exist. The avoirdupois ounce and the imperial fluid ounce are commensurate, because an avoirdupois ounce of water measures an imperial fluid ounce. The gram and the cubic centimeter are commensurate units, because a cubic centimeter of water weighs a gram; and the liter and the kilogram are commensurate, because the liter is the volume of a kilogram of water. A kilogram of any liquid having the specific volume 0.800 must measure 800 cubic centimeters.

As 6 wine pints of water weighs 100 avoirdupois ounces, it follows that 96 American fluid ounces of any liquid having the specific weight 0.960 must weigh 96 fluid ounces. The specific weight of castor oil is 0.960; hence an American fluid ounce of it weighs one avoirdupois ounce.

443. How the Specific Weight is Found. As the specific weight of any solid or liquid is the number of times the weight of a given volume of water is contained in the weight of the same volume of the solid or liquid, it follows that a simple method of finding the value sought is to divide the weight of the solid or liquid by the weight of the same volume of water.

But the specific weight of a solid or liquid may be found in several other ways, directly or indirectly. The weight of 1000 cubic centimeters of any liquid stated in kilograms at once expresses the specific weight of that liquid. Hence, if we have a flask with a long neck graduated by means of an etched line around the neck indicating the point to which one kilogram of water reaches at the standard temperature, we may fill that flask up to the mark on the neck with any other liquid, take the weight of it, and thus at once find its specific weight. Graduated flasks of other capacities can, of course, be used for the same purpose.

444. A **pycnometer**, or specific gravity bottle, is a flask constructed to hold a given quantity of pure water at standard temperature when completely filled. The size of the flask is such that the weight of the water can be expressed in a simple number of weight units, such as will be an easy divisor, as, for instance, 50 or 100 or 500 or 1000 units. This bottle is then used in the same manner as the graduated flask already described. The most complete pycnometers made are glass-stoppered bottles provided with thermometers, so that the temperature of the liquid may be conveniently observed in the same operation with the determination of the weight of the contents. A counterpoise representing exactly the weight of the empty pycnometer accompanies the apparatus. The filled pycnometer is then placed on one pan of the balance and the counterpoise on the other, after which it is only necessary to restore the equilibrium of the balance by placing the requisite weights on the pan with the counterpoise. If the pycnometer is so made as to hold 50 grams of water, we can take the weight of the other liquid in grams, multiply that by 2 and divide the product by 100, when the quotient will be the specific weight sought.

Any glass-stoppered bottle may be used for the same purpose, the weight of the water it will hold being taken and the weight of the other liquid required to fill the bottle also determined, after which the division follows. But when an ordinary bottle is used, the divisor, or the weight of the water the bottle holds, will not be a *simple* number of weight units, and the division will consequently not be so easy.

Another way of finding the specific weight of a liquid is based upon the law of Archimedes.

445. The **law of Archimedes** may be stated as follows: Any solid immersed in a fluid is buoyed up by that fluid with a force measured by the weight of the fluid displaced by the solid. If, for instance, a cubic inch of lead rests upon the table, it does not press upon its support with its whole mass, but with its mass minus the weight of a cubic inch of air, in which the piece of lead is immersed. The difference between the weight of that cubic inch of lead in a vacuum and its weight in air must be, according to the law of Archimedes, the weight of one cubic inch of air. If the same cubic inch of lead be weighed suspended in water, the difference between its weight in air and its apparent weight when suspended in water will be the weight of one cubic inch of water. If it be weighed suspended in olive oil, then the difference between its weight in air and its weight in olive oil will be exactly measured by the weight of one cubic inch of olive oil. If a piece of glass or any other solid be weighed first in air and then in water while suspended from a balance by means of a wire or thread, the difference between its weight in air and its weight in water must be the weight of the same volume of water. If, now, the same piece of glass be weighed in any other liquid, the difference between the weight of the glass in air and its weight in the liquid must be the weight of the same volume of the other liquid. We then have the necessary factors from which to find the specific weight of the second liquid, namely, the weight of a definite volume of water and the weight of the same volume of the other liquid. We then divide the weight of the water into the weight of the other liquid. If the piece of glass used for this purpose be of such size that it displaces a simple number of weight units of water, as for instance 5 grams or 10 grams, and the number of grams it displaces be known, it need not be weighed in water again, but only in the liquid the specific weight of which is to be ascertained.

446. The specific weight of a solid heavier than water may be found by submerging the solid in water in a graduated cylinder, as follows: If the cylinder is graduated in grams and fractions of grams and a solid whose weight in air is known in grams be dropped in the water contained in the graduated cylinder, then, as the solid sinks below the surface of the water, the level of the water necessarily rises to correspond with exactly the volume of the solid. If the solid weighs 10 grams in air, and when dropped in the water in the graduated cylinder causes the level of the water to rise 2 grams, according to the graduated scale, then the same volume of water weighs 2 grams, and the specific weight of the solid must be 5.

447. Any solid having a specific weight greater than that of water must sink below the surface of the water when placed in it, and any solid having a less specific weight floats in water, and only descends into the water far enough to displace its own weight.

Any solid having precisely the same density as that possessed by water may be placed in any position in the body of the water and will neither sink nor rise.

Lard is lighter than water, but heavier than alcohol. The specific weight of lard may therefore be found by putting a piece of it in a vessel of water and then adding gradually enough alcohol, mixing the two liquids cautiously until the piece of lard may be placed in any part of the mixed liquid and will remain in its position without sinking or rising. The specific weight of the liquid is then taken and must, of course, be identical with the density or specific weight of the lard.

448. Specific gravity beads are hollow glass beads the specific weights of which have been ascertained and etched upon them. If a handful of such beads be thrown into any liquid, the beads having a greater density than the liquid will sink to the bottom and those having a less density will float at the surface, but any bead having the same density as the liquid may be made to swim about in the body of the liquid in any position. The density of the liquid in this case is, of course, that marked upon the bead that neither sinks nor floats. This fact is taken advantage of for the purpose of finding deviations from the normal density of urine, for if a glass bead or bulb so made that it has precisely the specific weight of normal urine be put in a sample of urine, it will sink if the urine is abnormally light, or it will float if the urine is abnormally heavy.

449. A **hydrometer** is a float of nearly cylindrical form loaded at one end with shot or mercury so as to bring the center of gravity of the whole instrument to that end, in order that when the hydrometer is placed in a liquid it may assume a vertical position. If the whole instrument weighs more than its own volume of the liquid in which it may be placed, it will, of course, sink below the surface of that liquid. If it weighs less than its own volume of that liquid, it will sink down into the liquid just far enough to displace its own weight of the liquid. The floating hydrometer, therefore, sinks farther down in a light liquid than in a heavy one, and the tube or stem of the hydrometer may be graduated, or provided with a graduated scale indicating the density of the liquid in which it may be placed.

If the hydrometer is constructed especially to take the specific weights of heavy liquids, then the point to which it sinks in water is marked by the figure 1 at the top of the scale, and the point to which it sinks in a liquid having, for instance, a density twice as great as that of water would be marked 2, after which the distance between the two graduation marks is accurately divided into equal spaces indicating the densities of liquids between the specific weight 1 and the specific weight 2.

If the hydrometer is to be used to find the densities of liquids lighter than water, then the instrument is so made that it descends into the water only to the lower end of the scale. We shall then have the unit at the bottom of the scale and the densities of the lighter liquids graduated above as far as may be necessary. The most common hydrometers are of two kinds—one for densities ranging from 1.000 up to 1.300 and the other for densities ranging from 1.000 down to 0.700.

Test Questions

1. Define specific weight.

2. What is the difference between specific weight and specific gravity?

3. Define specific volume.

4. How are specific weights expressed?

5. What is the unit of expression for the specific weights of gases?

6. What is the unit of expression for the specific weights of liquids?

7. What unit is employed for expressing the specific weights of solids?

8. What is the quotient obtained when 1 is divided by the specific weight?

9. What is the quotient obtained when 1 is divided by the specific volume?

10. What is the specific volume of a liquid the specific weight of which is 1.111?

11. What is the specific weight of a liquid the specific volume of which is 1.111?

12. What is the product obtained from multiplying the specific volume of a substance by its specific weight?

13. What practical uses are made of specific weight?

14. What are the practical uses of specific volume?

15. What is meant by commensurate units of weight and volume?

16. Name several pairs of such units.

17. When it is stated that hydrochloric acid has the specific weight 1.160, what does that number mean?

18. What is the standard temperature adopted by the pharmacopœia for finding and expressing specific weights?

19. Mention a convenient method of taking the specific weight of a fluid extract.

20. Give a method of finding the specific weight of lead.

21. What is a pycnometer?

22. State the law of Archimedes.

23. What are specific gravity beads?

24. Describe a hydrometer.

25. A piece of metal weighs 8.3 ounces. The same volume of water weighs 1 ounce. What is the specific weight of the metal?

26. A bottle holds 480 grains of water, but 576 grains of nitric acid. What is the specific weight of the acid?

27 If 20 imperial fluid ounces of a liquid weigh 1¼ avoirdupois pounds, what is the specific weight of the liquid?

28. A one-thousand-grain pycnometer holds 735 grains of ether. What is the specific weight of that ether?

29. A fluid ounce of alcohol at 22° C. weighs 373 grains and a fluid ounce of water at the same temperature weighs 455 grains. What is the specific weight of that alcohol referred to water at 22° C. as unit?

30. Is the specific weight of that alcohol greater or less referring to water at 15° as unit?

31. A liter of diluted alcohol weighs 925 grams. What is its specific weight?

32. A liter of glycerin weighs 1250 grams. What is its specific weight?

33. A bottle which holds ½ ounce of water holds 5 drams

of a certain solution. What is the specific weight of that solution?

34. If 1 gallon of ether and $\frac{1}{2}$ gallon of chloroform have the same weight and 2 pints of chloroform weigh the same as 3 pints of water, what is the specific weight of the ether?

35. I have a solid weighing 13 grams in air. I drop it into a graduated cylinder containing 30 cubic centimeters of water and find that the level of the water rises to 40 cubic centimeters when the solid sinks to the bottom of the cylinder. What is the specific weight of the solid?

36. The weight of 3 gallons of water is 400 avoirdupois ounces and the weight of a gallon of alcohol is 109 avoirdupois ounces. What is the specific weight of the alcohol?

37. An imperial gallon of oil of peppermint weighs 9 avoirdupois pounds. What is its specific weight?

38. Six pints of solution of zinc chloride weigh 155$\frac{1}{2}$ avoirdupois ounces. What is its specific weight?

39. A mass of thirteen grams of a certain solid has a volume of 10 cubic centimeters. What is its specific weight?

40. A solid weighs 4.75 grams in air and 4 grams in water. What is its specific weight?

41. A piece of metal of the bulk of 161.7 cubic inches weighs 347624.55 grains in air and 306839.75 grains in water. What is the weight in grains of 231 cubic inches of water?

42. A crystal weighs 10 grams in air and 9 grams in oil of turpentine. The specific weight of the oil of turpentine is 0.860. What is the specific weight of the crystal?

43. One cubic centimeter of a certain solid weighs 870 milligrams. What is its specific weight?

44. A piece of cork weighs 0.732 grams in air. A piece of metal weighs 7.7 grams in air, but only 6.6 grams in water. Cork and metal tied together and weighed in water are found to weigh 4.182 grams. What is the specific weight of the cork?

45. A piece of lard is put in a vessel of water, and alcohol is gradually added and mixed with the water until the piece of lard instead of floating on the surface may be placed at will in any position in the body of the liquid. A fifty-gram pycnometer is now filled with the liquid and the contents of the pycnometer found to weigh 46.9 grams. What is the specific weight of the lard?

46. If a piece of metal weighs 9 ounces in air, 8 ounces in water and 8.1 ounces in oil, what is the specific weight of the oil?

47. A solid measuring 10 cubic centimeters when immersed in oil of turpentine is found to displace 8.6 grams of the oil. What is the specific weight of the oil?

48. Glycerin has the specific volume 0.800. The weight of three volumes of glycerin is the same as that of five volumes of ether. What is the specific weight of the ether?

49. Fifty cubic centimeters of nitric acid weigh 71 grams and 50 cubic centimeters of hydrochloric acid weigh 58 grams. The specific weight of the hydrochloric acid is 1.160. What is the specific weight of the nitric acid?

50. A certain bottle holds 100 ounces of glycerin, the specific weight of which is 1.250. How many ounces of water will it hold?

51. How much will the same bottle hold of ether having the specific weight 0.720?

52. How much will it hold of chloroform of the specific weight 1.470?

53. How much will it hold of syrup having the specific weight 1.330?

54. A solid weighs 3 ounces. It has the specific weight of 8.300. When weighed in a certain liquid its apparent loss of weight is $\frac{1}{2}$ ounce. What is the specific weight of the liquid?

55. The specific weight of water is 1. What is its specific volume?

56. One thousand avoirdupois ounces of a liquid measure 60 pints. What is the specific volume?

57. If 300 grams of a liquid measure 280 cubic centimeters, what is its specific volume?

58. One kilogram of a liquid measures 755 cubic centimeters. What is the specific volume?

59. If 4 imperial pints of a liquid weigh 6 pounds, what is its specific volume?

60. What is the weight of 255 cubic centimeters of a liquid having the specific weight 1.100?

61. What is the weight of 30 cubic centimeters of a liquid having the specific weight 0.700?

62. What is the weight in avoirdupois ounces of 100 imperial fluid ounces of a liquid having the specific weight 1.960?

63. What is the weight in pounds of an imperial gallon?

64. What is the weight in avoirdupois ounces of 96 American fluid ounces of a liquid having the specific weight 1.820?

65. What is the weight in avoirdupois ounces of 16 United States fluid ounces of a liquid having the specific weight 1.260?

66. If a cubic inch of water weighs 252.5 grains, what is the weight of 231 cubic inches of a liquid having the specific weight 0.900?

67. If an American fluid ounce of water weighs 0.95 apothecaries' ounce, what is the weight of 1 American fluid ounce of a liquid having the specific weight 0.860?

68. What is the volume of 3 kilograms of nitric acid having the specific weight 1.420?

69. What is the volume of 5 pounds of a liquid having the specific volume 1.111? Give the answer in pints.

70. Castor oil has the specific volume 1.042. What is the volume of 6 pounds stated in American fluid ounces?

71. A piece of metal weighs 6445.380 grains in air. When suspended in water, its apparent weight is 5585.996 grains. Its bulk is 3.40 cubic inches. What is the specific weight of the metal, and what is the weight of a cubic inch of water?

72. A piece of metal weighs 480 grains in air, 420 grains in water and 400 grains in a solution of sugar. What is the volume of 500 grams of that solution?

73. A kilogram weight of brass and a kilogram weight of platinum balance each other perfectly in a vacuum. Which has the greater mass?

74. Which has the greater volume?

75. Which of them seems to weigh more in air?

76. You weigh in the usual manner a pound of wood and a pound of lead. Which is really the heavier of the two?

77. A solid measuring 0.1 cubic decimeter is weighed first *in vacuo*, then in air, and lastly in water. One cubic inch of air weighs 0.3 grains and a cubic inch of water 252.50 grains. Find the difference between the weight of that solid *in vacuo* and its weight in air; the difference between its weight in air and its weight in water.

78. A ten-dollar gold coin weighs 258 grains in air. Assuming its specific weight to be 18.300, what is its apparent loss of weight when weighed suspended in water?

79. If an imperial gallon of sulphuric acid weighs 18.35 avoirdupois pounds, what is the volume of 1000 grams of that acid expressed in cubic centimeters?

80. If the specific weight of oil of vitriol be twice that of olive oil, and if 1 liter of olive oil weighs 917. grams, what is the weight of 500 cubic centimeters of oil of vitriol?

81. If a solid weighs 75 ounces and the same volume of water 10 ounces, what is the apparent weight of that solid when weighed suspended in water?

82. If a bullet weighs 13 ounces in air and 12 ounces in

water, what will it appear to weigh in a liquid having 1.400 specific weight?

83. If a pound of water measure $15\frac{3}{8}$ fluid ounces and a pound of a certain solution $7\frac{11}{16}$ fluid ounces, what is the specific volume of the solution?

84. What number of cubic centimeters expresses the volume of 85.33 grams of a liquid having 1.01 specific volume?

85. The specific weight of solution of mercury nitrate being 2.100, what is the weight of one liter of it?

86. Solution of citrate of iron has the specific weight 1.260. What is the weight of one American pint in avoirdupois ounces?

87. The specific weight of oil of turpentine is 0.860. What is the weight of 96 American fluid ounces of it in commercial ounces?

88. Which is greater, the number expressing the specific weight of acetic acid referring to water at 4° C. as unit, or the number expressing the specific weight of the same acid referring to water at 15° C. as unit?

89. A certain liquid at 39.2° F. has the specific weight 1.200 referring to water at 22° C. as unit. Will the number expressing its specific weight at 60° F. referring to water at 4° C. as unit be greater or less than 1.200?

90. The weight of one liter of water at 4° C. is 15,432 grains, but the weight of 500 cubic centimeters of water at 22° C. is 7696 grains:

(*a*) What is the specific weight of water at 22° C. referring to water at 4° C. as unit?

(*b*) What is the specific weight of water at 4° C. referring to water at 22° C. as 1?

91. An imperial gallon of water at 62° F., barometer at 30 inches, weighs 70,000 grains:

(*a*) Does it weigh more or less at 15° C.?

(*b*) Does it weigh more or less when the atmospheric pressure is greater?

92. A cubic inch of water at 22° C. weighs 252.5 grains. What is the weight of 231 cubic inches of an alcohol having 0.860 specific weight, referring to water at 22° C. as 1?

93. What is the volume of 100 apothecaries' ounces of oil of 0.900 specific weight, if one cubic inch of water weighs 250.5 grains?

94. What is the specific volume corresponding to each of the following specific weights, respectively: (*a*) 1.000; (*b*) 1.250; (*c*) 1.333; (*d*) 0.500; (*e*) 0.750; (*f*) 0.800; (*g*) 2.000; (*h*) 0.720; (*i*) 0.820; (*j*) 0.950; (*k*) 1.500; (*l*) 1.300; (*m*) 1.320?

95. What is the volume of 1000 grams of a liquid having the specific volume 1.200?

96. What is the volume in imperial fluid ounces of 100 avoirdupois ounces of a liquid having the specific volume 0.800?

97. What is the volume in United States fluid ounces of 25 avoirdupois ounces of a liquid having the specific volume 1.000?

98. What number of cubic centimeters expresses the volume of 85 grams of a liquid having the specific weight 1.010?

99. What number of cubic centimeters expresses the volume of 85 grams of a liquid having the specific volume 1.010?

100. What number of grams expresses the weight of 85 cubic centimeters of a liquid having the specific weight 1.010?

101. What number of grams expresses the weight of 85 cubic centimeters of a liquid having the specific volume 1.010?

102. The total weight of a bottle filled with water is 30

ounces. The same bottle filled with olive oil weighs 28 ounces. What is the weight in ounces of the water the bottle is capable of holding? How many ounces of oil will it hold? What is the weight of the bottle itself?

103. A bottle filled with water weighs 16 ounces; filled with chloroform having the specific weight 1.470 it weighs 19.877 ounces; filled with acid it weighs 17.32 ounces. How much does it hold of water, of chloroform and of acid, respectively, and what is the specific weight of the acid?

104. A solid measuring 2 cubic inches weighs 6000 grains in air, but only 5400 grains when weighed suspended in a certain liquid. What is the specific weight of that liquid?

105. A solid measuring one cubic centimeter and weighing 10 grams loses one gram in weight when weighed in a certain liquid. What is the specific weight of that liquid?

106. Alcohol has the specific weight 0.820 at 15.6° C. The net weight of a barrel of alcohol at that temperature is found to be $300\frac{2}{3}$ pounds. How many gallons of the alcohol does that barrel contain?

107. A certain mixture of water with a syrup of the specific weight 1.330 is found to have the specific weight 1.200. What are the proportions of syrup and water in the mixture?

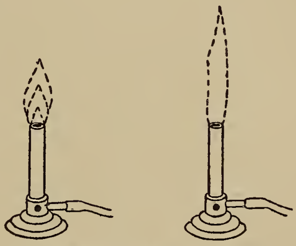
LESSON EIGHTEEN

XXVII

Pharmaceutical Operations

450. **Heat** for pharmaceutical purposes may be obtained most conveniently by means of gas burners, but where gas is not available, coal oil and alcohol lamps or burners are used.

The **Bunsen burner** is the most approved gas burner for pharmaceutical and chemical purposes. It is a tube in which the gas is mixed with air admitted near the bottom of the tube, and the mixture ignited at the top. The flame of the gas burner is bluish when sufficient air is mixed with the gas so that the combustion is complete, but when the gas supply is too abundant or the amount of air insufficient, the flame is yellow and deposits unconsumed carbon upon the vessels heated over the flame.



BUNSEN BURNER, CONTRASTING THE PROPER FLAME WITH ONE THAT RESULTS WHEN THE GAS IS "LIGHTED BACK" INTO THE TUBE

451. The **sand bath** is an iron dish containing a layer of sand which may be used for the purpose of distributing the heat of the flame. The flask, dish or other vessel to be heated is placed in the sand.

A **water bath** is a vessel of water intervening between the flame and the vessel to be heated. The object of the water bath is to prevent the temperature from rising above the boiling point of water. The contents of vessels heated upon the water bath rarely attain a higher temperature than a little above 90° C. To control the temperature when substances must be heated above 100° C., glycerin baths, oil baths and solution baths are employed.

452. **Exsiccation** is a term used to express the heating of chemical compounds for the purpose of expelling water of crystallization. Sulphate of iron, alum, sodium carbonate, sodium phosphate, magnesium sulphate and various other salts containing large quantities of water of crystallization may be dried so as to expel all water or a portion of it.

453. **Calcination** is the process of converting metallic carbonates and other metallic salts into metallic oxides by heat. Strong heat is usually required for this purpose, and the by-products formed are volatile. When a carbonate is calcined, the by-products are CO_2 and water, or CO_2 alone, according to the composition of the carbonate decomposed. Nitrates and sulphates can also be calcined. The word calcination is derived from the Latin *calx*, which means lime, because lime is produced by strongly heating limestone or calcium carbonate in kilns.

454. **Dry distillation**, or "destructive distillation," is a term employed to express the decomposition of organic substances by strong heat, resulting in the formation of new products, some of which are volatile and others fixed. For example, when oak billets are heated strongly in closed iron cylinders provided with an outlet for the volatile products, the oak wood undergoes decomposition, and, among the volatile products which distill over, acetic acid is one of the most valuable, and the residue in the cylinder is a tarry mass of mixed composition.

455. **Sublimation** is the distillation of solids; in other words, volatile solids are vaporized, and the vapor conducted into condensing vessels in which they reassume a solid form. The product is called a *sublimate*, and is generally of

crystalline character. Sublimation is employed as a method of separation of volatile substances from fixed substances for purposes of purification.

456. The coarse **mechanical division** of drugs is an important pharmaceutical operation.

For the preparation of mixed teas, drugs are required to be very coarsely comminuted. If they are flexible, they may be cut with sharp-edged tools so as to produce pieces free from dust or powder, but if they are hard so that they cannot be cut, they are comminuted by crushing, in which case more or less powder is unavoidably produced. The crushing of plant drugs is best accomplished in an iron mortar with an iron pestle, but smaller pieces of drugs can be crushed also in hand-mills of iron.

457. An **iron mortar** used for crushing and powdering drugs must be very large in proportion to the amount of drug operated upon in order to do effective work. It should be solid, heavy, and placed upon a solid block, which, if possible, should rest upon the ground instead of upon the floor. The crushing of drugs in a mortar by means of blows with the pestle is technically called **contusion.**

458. The **iron mill** used by druggists for making coarse powders of drugs is similar to the mill used by grocers for grinding coffee, but there is an essential difference in the construction and position of the grinding plates, so that the hand drug-mills are not identical with coffee mills and spice mills. There are several makes of hand drug-mills, and the best forms are those which have the grinding plates in a nearly horizontal instead of vertical position.

These hand-mills are provided with set-screws which enable the operator to move the grinding plates nearer to each other or farther apart at will, to make coarser or finer powder, as may be desired. It is usually necessary to pass a drug through the hand-mill more than once, if a comparatively fine powder is required; in other words, the drug is first crushed, then passed through the mill to make a coarse powder, then the mill is set finer and the coarse powder passed through the mill again, this operation being repeated until the required fineness is attained. But very fine powder cannot be made with the hand drug-mill.

A coarse powder can, however, be easily enough made very fine by contusion in the iron mortar.

459. Trituration is the grinding produced in the mortar by a rotary motion of the pestle accompanied by pressure. When trituration is performed, the pestle is grasped firmly by the whole hand in order to apply sufficient force to crush the particles of substance triturated. Comparatively brittle substances can be powdered by trituration, but in order to do effective work the trituration mortar should be large in proportion to the quantity of substance triturated, for if too deep a layer of powder is operated upon at one time, the operation is necessarily slower.

A SMALL PORCELAIN MORTAR

Trituration is also employed for mixing powders, but if the ingredients of the mixture are already sufficiently fine, no pressure is required in mixing them. The *spatula* is usually necessary, in accomplishing trituration, to scrape the substances from the end of the pestle and the bottom and sides of the mortar, in order to do rapid and effective work.

A STEEL SPATULA

Trituration mortars are generally made of porcelain or of Wedgewood ware.

460. Levigation is the trituration of substances in a fine state of division, either upon a slab with the muller or in a mortar with the pestle, with the addition of some liquid to the solid substance to aid in its further division. Water, alcohol and oil are all used for such purposes.

Sometimes the levigation has for its object not only the production of a very fine powder, but also the removal of impurities with the aid of the liquid added. For example, calomel is levigated by trituration with water in order to wash out from it the corrosive sublimate which may be contained in sublimed calomel and which is soluble in water. When purification of calomel is effected by levigation, several successive portions of water must, of course, be used until all of the corrosive sublimate has been finally removed.

461. Elutriation is also a process employed for the purpose of producing very fine powders of insoluble substances. The finely powdered solid is put in water, with which it is well mixed by stirring. The mixture is then allowed to stand at rest until the coarser and heavier particles have subsided, while the finer particles still remain suspended in the liquid, which is decanted, after which the finer powder is allowed to settle to the bottom. When this process is repeated several times an almost impalpable powder can be produced. Prepared chalk and purified antimony sulphide are prepared by elutriation, according to the directions of the pharmacopœia.

462. Powders, however they may be made, are never perfectly uniform. To render them as nearly uniform as practicable they are passed through **sieves** made out of sieve-cloth of various grades of fineness. The fineness of sieves is indicated in the pharmacopœias according to the number of meshes in the sieve-cloth. Sometimes the number of meshes is counted according to linear measure, but a better way is to count the number of meshes per square measure. In the United States pharmacopœia the fineness of sieves and powders is indicated by the number of meshes to the linear inch. Thus, a No. 60 sieve means a sieve having sixty meshes to the linear inch, and a No. 80 sieve is one having eighty meshes to the linear inch. But the meshes of sieve-cloth are not always square, so that a different number of meshes may be counted to the linear inch, according to whether the count is made along the woof or along the warp. Moreover, the wire or silk thread or hair out of which the sieve-cloth is made may be of varying caliber, so that this method of determining the fineness of powders is very uncertain. The student will readily understand this by an extreme example: Suppose a sieve has one hundred meshes to the linear inch and is made of brass wire. If the wire cloth is made of wire one one-hundredth part of an inch in diameter, it follows that there would be no openings in the sieve-cloth at all.

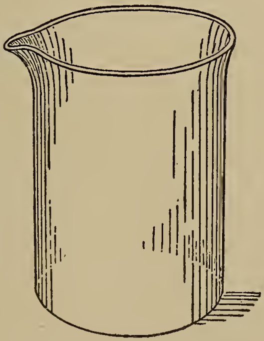
463. While the pharmacopœias always prescribe a method of expressing the fineness of powders, they do not all of them prescribe a given degree of fineness for each individual drug. In the American pharmacopœia, for instance, there is no information given as to how fine powdered digitalis should be when ordered by the physician, although the powder to be used of digitalis for the preparation of the tincture, the fluid extract or the extract is specifically prescribed. Very full directions are given in some pharmacopœias, stating how fine the powder should be of any important drug prescribed by a physician to be used in powder form or in pill-masses, and to fail to give such directions would seem to be a serious omission.

464. By "dusted powders" is meant powders so fine that when made in a mill constructed expressly for the purpose, they rise in the mill-box like dust, which settles upon shelves along the walls of the mill-box or on the floor of that box away from the circle in which the millstones run like wheels.

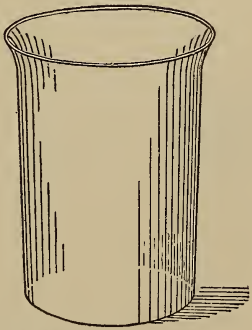
465. Colored substances become lighter when reduced to fine powder, and the color grows lighter as the powder gets finer.

466. The **solution** of soluble substances may be effected in many different ways, but most quickly by reducing the substance to be dissolved to a more or less fine powder, except in cases where the fine powder would become agglutinated by the action of the solvent. A *solution mortar* is a deep mortar provided with a lip. A salt or other substance to be dissolved in water may be put in the solution mortar and there crushed, after which one portion after another of solvent is added and poured off as solution results, until all of the solvent to be used has been employed and the solid substance liquefied.

A PORCELAIN SOLUTION MORTAR



A BEAKER WITH LIPS, USED IN MAKING SOLUTIONS



A BEAKER WITHOUT LIPS, USED IN MAKING SOLUTIONS

467. Circulatory displacement consists in placing a soluble substance on a strainer at the top of a vessel containing the solvent, just below the surface of the liquid; the solution formed, being denser than the solvent itself, then runs down to the bottom of the vessel so that fresh portions of solvent come in contact with the solid matter, and the solution is thus more rapidly effected. This method is a very useful one, and if a strainer of the right kind is employed the solution obtained by circulatory displacement may be rendered so clear as not to require further clarification.

468. **Extraction methods** by which soluble substances contained in plant drugs are extracted and separated from the insoluble substances are of great importance. The solvents employed are called "menstrua," and the most common menstrua are alcohol and water and mixtures of these. The extraction methods are maceration, digestion, infusion, decoction and percolation.

469. **Maceration** consists in placing the comminuted drugs in the menstruum and permitting them to remain in contact with each other a sufficient length of time at the ordinary room temperature, after which the solution obtained is separated from the undissolved residue, which is called the "marc."

But maceration may be varied so as to be rendered more effective, by using several successive portions of menstruum upon the undivided amount of drug to be exhausted of its soluble matter. If, for instance, a pound of drug be mixed with enough diluted alcohol to produce a thick mixture, and this mixture be allowed to stand a day or two, after which the solution formed is expressed by means of a hydraulic press or other effective pharmaceutical press, the press-cake can then be disintegrated again and mixed with another portion of fresh menstruum to produce a thick mixture as before, allowing this new portion of menstruum to extract as much of the remaining soluble matter as it may, after which this second solution is separated by expression as before. These successive macerations with new portions of menstruum may be repeated until absolutely no more soluble matter remains in the drug.

If at the same time the several macerates or solutions obtained by maceration be kept separate from one another, these several macerates may be employed over again as menstrua upon a fresh portion of drug, the drug being macerated first with the first macerate from the preceding portion of drug and then with a second and third and fourth macerate, and finally with a fresh portion of previously unused menstruum, until this second portion of drug has also been completely exhausted, the object being to use each portion of menstruum over and over again as long as it still retains any solvent power, in order to effect the extraction of all the soluble matter with the smallest possible amount of menstruum, so as to obtain as concentrated a solution as may be made. [This is also the object of percolation and re-percolation, as will be seen later on.] A very common form of maceration when employed in the preparation of tinctures is to use two-thirds of the whole amount of menstruum upon the whole amount of drug in the first period of maceration, and then, after separating the solution formed, to use the remaining third of the menstruum to finish the exhaustion of the drug.

470. Digestion differs from maceration in one particular only, namely, the temperature. While maceration is performed at any ordinary room temperature, or, in other words, without the application of artificial heat, digestion is performed at any temperature above that of the work-room, or, in other words, with the application of more or less heat.

The temperature of digestion may be any degree of heat from 25° C. up to nearly 90° C.

The effectiveness of digestion as compared with maceration is great, and the employment of even a comparatively moderate degree of heat generally increases the solvent power of the menstruum so greatly that digestion ought to be employed more largely than it is, for it accomplishes in great part the same object as is gained by percolation and re-percolation, namely, the exhaustion of the drug with a minimum amount of menstruum.

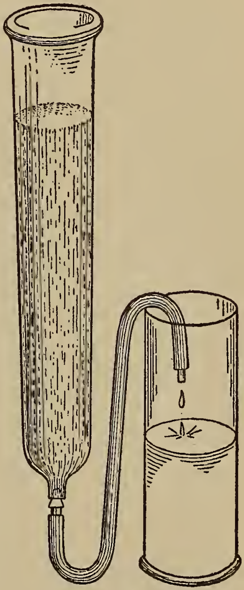
471. **Infusion** is a process consisting of putting boiling water upon a plant drug and letting the hot water exert its solvent action upon the drug without taking any measures to maintain the temperature, but allowing that to gradually fall even to the temperature of the atmosphere of the room, after which the solution formed is separated from the marc by straining and expression. But the process of infusion is at the present time most frequently performed by means of a water bath or "digestorium," and when this is the case, the temperature is maintained at such a high degree that the result is very different from that obtained by the old method of infusion. The products or preparations made by the process of infusion are generally called infusions.

472. **Decoction** is a process of extraction consisting of boiling a drug in the menstruum for a given length of time. This process is rarely applicable except when water is the menstruum and the drug contains no substance of value liable to be injuriously affected by the high temperature. The products made by decoction are called "decoctions," and decoctions are rarely made of potent drugs.

473. **Percolation** is an effective method of extraction which is extremely useful when concentrated liquid extracts are to be made or when it is desired to exhaust the drug with a minimum amount of menstruum. These objects are gained in the process of percolation by using the same quantity of solvent over and over again on successive portions of drug, until the solvent is so charged with soluble matter or so nearly saturated that it is no longer capable of doing

effective work. This can be accomplished in various ways.

The simplest form of percolation consists in moistening the drug in the form of powder with a sufficient amount of menstruum to dampen it, after which the dampened powder is allowed to lie long enough thoroughly to absorb the menstruum, so that each particle of powder may be softened and permeated by the solvent as far as it can be. The dampened drug is then packed more or less firmly in a tall cylindrical tube called a percolator, the form of which is indicated by the illustration on this page. If the drug is uniformly and not too firmly packed in the percolator by means of the plunger or packer, the descent of the menstruum, afterwards poured upon the drug, will be very regular. A sufficient quantity of menstruum is poured upon the drug in the percolator completely to saturate the packed drug from top to bottom, leaving a layer of menstruum above the surface of the drug, after the packed mass has been filled and saturated. The apparatus is closed so that no liquid can pass out from it. In the percolator described in the pharmacopœia and figured in the text, a rubber tube is attached to the lower end of the percolator, and when this tube is raised and tied to the side of the percolator so that the end of the tube is above the level of the liquid, the atmospheric pressure will prevent any portion of liquid from passing out. The apparatus is left in this condition a greater



OLDBERG'S PERCOLATOR

or less period of time, according to circumstances, in order that the menstruum may have time enough to act upon the drug and to dissolve the soluble substances in it. The tube is then lowered and the displacement of the liquid from the mass of drug in the percolator is allowed to proceed. The liquid or solution flowing out of the percolator is called the *percolate*, and the rate of its flow is regulated so that it may pass out slowly, the object being to permit the liquid in the percolator to gather up more soluble matter as it passes through successive layers of the packed drug.

The student can readily see that when the menstruum is poured upon the drug in the percolator, each drop of liquid passes through the entire distance from the top to the bottom, first taking up soluble matter from the upper layer and then from the next layer of drug, and so on, so that if the column of drug is tall enough, it may happen that the solution formed will finally be so thick that it can pass no further. This, of course, is to be avoided, but the column of drug is always made sufficiently tall to insure that the menstruum may form as saturated a solution as can readily pass down and out.

If the process is successfully performed, the percolate passing out from the percolator will be clear or free from solid particles.

Fresh menstruum is added from time to time, being poured into the percolator at the top and allowed to percolate through the drug, following the preceding portions until finally no more soluble matter remains in the marc.

If the percolator is put in a warm place, the effectiveness of this operation is very much increased.

When liquid preparations are made of such strength that they represent more than one-fifth of their weight of the drug, percolation is unquestionably the best method of extraction, but most of the pharmacopœias of the world order maceration for making tinctures of 20 per cent. strength or less.

Percolation is a difficult process, which should never be undertaken by inexperienced operators without constant supervision exercised by persons familiar with the necessary conditions of success. In other words, it requires considerable practice and close attention to perform percolation successfully. Maceration, on the other hand, is a very simple process, and this undoubtedly is the reason why most of the pharmacopœias prefer it to percolation, except in cases where maceration proves insufficient.

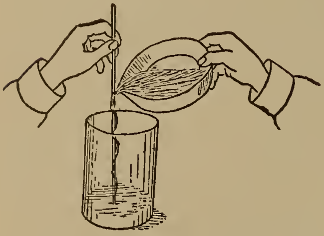
474. By **re-percolation** is meant a process of percolation in which one portion after another of the drug is subjected to displacement or percolation in the manner described, using part of the same menstruum for the second portion of drug as for the first, and part of the same menstruum for the third portion of drug as for the second. This plan is adopted for the purpose of further increasing the effectiveness of the process. In simple percolation the last portion of the percolate is a comparatively diluted solution, which can readily be used again as an effective menstruum, and it is so used when re-percolation is employed. (See p. 275.)

475. The **clarification of liquids** is accomplished in various ways. Sometimes clarification is effected by subsidence, the solid particles suspended in the liquid being simply permitted to sink to the bottom, forming a *sediment* from which the clear "supernatant liquid" may be decanted by means of a siphon.

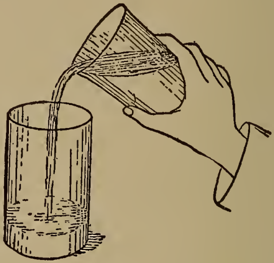
The decantation of liquids from sediments and precipitates and the transfer of liquids from one wide-open vessel to another may also be effected in the manner shown in illustrations on page 280.

Another method of clarifying a liquid is by passing it through a straining cloth or bag. This is called *colation*, and the strained liquid obtained by colation is called the *colature.*

476. Another and still more effective method of clarification wherever practicable is to pass the liquid through a paper *filter.* Paper is manufactured expressly for this purpose and called *filter paper.* It is usually obtained in circular disks of various diameters, and these disks, when folded, form the paper filters which are placed in glass funnels in order to perform the **filtration.**

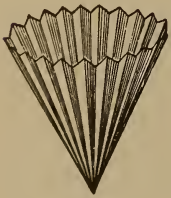


DECANTATION BY A GUIDING ROD



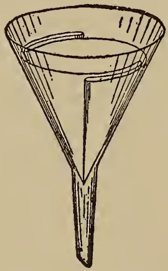
DECANTATION OVER A GREASED RIM

A *simple paper filter* is one so folded that when bent in the funnel it lies close against the sides of the funnel all around, leaving no channels through which the liquid can pass out. Such filters are useful in washing precipitates, but as the liquid can pass out of the paper filter only at the apex in the throat of the funnel, the process of filtration with simple filters is very slow. *Plaited filters* are so folded as to leave channels between the filter paper and the funnel all around, and such filters, of course, permit of rapid filtration. The pores of the filter paper are close enough or small enough to arrest the passage of all solid particles, so that the filtrate is usually perfectly clear. However, some substances in a very fine state of

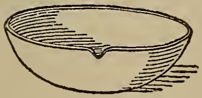


A PLAITED PAPER FILTER

division pass through the pores of filter paper so readily that they cannot be separated by this method. In such cases double or triple filters may sometimes prove effective, or the unclear liquid first may be mixed with magnesium carbonate or calcium phosphate, or some other insoluble filtering medium in the form of powder, through which the liquid must pass before it can run out of the filter. The use of a layer of wetted magnesium carbonate, calcium phosphate or other filtering medium put in the paper filter often proves sufficient to clarify liquids which cannot be rendered clear by paper alone.


A PLAIN PAPER FILTER IN POSITION

477. The process of **evaporation** as carried out for pharmaceutical purposes is comparatively simple. "Evaporating dishes," or vessels in which liquids are heated to evaporate them, are shallow, in order that the liquid contained in them may present a large surface exposed to the air. The rate of evaporation is further facilitated or increased by stirring, which causes the vapor formed in the body of the liquid to be more readily disentangled so that it can escape. Rapid evaporation is called *vaporization.* The term "spontaneous evaporation" means the slow evaporation of liquids which takes place at ordinary temperatures, or, in other words, without the application of artificial heat.


A PORCELAIN EVAPORATING DISH

478. **Distillation** is the vaporization of liquids in an apparatus so constructed that the vapor is again condensed to a liquid form and the distilled liquid, called the *distillate,* collected.

479. **Pharmaceutical stills** are usually made of copper or tinned iron, and they are also usually provided with water

baths or double bottoms so that they can be used with water-bath heat.

Water stills for making distilled water are not provided with water baths, because the heat applied to them must be sufficient to produce rapid distillation of the water. But when alcohol and other more volatile liquids are to be distilled, water-bath heat is not only sufficient but also much safer, if the liquid contains in solution substances liable to be injured by high temperatures.

Stills of the most simple construction are the best, because they can be most readily cleaned and kept in order. Manufacturers of pharmaceutical apparatus have various kinds to offer, and students as well as pharmacists are freely supplied with illustrated descriptive catalogues of such apparatus, from which they may learn about the various forms of construction.

480. Condensers used in connection with stills are also of various kinds.

The usual condensing worm, or *worm-condenser*, consists of a spirally bent block-tin tube or glass tube, placed in a vessel of water so that it may be surrounded by cold water, called the condensing water, which is intended to absorb the latent heat given up by the vapor as it reverts to the liquid form.

Liebig's condenser consists of two tubes, one without the other. The inner tube is the one through which the vapor is conveyed, while the outer tube holds the condensing water. The outer tube is, of course, open at both ends, so that the condensing water may pass through it. The condenser is placed in a slanting position and the condensing water is admitted at the lower end and runs out at the upper end.

Mitscherlich's condenser consists of three tubes. The outer tube is a large tank containing the condensing water. In this is placed a double cylinder, composed of two tubes soldered together at the ends. An opening into the space between the two tubes is made both at the top and at the bottom. The space between the tubes is the condensing space, and the condensed liquid runs out at the bottom of the apparatus, through a tube leading from the lower opening of the double cylinder through the wall of the tank. The student will see that the vapor to be condensed, being contained in the space between the two tubes constituting the double cylinder immersed in the tank, must form a thin sheet surrounded by water on both sides, for the condensing water passes all around the outer one of the two tubes forming the double cylinder and fills the inner tube completely. This is the most effective condenser that can possibly be constructed.

The *dome-shaped condenser* has a funnel-shaped still-head, or top of the still. This funnel-shaped top constitutes the bottom of a water vessel. In other words, the inverted funnel is surrounded along the lower edge by a wall so that the water can be kept on top of the funnel. The liquid heated in the still below forms vapor, which rises to the dome-shaped top and condenses against the sides of the dome or inverted funnel, and then runs down the sides to a gutter running along the inner and lower edge of the funnel. This gutter is lower at one point than elsewhere, so that the liquid runs out at that point through a tube. This dome-shaped condenser, in combination with the body that belongs to it, is one of the most useful pharmaceutical stills.

Condensers made of glass are also in various forms, and are used in connection with flasks and retorts employed in distilling comparatively small quantities of liquids.

481. Crystallization is the formation of regular geometric solids resulting from the arrangement of the molecules in accordance with inherent natural laws. Solid substances assume the crystalline form most readily when passing from a liquid form in the state of solution, or from a state of vapor, back to the solid condition; but crystallized and crystalline substances are also obtained by precipitation and in other ways.

The most common method of making crystals is to dissolve the crystallizable substance in a suitable solvent, after which the solvent is separated from the solution by evaporation. As soon as the solution becomes supersaturated, the dissolved substance separates in the form of crystals.

A saturated solution may also be made at a high temperature, and then cooled to a lower temperature, at which the amount of solvent present is no longer sufficient to hold the substance in solution. Large and well-defined crystals are most readily obtained by slow concentration of solutions, for crystals grow by deposition of more of the solid matter on the surface of the smaller crystals, or nuclei, first formed.

Special vessels for making crystals from solutions are called *crystallizers*. As the crystals are formed from solutions, on account of the deficiency of solvent, it follows that the liquid remaining after the crystallization must always be a saturated solution. This saturated solution in which crystals are being formed is called the "mother-liquor." When crystals are formed very rapidly and when the liquid in which the crystals are being formed is agitated in any way, the crystals are necessarily small and not well-developed. The formation of small crystals obtained by rapid evaporation accompanied by stirring or by rapidly cooling a hot saturated solution is called *granulation*.

Pharmacists are sometimes required by physicians' prescriptions to make saturated solutions of medicinal substances. When such solutions are dispensed, it happens that if the liquid is placed in a cold room, some of the dissolved matter separates in crystalline form; to prevent this, directions should be given to keep this preparation in a warm place.

Crystals obtained by sublimation are usually quite small, especially if the vaporized substance is condensed at a temperature considerably below that at which the vapor was formed.

A cake, or large crystals, may be obtained when the vapor is slowly condensed at a temperature but little below the heat required for the sublimation.

Crystals can also be obtained by fusing crystallizable solids and permitting the fused substance to cool gradually.

482. Precipitation is the formation of insoluble solids in liquids. It takes place in a liquid previously free from undissolved matters, and consists in the formation of solid particles insoluble in that liquid. It is caused by a change in the relation of the solvent to the matter held in solution. It may, therefore, result from a change in the solvent or by a change in the substances dissolved in the liquid.

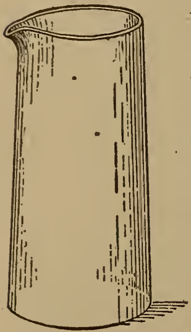
Physical precipitation results when a non-solvent is added to the solution, as, for instance, when water is added to an alcoholic solution of a resin. The resin precipitates because it is insoluble in a mixture of alcohol and water. Alcohol precipitates mucilage from a water-solution for a similar reason, mucilage being insoluble in alcohol. Many metallic salts which are soluble in water are insoluble in alcohol, and for this reason strong water-solutions of such salts cannot be mixed with alcohol without causing the separation of the salts.

Chemical precipitation results from the formation of new substances insoluble in the liquid. It is, in other words, the result of chemical reaction. When physical precipitation takes place, the molecules at the end of the process are the same as at the beginning, but in chemical precipitation the molecules present at the beginning give place to entirely new molecules. In most cases the reaction which takes place is one of double decomposition.

When precipitates are intentionally made, the product sought may be either the insoluble substance itself or the soluble substance remaining in solution in the liquid.

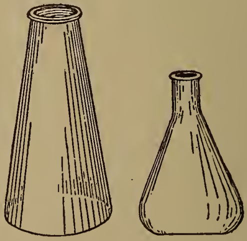
The "supernatant liquid" standing over the precipitate is called the *mother-liquor*.

When the principal product consists of the precipitate, the latter must be **washed** with pure water until free from mother-liquor, when it is collected and dried. Heavy precipitates which readily subside in the liquid are easily washed, but light and bulky precipitates which remain suspended in the liquid longer are sometimes difficult to handle. In cases of double decomposition, coarser and heavier precipitates may often be obtained by using strong, hot solutions of the factors of the reaction, while more finely divided and bulky precipitates are formed when the solutions used are cold and diluted.


A PRECIPITATION JAR

Precipitates unintentionally formed in certain pharmaceutical preparations are often troublesome, and they always indicate that a change has taken place which may lessen the value of the preparation.

The process of precipitation employed for the production of chemical compounds is, of course, intentional, and can generally be regulated so as to give entirely satisfactory results.


PRECIPITATION FLASKS, CALLED ERLENMEIER FLASKS

Test Questions

1. Describe a Bunsen burner.

2. What is the object of the sand bath?

3. For what purposes is the water bath used?

4. What other means are employed to prevent the temperature from rising too high in pharmaceutical operations requiring high heat?

5. What is exsiccated alum?

6. What is calcined magnesia?

7. By what means can volatile substances be separated from fixed substances in a solid condition?

8. By what means is the coarse comminution of plant drugs effected?

9. By what means can the druggist make fine powder of roots and barks?

10. What is the difference between contusion and trituration?

11. What is levigated calomel and what is the difference between it and sublimed calomel?

12. How is prepared chalk obtained in such extremely fine powder?

13. What is a No. 50 powder?

14. Are all powders that pass through a No. 80 sieve of the same degree of fineness?

15. What is meant by dusted powders?

16. Why is powdered guaiac resin almost white, although the resin in the whole piece appears almost black?

17. For what reasons can soluble salts be dissolved more quickly with the aid of the solution mortar?

18. Describe circulatory displacement.

19. What are the most common pharmaceutical menstrua?

20. What is the difference between maceration and digestion?

21. What is the most effective method of maceration?

22. What is meant by the term marc?

23. Which is the more effective method of extraction, maceration or digestion? State the cause of the difference, if any.

24. What is meant by the process of infusion? Describe it.

25. Describe decoction.

26. For what purposes is percolation employed?

27. Describe succinctly the various steps of the process of percolation.

28. Describe a percolator.

29. Why is the drug moistened before being packed in a percolator for percolation?

30. How tall can the column of packed drug be in the percolator without disadvantage?

31. What is meant by re-percolation?

32. Why is percolation more effective than maceration?

33. What results can be accomplished by percolation which cannot be accomplished by ordinary maceration?

34. Can all drugs be subjected to percolation? If not, what drugs cannot be so treated?

35. Name the several means commonly employed for rendering liquid preparations clear.

36. Make one plain filter and one plaited filter and return both with your recitation paper.

37. By what means can the passage of fine particles of powder through paper filters be prevented in certain cases?

38. For what purposes is evaporation employed in pharmaceutical processes? How is it rendered most effective?

39. What are the practical uses made of distillation in pharmacy?

40. What kind of a still is best for distilling volatile liquids?

41. What is the difference between the Liebig condenser and the Mitscherlich condenser?

42. Describe the worm-condenser.

43. Can a still be so made that a separate condenser is not necessary? If so, how?

44. By what several means can solids be made to assume a crystalline form?

45. What is meant by granulation?

46. What is the technical term used to designate the liquid from which crystals are deposited?

47. Define precipitation.

48. What are the practical uses of crystallization?

49. What are the practical uses of precipitation?

50. What is meant by the term supernatant liquid?

51. How long should a precipitate be washed before it is dried?

52. How is the washing of a precipitate effected?

53. What is the difference between physical precipitation and chemical precipitation?

54. By what means can precipitations be rendered heavy instead of light, or fine instead of coarse?

55. Draw a figure showing the construction of a Liebig condenser.

56. Make an outline drawing showing the construction of a Mitscherlich condenser.

57. What would you call the kind of chemical reaction by which precipitation is produced?

58. What are the usual means adopted to produce large crystals of water-soluble salts?

59. By what means can very small crystals of water-soluble salts be secured?

60. How would you produce crystals of insoluble volatile substances?

61. Give three examples of physical precipitation.

62. Give ten examples of chemical precipitation.

63. What is contained in the liquid in which a precipitate is produced by chemical reaction, and how can the substance contained in that liquid be recovered from it, if desired?

LESSON NINETEEN

XXVIII

The Chemical Constituents of Plant Drugs

483. The substances contained in plant drugs may be classified into groups, as follows: 1, water; 2, cellulose in its various forms, the principal of which is woody fiber; 3, starch in its many forms; 4, pectinous substances; 5, vegetable mucilage; 6, sugars; 7, albuminoids; 8, fixed oils and fats; 9, organic acids; 10, tannin; 11, bitters, called in Latin *amara;* 12, volatile oils; 13, resins; 14, glucosides; 15, alkaloids.

484. Water is contained in all plants. Some fresh plants contain over 90 per cent., others much smaller amounts.

Plant drugs must be dried in order to preserve them. The condition in which they are ordinarily employed is that called "air-dry." An air-dried drug contains no more moisture than it necessarily must contain as usually kept, exposed as it is to the ordinary atmosphere. If dried beyond that point, it absorbs moisture again; if it contains more than that amount of moisture, it is liable to be damaged by mold or fermentation.

Fresh drugs are also used for making pharmaceutical preparations, but whenever this is done, the amount of moisture contained in the undried drug must be considered in connection with the method of preparation adopted.

485. Cellulose, starch, pectin, mucilage and sugar are all so-called **carbohydrates.** By the term carbohydrate is meant an organic substance having the formula or composition $C_6H_{10}O_5$, or a multiple of that formula. Some carbohydrates differ from this formula, but only by two hydrogen atoms and one oxygen atom, added or deducted. The carbohydrates have no medicinal action of great importance, but some drugs containing starch, and others containing mucilage, are employed for the purpose of preparing demulcent or mucilaginous liquids, to serve as vehicles for more potent remedies, or to protect local mucous surfaces.

486. Cellulose, which exists in plant drugs chiefly as woody fiber, is entirely insoluble in all ordinary solvents, such as water, alcohol, glycerin, etc. Therefore, cellulose constitutes a large proportion of the undissolved residue obtained when extracts are made of plant organs.

487. The various classes of constituents of plant drugs are contained in the cells and the intercellular spaces in the tissues. These cavities are bounded by the cell walls, made of the insoluble cellulose. Hence, the cellulose offers more or less obstruction to the extraction of soluble substances contained in the drugs. This fact renders it necessary to grind or powder the plant drugs sufficiently to break down the obstruction.

488. Water has the power to pass through vegetable membranes, even when the pores in those membranes are extremely minute. This power of liquids to pass through vegetable membranes is called **osmosis.** Its passage outward is called exosmosis. The current inward is called endosmosis. We make use of this property of water in our pharmaceutical operations, as will be explained in the next paragraph.

489. Certain substances soluble in water may pass through vegetable membranes in a state of solution, and this phenomenon is called **dialysis.** Other substances soluble in water cannot pass through vegetable membranes, or do it so slowly as to be practically undialyzable. We are therefore able to separate dialyzable substances from the undialyzable substances, even in drugs so coarsely powdered that only a small proportion of the cells and intercellular cavities are broken into. Therefore, whenever the valuable constituents of a drug are best dissolved in water, it is not necessary to powder the drug finely. Even a piece of whole drug will give up a good deal of its dialyzable constituents when put in water. For instance, a piece of gentian placed in water will very quickly make all of that water bitter.

490. Alcohol passes through plant membranes so extremely slowly that we cannot take any advantage of its slight power to do so. We consider it practically unable to penetrate plant membranes. Whenever, therefore, the valuable constituents of a plant drug are such as require alcohol for their solution and extraction, it is necessary that the drug shall be powdered finely so that the alcohol may come in actual contact with the substances to be dissolved, for the alcohol will only wash off what is on the surface of the particles of powder, and will extract nothing from the interior of cellular structures.

491. Starch in its normal condition is entirely insoluble in alcohol and in water, but the starch in plant drugs is often *altered starch.* It has been changed under the influence of heat, moisture and the action of various substances contained with the starch in the drug, in such a way that it is not insoluble. Altered or partially altered starch is sometimes soluble in water to such an extent that when extracted from the drug by a very diluted alcohol, it may form a considerable deposit on the bottom of the bottle upon standing for some time; for the altered starch, although soluble in water and very diluted alcohol, reverts to its normal insoluble condition when long in contact with alcohol. Hence, when sarsaparilla or licorice root is extracted by percolation with a very diluted alcohol, the liquid extract, although perfectly clear or free from solid particles, will, in the course of a few weeks, deposit a large layer of white or nearly white starch.

Starch is altered by water having a temperature above 60° C., so that the starch granules burst and a mucilage results. From this starch-mucilage the starch cannot be recovered in its normal condition. Yet the starch held in the mucilage is not, strictly speaking, dissolved; it is simply held in suspension, distributed through the liquid uniformly. To make starch-mucilage, it is customary to employ one part of starch to one hundred parts of water; but to make a starch-paste, one part of starch is necessary with ten parts of water.

492. To illustrate how the constituents of drugs guide us in making pharmaceutical preparations, I may mention that some drugs containing a large amount of starch in addition to their more important constituents may be treated in different ways, according to whether or not we desire the product to contain the starch. The pharmacopœias contain an infusion of calumba and also a decoction of calumba. The infusion is made with hot water, but the temperature is not maintained and hence the starch is not extracted and rendered mucilaginous. But the decoction is made by boiling the drug in water, and that preparation accordingly is thick and demulcent, because it contains the starch.

Barley, rice, oats and wheat consist largely of starch, and decoctions are made of them. Whenever a decoction of starch or a starchy drug is made, it is intended that so much drug shall be used that the preparation will be sufficiently thick. Other preparations are scarcely ever made from starchy substances.

493. Pectin and pectinous substances are water-soluble. They resemble mucilage in many respects, but have the characteristic property of forming jellies. Apples, currants and other fruits form jellies because they contain pectin.

Some other fruits, like cherries, do not form jelly because they contain an insufficient amount of pectin. The formation of the jelly requires the presence of a sufficient amount of pectin, and the formation of the jelly is aided by the addition of much sugar.

Some drugs contain pectin. As an example, we may mention kino, which contains so much pectin that a tincture of kino made with diluted alcohol sometimes changes to a solid jelly in the bottle. Pectin is insoluble in alcohol, and is therefore not contained in pharmaceutical preparations made with strong alcohol.

494. Mucilage is contained in nearly all plants. It may be normal or *physiological* mucilage, formed in the natural growth and life of a plant, or it may be *pathological* mucilage, formed by the breaking down of plant tissues, caused by injury.

We see physiological mucilage in many leaves and in the inner bark of plants. We also find it covering the seed-coat of flaxseed, quince-seed and some other seeds.

Pathological mucilage occurs in masses on the trunks and branches of certain trees and shrubs, when the bark has been perforated by insects. Apple tree gum, peach tree gum, cherry tree gum and gums upon other trees of the same natural order are familiar. These solid gums are formed by the evaporation of the plant-juice exuding through the wound made in the bark of the tree by an insect.

495. There are two classes of gums—the *arabin* gums and the *bassorin* gums. The arabin gums are completely soluble in water; the bassorin gums simply absorb water and swell in it to form translucent jellies, but do not dissolve. Gum arabic is a typical example of the arabin gums. Tragacanth is a typical example of the bassorin gums. A piece of gum arabic put in water dissolves completely, forming a mucilage, but a piece of tragacanth put in a large amount of water simply swells and softens until it has taken up all the water it is capable of absorbing, and then forms a gelatinous mass, the outlines of which can be readily seen in the water, and this gelatinous mass remains distinct from the water about it. If the mixture is stirred actively, the jelly is, of course, disintegrated, but it does not dissolve, and if the mixture is thoroughly shaken in a bottle and then allowed to stand at rest, the gelatinous tragacanth separates again.

496. The word "gum" is so much misused that it perhaps ought to be discarded from technical nomenclature. Technically, gum is dry mucilage. It is either perfectly soluble in water or forms a mucilage with water, even if it is not really soluble. Hence, no substance insoluble in water, or nearly so, can be a gum. Nevertheless, many resins which are entirely insoluble in water are called gums, as, for instance, shellac, benzoin, copal, mastic, etc. Gums are entirely insoluble in alcohol. For this reason, when alcohol is added to a water-solution of any gum, the gum separates from the solution, or is precipitated. Aloes, kino and catechu are extract-like drugs soluble in diluted alcohol. They are therefore not gums, although frequently called so. There are, in fact, only two kinds of gums in the pharmacopœia, namely, acacia and tragacanth.

When a gum or dry mucilage is heated, it becomes drier and harder instead of fusing, and when the temperature is sufficiently high, the gum is charred but does not ignite so as to burn with a flame. Compare this behavior of the gums with the properties of resins.

Dried mucilage or gum undergoes no change when kept with ordinary care, but moist gum or a solution or mucilage undergoes fermentation when exposed to the air, and mucilage ferments so readily that it can be kept unaltered only a few days.

Acacia and tragacanth are employed pharmaceutically in making pill-masses and other masses cohesive, and also in making emulsions.

The pharmacopœias contain mucilages made of sassafras pith, slippery elm bark, flaxseed, quince-seed and other plant drugs containing mucilage of the arabin type.

When bassorin gum is heated twenty-four hours in water, it is rendered soluble.

The mucilage of acacia of the pharmacopœia is made by dissolving one part of whole acacia in two parts of water.

497. Sugars of various kinds are contained in many plants and plant drugs. All sugars are water-soluble. They are also soluble, though less freely, in alcohol.

A weak sugar-solution made with water undergoes fermentation when exposed to the air, forming alcohol. Hence, a small amount of sugar present in an aqueous liquid preparation invites fermentation, but when so much sugar is added to a watery solution that the solution acquires great density, it acts as a preservative, because it excludes air. Air is soluble in water, but is not soluble in a dense water-solution of other substances.

Sugar is used to a great extent to sweeten certain pharmaceutical preparations. Medicated syrups are both sweetened and preserved by sugar.

Fresh plant substances and animal substances placed in a large amount of sugar are in a measure preserved, especially plant tissues, because the sugar takes up the water, and water is essential to the changes that cause organic matter to decompose.

Sugar is also used in pharmacy and in medicine as a diluent. One class of dilutions ordered by the pharmacopœia is called triturations. These preparations are composed of one part of some active medicinal agent mixed with nine parts of milk sugar.

498. The principal sugars of interest to pharmacists are cane sugar and milk sugar. Cane sugar, or ordinary white sugar, is extensively used. Milk sugar, which is much less readily soluble, is employed as a diluent mainly for insoluble substances. Starch-sugar, or glucose, is employed in the form of a solution, called glucose syrup. Other saccharine substances used in pharmacy and medicine are honey and manna.

499. When sugar ferments, it forms alcohol, as has already been mentioned, but the process of fermentation ceases as soon as 14 per cent of alcohol is contained in the liquid. Accordingly, when wine is made from grape juice, the product cannot naturally contain more than 14 per cent of alcohol. Any wine containing a larger percentage of alcohol has been fortified by the addition of alcohol after the process of fermentation.

Alcohol acts as a preservative. For this reason, many liquid pharmaceutical preparations are made with alcohol. The principal preparations of this kind are the tinctures and the fluid extracts, but other liquid pharmaceutical preparations are also preserved by the addition of smaller quantities of alcohol. From what has already been said, it is evident that any liquid containing fermentable matter must have at least 14 per cent of alcohol in it in order to be proof against fermentation. Usually 15 per cent or more is added for this purpose.

500. **Albuminoids**, or vegetable albumins, are contained in many plants and drugs. Vegetable albumin is much like animal albumin, and the most familiar and striking type of animal albumin is the white of egg. It is a colorless, water-soluble substance, insoluble in alcohol, and coagulated by heat.

When an egg is boiled or heated to a temperature above 60° C., the white of the egg becomes a solid, white, insoluble substance, which cannot again be changed back to its original soluble condition, and we say that it is coagulated. Alcohol has a similar effect upon the white of egg.

Albumin, when exposed to the air in the presence of moisture, putrefies; that is, it undergoes decomposition, resulting in the formation of ill-smelling sulphur compounds, because all albumin contains sulphur, together with carbon, hydrogen, oxygen and nitrogen. The fact that albumin so easily undergoes decomposition renders it desirable that most pharmaceutical preparations shall not contain it. Moreover, if the albumin is present in any considerable quantity, it dilutes the preparation unnecessarily. Therefore, in making aqueous extracts of plant drugs, the watery liquid containing the soluble matters is brought to the boiling point, or at least to a temperature above 60° C., in order to coagulate the albumin, when it forms solid flocculi that can be removed by straining, after which the liquid is concentrated by evaporation to obtain the solid substances free from the water used. Preparations of plant drugs, if made with alcohol, cannot contain albumin, since it is not soluble in that liquid.

501. Fixed oils, fats and waxes are contained in seeds and various other plant parts. The student will probably be surprised to learn that fats and oils and waxes are salts; yet, such is the case. They are compounds formed by certain acids with certain bases. The principal acids forming fats are called oleic acid, palmitic acid and stearic acid. The basic function in a fat is performed by an atomic group composed of three atoms of carbon and five atoms of hydrogen, C_3H_5, called glyceryl. Our familiar glycerin is the hydroxide of glyceryl. Other basic groups may also form fats.

When a strong alkali like potassium hydroxide or sodium hydroxide is added to a fixed oil or fat, a soap is formed. The fat-acid forms a potassium salt or sodium salt, which constitutes the soap, in place of the glyceryl salt, which constituted the fixed oil or fat. If potassium hydroxide is used, *soft soap* is formed; if sodium hydroxide is used, *hard soap* is formed. Castile soap consists almost entirely of sodium oleate.

Oleate of glyceryl is called olein. Palmitate of glyceryl is palmitin, and stearate of glyceryl is stearin. Olein is perfectly liquid. Olive oil and almond oil consist very largely of olein. Palmitin is like a soft ointment and palm oil contains a good deal of it, so that palmitic acid and palmitin are named after palm oil. Stearin is hard. Solid fats are solid because they contain a considerable amount of stearin, and their hardness is in direct ratio to the percentage of stearin.

Fixed oils are called so because they are not volatile; they cannot be distilled. If heated strongly enough, they decompose. They burn with a smoky flame if the supply of oxygen is insufficient, but with a smokeless flame if arrangements are made to supply an abundance of the oxidizing agent.

Fixed oils, fats and waxes are all absolutely insoluble in water. They are all lighter than water. They are soluble to some extent in alcohol, more soluble if the alcohol is strong. They dissolve freely in ether, chloroform, liquid hydrocarbons and volatile oils. Pure fixed oils and fats are odorless and colorless, but many of these substances are more or less impure, or contain naturally other substances that impart color and odor.

Fixed oils have no action whatever upon vital organs of the body, and therefore are very harmless when taken internally. In fact, it may be said that their only use medicinally depends upon their emollient effect. They soften and penetrate the skin so that certain medicinal agents can be administered through the medium of ointments and cerates applied to the skin, or ointments and cerates are used as local dressings for protection, etc. Castor oil has a laxative effect, but that effect is not due to the fixed oil as such, but to some other substance held in solution in it. This laxative or cathartic substance contained in the castor oil abounds in the whole castor oil plant, so that the bruised leaves are far more active than castor oil.

When strong alcohol is used as a menstruum in making a pharmaceutical preparation of a plant drug, any fixed oil contained in the drug is dissolved by alcohol and may afterwards separate, at least in part, from the alcoholic solution on standing, and if the alcoholic liquid extract is evaporated until a solid mass remains, the fixed oil or fat may be readily seen to constitute a part of the residue, and if there is a large amount of fat present, it should be removed. There are several methods by which fixed oil can be removed in preparing solid extracts. One method consists in dissolving out the fixed oil with ether before using any other solvent. This can be done whenever the valuable constituent of the drug is not soluble in ether. Another method consists in using as a menstruum or solvent a liquid which, while extracting the valuable constituents, will not dissolve the fixed oil or fat. A third method consists in extracting the grease, together with the active constituents, and then separating the grease afterwards.

502. Organic acids occur in abundance in some fruits. Small amounts of numerous kinds of organic acids occur very generally in plants. There is probably not a plant growing that does not contain one or more kinds of organic acid. Among the organic acids that occur in fruits and other plant parts in considerable quantities, we may mention oxalic acid, tartaric acid, citric acid and malic acid. None of these acids has any important medicinal action, and probably not one plant drug owes its medicinal value to any organic acid, unless it be what is called a "resin-acid."

503. We have now enumerated all the classes of plant constituents without decided medicinal action. They are commonly referred to as inert constituents of the plant drugs. In making pharmaceutical preparations and particularly in making solid extracts, the aim of the pharmacist is to eliminate from his products all the inert constituents, or as great a proportion of them as possible, in order that the preparation may be as concentrated as practicable.

504. Tannin is a peculiar substance contained in almost every growing plant, and, therefore, also in almost every plant drug. When extracted from the plant and separated from other substances, tannin is a dry solid of a very light yellow color. It is soft, friable, and soluble in water, alcohol and glycerin. It is insoluble in absolute ether, but soluble in ether saturated with water; in fact, it is usually extracted from nutgall with an ether containing 10 per cent of water in solution. Tannin is astringent, and all drugs containing a sufficient amount of tannin are also astringent and used for their astringent properties, unless they also contain other and much more important constituents. An astringent drug, in order to be effective, ought to contain not less than 10 per cent of tannin. Several astringent drugs contain more than 20 per cent and nutgall contains from 50 to 60 per cent.

Tannin is named so because it has the property of tanning raw hide, converting it into leather. But there are two classes of tannins, and only the tannins of one of those classes will make leather. *Physiological tannins* are the tannins naturally contained in live plants. It is found chiefly in barks. Physiological tannin has the property of forming leather. *Pathological tannin* is the tannin formed in large quantities in galls or excrescences on the barks and leaves of trees when stung by insects. The nutgall is formed in such a way. When the insect stings through the bark, there is a flow of sap to the spot, and a gall is gradually formed surrounding the egg laid by the insect.

Tannin forms insoluble compounds with a large number of other substances. It therefore makes precipitates in solutions containing gelatin, mucilage, alkaloidal salts, metallic salts, etc. With iron compounds dissolved in water, liquids containing tannin form ink. Hence, the tincture of chloride of iron which is so much used by physicians always forms an inky mixture with the tinctures of nearly all plant drugs, because the tinctures of plant drugs contain tannin.

Tannin in water-solution rapidly undergoes decomposition, but alcoholic liquid preparations containing tannin can be kept a reasonable length of time without serious deterioration. Fluid extracts and tinctures made out of astringent drugs are all made with diluted alcohol containing a certain amount of glycerin, because the tannin compounds insoluble in water and in alcohol are many of them soluble in glycerin, so that the addition of glycerin to the preparation prevents precipitation.

505. Amara, or bitters, are a miscellaneous class of plant constituents of no great importance. They are sometimes called neutral principles, simply because they are neither acids nor bases. It is impossible to describe them, because they have few properties in common. Many of them are water-soluble, but scarcely soluble in alcohol. Others are freely alcohol-soluble and scarcely soluble in water. Most of them dissolve sufficiently well in a mixture of alcohol and water, or, in other words, in diluted alcohol. Hence, both tinctures and fluid extracts of bitter drugs or simple stomachic tonics are made with diluted alcohol, and some of the solid extracts of such drugs are made with diluted alcohol, while others are made with water.

The dose of an amarum may be said to be altogether indefinite. A quantity sufficient to produce a bitter impression to the taste is usually a sufficient dose, and a much larger dose will probably produce no greater effect. Hence, a very large dose of a simple bitter stomachic tonic cannot do any harm, beyond the inconvenience of the bitter taste.

506. **Volatile oils** are a very miscellaneous class of substances, too. The name volatile oil is quite misleading. The word volatile usually suggests that volatile oils are exceptionally volatile, whereas they are much less volatile than water, for water boils at 100° C., whereas the average boiling point of volatile oils is above 120° C. The term "volatile oil" suggests that these substances resemble fixed oils, whereas they do not resemble fixed oils any more than they resemble a great many other liquids. Volatile oils are in fact radically different from fixed oils, not only in that the volatile oil is distillable while the fixed oil cannot be distilled, but also in that volatile oils are always odorous, whereas fixed oils, when pure, are odorless. The volatile oils have a pungent or hot taste, whereas fixed oils have a very bland taste, if any. Volatile oils burn fiercely with a smoky flame, even in an abundant supply of air or oxygen. Volatile oils dissolve to a slight extent in water, while fixed oils are insoluble in water. The volatile oils dissolve very freely in alcohol, whereas fixed oils dissolve only to a limited extent in that solvent. Volatile oils do not contain any fat-acids nor any glyceryl compounds, whereas fixed oils are composed of nothing else.

The most common constituents of volatile oils are hydrocarbons of the formula C_5H_8 or a multiple of C_5H_8, such as $C_{10}H_{16}$ or $C_{15}H_{24}$ or $C_{20}H_{32}$. The hydrocarbons having the formula $C_{10}H_{16}$ are called terpenes; those of the composition C_5H_8 are called semi-terpenes; those having the formula $C_{15}H_{24}$ are called sesqui-terpenes, and those of the composition $C_{20}H_{32}$ are called diterpenes or double terpenes. These hydrocarbons are liquids. They are oxidized on exposure to air and form oxidation products which are also usually contained in greater or less proportion in all volatile oils. The oxidation products are some of them camphors, while others are resins.

Volatile oils are nearly all liquids at common temperatures, but some of them solidify at but a few degrees below the ordinary room temperature. When a volatile oil is placed in a cold room, a solid substance may crystallize out from it. In other words, some volatile oils are separable into a liquid portion called the elæopten and a solid portion called the stearopten. The elæopten contains most, if not all, of the hydrocarbons, while the stearopten contains most, if not all, of the oxidation products, or compounds containing oxygen.

Scarcely a single plant or flower having a distinctive odor is free from volatile oil, to which that odor is due. The odorous substance in sweet clover is not a volatile oil, but contains the odorous crystallizable substance called coumarin. But odorous substances of plant origin that are not volatile oils are rare.

The odors of volatile oils are so powerful that an extremely minute amount will impart a characteristic odor to the plant, flower or drug. Aloes is a drug having an intensely strong, disagreeable odor, and that odor is due to volatile oil. The amount of volatile oil in aloes is so small that it takes three hundred pounds of the drug to make a single ounce of the volatile oil.

Some flowers having a powerful and agreeable fragrance contain so little volatile oil that it is extremely difficult to extract it, and perfumes of such flowers are made not from the volatile oils, but from the flowers themselves.

It has been found that volatile oils containing oxygen compounds have more pronounced odors than volatile oils that do not contain them, or that contain smaller amounts of the oxygen compounds. It is said that certain volatile oils consisting almost entirely of hydrocarbons without any oxygen have no odor at all, although they are generally believed to be very fragrant. It is thought, for instance, that oil of lemon has no odor, but that when the vapor of oil of lemon mixes with air before it reaches the nostrils, the odor perceived is created by the oxidation resulting from the admixture of air. Oil of cloves has a powerful odor because it contains a considerable quantity of oxygen compounds. Certain other volatile oils contain sulphur compounds, and also cyanogen compounds, and they have very strong, disagreeable odors.

All volatile oils are stimulants. All of them are diuretics. Some of them are anthelmintics. Many oils are so irritant as to be rubefacient when applied externally. Other medicinal uses of volatile oils are comparatively unimportant.

Water-solutions of volatile oils contain usually much less than one-tenth of 1 per cent. of volatile oil, although they are saturated, but this small amount of volatile oil renders the water both fragrant and pungent.

All of our spices contain volatile oils and most of them contain, in addition, resins formed by the oxidation of the volatile oils.

Since alcohol is the most effective solvent for volatile oils, the pharmaceutical preparations made out of plant drugs containing volatile oils are generally made with a strongly alcoholic menstruum, and diluted alcohol is used only when the quantity of volatile oil in the drug is comparatively small.

Drugs containing volatile oils as their only valuable medicinal constituents are called aromatic stimulants.

If a mixture of alcohol and volatile oil is put in a graduated glass tube and water is added in large quantity, the alcohol leaves the volatile oil and enters solution in the water, so that the volume of the volatile oil is diminished by just the amount of alcohol it contained. The adulteration of volatile oils with alcohol is easily detected in this way, and even the quantity of adulterant may be accurately determined.

507. Resins are oxidation products of volatile oils, and as the volatile oils are usually mixtures of several substances, the resulting resins are also mixtures. Most of the resins are dry solids, but some of them are soft solids, or semi-solids.

All resins are insoluble in water, but perfectly soluble in alcohol. Some resins are also soluble in ether and in chloroform, and all resins are soluble in volatile oils.

Resins are in some respects like feeble acids. While not exhibiting strongly acid properties, they form water-soluble compounds with the alkalies and with the alkaline earths. Resin soaps are made from alkalies and resin instead of alkalies and fats. The resin-soaps have detergent properties like the true soaps, but they are easily decomposed in boiling water.

Resins ignite readily and burn with a smoky flame, owing to the large amount of carbon they contain which is not consumed. They melt when heated and do not decompose until ignited.

Soft resins are usually acrid, but some dry resins are also acrid to such an extent that when applied to the skin they raise blisters. The soft resins cannot be dried so as to become hard.

Pharmaceutically, the resins are used in making plasters, cerates and ointments. Industrially, the resins are used in making varnishes, sealing wax and various other products.

Irritant resins usually have a cathartic action, and most, if not all, of the plant cathartics contain either resins or resin-compounds, to which their medicinal action is due. Some resins which are hard and dry do not dissolve in the stomach, but pass beyond it and are dissolved only when they come in contact with the alkaline bile. For this reason physicians sometimes order hard, dry, inert resins added to pills in order to make them slowly active.

Tinctures and fluid extracts of resinous drugs are, of course, prepared with strong alcohol.

508. Glucosides are named after glucose, and they have received the name glucoside because, when they decompose, one of the products of the decomposition is sugar. They are very unstable as a rule, decomposing easily when heated in water in the presence of a little acid or in the presence of certain kinds of ferments.

The first glucoside to be definitely described as a typical substance of this class was amygdalin. Amygdalin is the bitter substance contained in bitter almonds, and it is decomposed when water is added to the bitter almond, the decomposition being effected through the action of the white fleshy substance of the almond, which is called emulsin or synaptase, which is a nitrogen compound acting as a ferment. As long as the bitter almond is dry, the amygdalin remains intact, but upon the addition of water, it all decomposes within twenty or thirty minutes, and then splits up into volatile oil of bitter almond, hydrocyanic acid and sugar. Amygdalin exists also in peach kernels, cherry seeds and a number of other seeds, which are therefore poisonous. They do not contain any poison, but they contain the glucoside amygdalin, which gives rise to the formation of the highly poisonous hydrocyanic acid as soon as wetted with water.

No general description of glucosides beyond what little has already been mentioned can be made, because they are so miscellaneous in character. Some of them are soluble in water, but not in alcohol, while others are soluble in alcohol, but not in water. A large number of the glucosides are either poisonous or form poisons when decomposed. In fact, two-thirds of all poisonous plant drugs contain alkaloids, and the remaining one-third contain glucosides.

Many of the glucosides contained in drugs have a decided action on the circulatory system, affecting the heart strongly.

Tinctures and fluid extracts are made of drugs containing glucosides, but solid extracts are not made of all glucosidal drugs, because of the unstable character of the glucosides.

509. Alkaloids are chemical compounds containing carbon, hydrogen and nitrogen, or carbon, hydrogen, nitrogen and oxygen, having the power of neutralizing acids to form salts and of turning certain red vegetable colors blue. They are called alkaloids because they resemble the alkalies in the properties just mentioned. They are also called vegetable bases.

When the alkaloids form salts with acids they act in the same manner as ammonia, in that the entire molecule of the alkaloid enters into combination with the entire molecule of the acid by a rearrangement of the atomic linking. When ammonia, H_3N, reacts with hydrogen chloride, HCl, the compound formed is H_4NCl, from which it will be seen that the hydrogen and the chlorine of the hydrogen chloride are separated from each other by the nitrogen of the ammonia. When ammonia reacts with nitric acid in ammonium nitrate, H_4NNO_3, it will also be seen that the nitrogen of the ammonia separates the hydrogen of the nitric acid from its NO_3. Alkaloids and acids form salts in a similar way. For this reason alkaloids have sometimes been called compound ammonias.

Alkaloids are always poisonous, and some of them are so potent that the customary dose may be less than the two-hundredth part of a grain.

Examples of alkaloids are found in quinine, morphine, strychnine, cocaine and caffeine. It is true that quinine and caffeine and some other alkaloids are not generally looked upon as being poisonous, but if a considerable quantity be taken internally of either of them, alarming effects will undoubtedly be produced. From what has been said, it will be apparent that a very large number of our most important plant drugs contain alkaloids as their principal active constituents. The English names of alkaloids are in this country given the ending *ine*, and the corresponding Latinic titles in the pharmacopœias have the ending *ina*.

There are two classes of alkaloids—the ternary alkaloids and the quaternary alkaloids. The ternary alkaloids are called so because they contain only the three elements carbon, hydrogen and nitrogen. They are volatile, so that they can be distilled or vaporized without decomposition, have a strong odor and are generally liquid. The quaternary alkaloids are called so because they contain four elements, carbon, hydrogen, nitrogen and oxygen. These are solids. Very few of them can be vaporized without decomposition, and they have no odor. The volatile alkaloids are few in number in comparison with the solid alkaloids.

The *volatile alkaloids* are soluble in water as well as in alcohol, and hence preparations of plant drugs containing volatile alkaloids may be made either with alcohol or water, or a mixture of the two. But the *alkaloids containing oxygen* usually require a strongly alcoholic menstruum, because they are rarely soluble in water.

Alkaloids seldom occur in the plants and plant drugs uncombined with acids. They are usually found in combination with peculiar organic acids which, like the alkaloids themselves, are rarely found in more than one plant genus. The salts which the alkaloids form with the organic acids referred to are generally alcohol-soluble, and to a much less extent water-soluble. But the alkaloids can be extracted from the plant drugs and separated from all other substances and then converted into salts with the ordinary acids. These salts are frequently freely water-soluble. From what has been said it will be understood that the alkaloids of plant drugs may be extracted with water to which has been added some acid forming a water-soluble salt with the particular alkaloid to be dissolved, or the drug may be mixed with an alkali which liberates the alkaloid from its natural salt, after which alcohol, ether, chloroform, petroleum spirit or some other suitable solvent for the free alkaloid may be used. But these are chemical methods of extracting alkaloids. The pharmaceutical method of extracting them consists in using an alcoholic menstruum which will extract the natural alkaloidal compound without chemical alteration.

510. The active principles of plant drugs belong to the classes described as tannins, bitters, volatile oils, resins, glucosides and alkaloids, and any plant drug containing no substance belonging to either of those classes is not likely to possess any medicinal value. The activity of any particular drug may be due to only one substance or it may be due to two or three or several substances.

511. The chemical constituents found in plant drugs are generally formed in the plant during its life, but several important valuable constituents of drugs are formed after the death of the plant, by chemical changes in the natural constituents. Opium, for instance, is a drug formed by drying the fluid that exudes from poppy capsules when full grown and just before they ripen, through incisions made in the capsules. No morphine or only traces of it or of any other alkaloids have been found in the poppy capsules, but the opium, when finished by drying the poppy juice in the sun, may contain over 20 per cent. of total alkaloids. Another illustration is furnished by the common drug called frangula, which, when just gathered, is a violent griping cathartic and even emetic, but which after having been kept for a year or two becomes a mild laxative, the cathartic substances being decomposed and giving place to decomposition products having a milder action. Some drugs are used in the fresh condition before the natural constituents undergo alteration, while other drugs are not used until after they have become modified by the chemical changes referred to. It is further to be understood that these chemical changes in the constituents of drugs continue through a long time, so that probably all plant drugs deteriorate when kept too long, and many of the plant drugs contain such unstable active principles that they cannot be preserved unaltered even for a few months. A fresh supply of an unstable plant drug can, of course, be obtained only once a year, and such drugs should accordingly be procured by the pharmacist at the right season, that is, immediately after the new crop comes into the market. Such drugs should be preserved with the greatest care. Very few drugs are comparatively permanent, so that they remain in good condition as long as two years.

Test Questions

1. What is a carbohydrate?
2. Which of the class of carbohydrates are water-soluble?
3. What is exosmosis?
4. What advantage can be taken of dialyzation in the extraction of the constituents of drugs?
5. Which of the several classes of chemical constituents of drugs are dialyzable?
6. Name a solvent for starch in its normal condition.
7. What is meant in pharmacy by the expression "altered starch"?
8. What kinds of drugs are employed for making demulcent decoctions and what drugs for mucilaginous infusions?

9. Name some substances containing normal starch and some other substances containing altered starch.

10. What kind of a menstruum can be used on plant drugs which will not extract carbohydrates?

11. What is the cause of gelatinization in certain liquid pharmaceutical preparations?

12. What is a gum?

13. Name all of the gums you can think of.

14. What is the difference between arabin and bassorin?

15. Can you name some gums soluble in alcohol?

16. If you have a liquid extract containing mucilage in solution, how can you remove that mucilage from the liquid?

17. What are the pharmaceutical uses of the official gums?

18. In what parts of plants is physiological mucilage usually found?

19. In view of the fact that mucilage ferments so easily, how can drugs containing mucilage be preserved?

20. In what manner does sugar act as a preservative of water-solutions of fermentable substances?

21. What are the pharmaceutical uses of sugar?

22. What proportion of alcohol must be contained in a solution of fermentable matter in order to prevent fermentation?

23. Mention some plant constituents contained in aqueous liquid extracts which are not contained in alcoholic liquid extracts.

24. Name some plant constituents contained in alcoholic liquid extracts which are not contained in aqueous extracts.

25. Name some plant constituents which are soluble both in water and in alcohol.

26. At what temperature does starch become pasty in water?

27. At what temperature does albumin coagulate?

28. Which kind of a liquid extract contains the most

albumin, a liquid extract made with cold water or with boiling water or with alcohol?

29. Which preparation contains the most starch, one made with cold water, boiling water or alcohol?

30. Can albumin in solution be separated from a liquid extract? If so, how?

31. What is glyceryl hydroxide commonly called?

32. Can you mention any other common glyceryl compounds?

33. What is hard soap and what is soft soap?

34. Name the most common fat-acids.

35. What is the chemical composition of olive oil, lard, tallow and cottonseed oil?

36. What is stearin?

37. What are the principal physical differences between olein, palmitin and stearin?

38. What liquid pharmaceutical preparations are most liable to contain fixed oils, those made with water, with diluted alcohol, with strong alcohol or with ether?

39. What are the pharmaceutical and medicinal uses of fixed oils?

40. What parts of plants contain fixed oil more frequently than other plant parts?

41. Can a solid extract be made from a plant drug containing fixed oil without obtaining a product mixed with grease? If so, how?

42. What are the best solvents for fixed oils?

43. What is tannin?

44. What are its most characteristic properties?

45. Name three different solvents for tannin.

46. What is the most notable difference between physiological tannin and pathological tannin?

47. What kinds of fluid extracts and tinctures are most liable to contain precipitates formed on standing?

48. What is meant by an *amarum?*

49. What menstruum is commonly employed in making tinctures of drugs containing amara?

50. What menstruum is commonly employed in making fluid extracts of drugs containing volatile oils?

51. What menstruum is commonly employed in making fluid extracts of drugs containing tannin?

52. Enumerate the differences you can think of between volatile oils and fixed oils.

53. How would you make a solid extract of a drug containing volatile oil as its only active constituent?

54. What are the most common constituents of volatile oils?

55. Do you think you can discover tannin in a plant drug without a chemical examination of it?

56. Do you think you can discover volatile oil in a plant drug without separating the volatile oil or detecting it by chemical means?

57. What is the difference between a carbohydrate and a hydrocarbon?

58. What volatile oils have the strongest odors?

59. What is the general physiological and therapeutic action of volatile oils?

60. What volatile oils produce a grease spot on clean white unsized paper?

61. What are the best solvents for volatile oils?

62. What are volatile oils liable to contain besides hydrocarbons and camphors?

63. What are the constituents contained in aromatic astringents; in astringent bitters; in aromatic bitters?

64. By what means can you detect alcohol in a volatile oil adulterated with that liquid?

65. What are the solutions of volatile oils in water called?

66. Why are resins usually found together with volatile oils in plants?

67. What are the differences between gums and resins?

68. What are the pharmaceutical uses of inert resins?

69. What are the medicinal effects most common in resins and resin compounds? Why does potash lye dissolve resin?

70. Bitter almond is the source of expressed oil of almond, as well as of volatile oil of bitter almond and amygdalin. The amygdalin is soluble both in hot alcohol and in water. What is the best way to extract the amygdalin from the bitter almond? What is amygdalin?

71. How can you separate the fixed oil of bitter almond without having that fixed oil contaminated with amygdalin?

72. How can you make volatile oil of bitter almond and subsequently also amygdalin out of the same lot of bitter almonds?

73. What are usually the active constituents of poisonous plant drugs? What makes peach kernels poisonous?

74. What differences can you mention in the chemical properties of glucosides and alkaloids?

75. Give the origin of the words glucoside and alkaloid.

76. In what respects do the alkaloids resemble ammonia?

77. What is the difference between a ternary alkaloid and a quaternary alkaloid?

78. Are any alkaloids in the free state water-soluble?

79. What class of alkaloids are alcohol-soluble?

80. What are the best solvents for making liquid extracts of alkaloidal drugs?

81. What are the most common chemical processes of extraction of alkaloids from drugs?

82. In what form do the alkaloids usually occur in plant drugs? How long should plant drugs be kept before they are used?

LESSON TWENTY

XXIX

Pharmaceutical Preparations

512. The materials out of which pharmaceutical preparations are made may be definite chemical compounds or simple elements, or they may be mixtures of two or more substances.

Chemical preparations are those made by processes resulting in the formation of new substances, or, in other words, processes involving chemical reactions.

Galenical preparations are preparations made by processes not involving any chemical changes. The Galenical preparations may be simply mechanical mixtures of the ingredients, or they may be solutions or extracts. Organic drugs are of such a complex character that their pharmacy is much less simple than that of definite chemical compounds. The Galenical preparations of plant drugs generally take the form of liquid or solid extracts, the object being to present the medicinal constituents of the drug in the most concentrated and convenient form.

513. The classification of pharmaceutical preparations may be based upon various considerations. Probably the most practical and convenient classification is the following:

1. Dry and semi-solid preparations for internal use, made by processes not involving extraction. These preparations include species, powders, triturations, confections and electuaries, masses, troches and pills.

2. Dry and semi-solid preparations for external use, including poultices, ointments, cerates, plasters and suppositories.
3. Liquid preparations for internal use, not made by processes of extraction, including solutions, waters, mucilages, syrups, glycerites, mixtures, emulsions and spirits.
4. Liquid preparations for external use, including lotions, gargles, injections, liniments, etc.
5. Liquid extracts, including infusions, decoctions, vinegars, tinctures, wines and fluid extracts.
6. Solid and semi-solid preparations made by processes of extraction, including solid extracts, oleoresins and precipitated resins.

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Solid Preparations Not Made by Extraction

514. Species are teas made of mixed plant drugs, very coarsely cut or crushed. Such preparations are not common in America. Breast teas, laxative teas, bitters and stimulant teas are among the most common.

515. Powders. Compound powders are made by triturating together two or more substances, so as to obtain a product in the pulverulent form. If the ingredients can be each in fine powder before being mixed, the process is very simple. But when one of the substances is a liquid or moist solid, it must be triturated with one or another of the dry ingredients in order to reduce it to a state of powder. When there is not a sufficient quantity of dry substance, it may be necessary after making the mixture to subject it to a drying process before finishing the pulverization. If the ingredients are nearly equal proportions, they may be mixed all at once, but if one ingredient is to be used in very small quantity and the other is several times as bulky, the ingredients used in large proportion should be divided and an intimate mixture made after adding each consecutive portion to the other ingredient before the next portion is added. When one or more of the ingredients are of such character as to adhere to the mortar and pestle when triturated under pressure, the trituration should be effected with as little force as possible. When the ingredients are such as have a tendency to act upon each other chemically, they should also be mixed lightly or without pressure, in order to avoid the chemical reaction as far as practicable. When potent substances are to be diluted in the form of powder, the diluents employed may be cane sugar, milk sugar, starch, acacia, tragacanth, marshmallow root, or other inert powders.

516. **Triturations** are powders made out of potent remedies with nine times their weight of milk sugar.

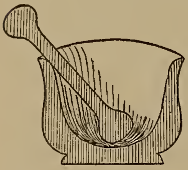
517. **Confections** and **electuaries** are soft solid mixtures, made by mixing powders or solid extracts, or both, with syrup or honey. These preparations are intended to be sufficiently sweetened so that they may be taken without difficulty. Very few such preparations are now used.

518. **Masses.** Confections and electuaries are, of course, masses, but the title *massa* used in the pharmacopœia means a mass of such consistency that pills can be made out of it. The manner in which ingredients are massed for making pills and troches will be described later.

519. **Troches** or lozenges or tablets are hard, dry pieces of medicinal substances weighing from two or three grains up to thirty grains. They contain either a large amount of sugar or in its place a sufficient quantity of extract of licorice to make them less disagreeable to the taste than the unsweetened medicinal agents usually are. In the preparation of troches, etc., the ingredients are, if possible, first reduced to a uniform mixture in the state of powder. A moist excipient is then added to mass the powder together, or to make it cohere so as to form a well-mixed mass which can be rolled

out into a cake of uniform thickness, out of which the tablets or troches are cut by means of a lozenge-cutter. The troches are most commonly circular disks, but they may be oblong, octagonal and of various other forms. They are usually dried so as to become hard, unless they contain extract of licorice, in which case they are not always entirely dry. Troches are often flavored with volatile oils or with aromatic waters.

520. **Pills** are small masses of mixed medicinal agents, usually of spherical form or oval, weighing from one grain to five grains, or from sixty to three hundred milligrams.



SECTIONAL VIEW OF A PILL MORTAR

In making pills, the ingredients are mixed uniformly in the same manner as medicinal substances are mixed in making compound powders, confections, masses and troches, and the massing is accomplished in such a way that the pills when formed out of the mass may be sufficiently firm to retain their shape.

The pills when finished should be either entirely soluble in the fluids of the stomach or they should contain enough soluble matter to become disintegrated when wetted. Pills which are very hard and almost insoluble are useless, and the pharmacist must choose his excipients for pill-masses in such a way as to avoid the formation of insoluble pills.

521. The **excipients** employed in making pill-masses include both solids and liquids. If the other ingredients make a soft mass, it is, of course, necessary to add a *dry excipient* to give the mass the right consistence. While the mass should be somewhat plastic in order that it may be comparatively easy to form it into perfectly round pills, it is also necessary that the mass shall be sufficiently cohesive

and firm so that the pills may not flatten after they have been finished.

To stiffen a soft mass, the following dry excipients will be found most useful:

Powdered slippery elm bark is useful, because it is highly absorbent and fibrous and contains very little soluble matter.

Powdered licorice root and *powdered althæa* are also fibrous and absorbent, but less useful than the slippery elm bark, because they contain considerable amounts of soluble constituents.

Starch may also be used to stiffen pill-masses, but it is not absorbent and hence somewhat larger quantities must be employed of starch than are necessary of such a substance as slippery elm bark.

Magnesium carbonate is an entirely insoluble but absorbent substance that can be used to advantage in soft pill-masses containing volatile oils or oleoresins.

None of the dry substances so far mentioned are adhesive. The *adhesive dry excipients* most suitable for making pill-masses are powdered *tragacanth* and powdered *extract of licorice*, but tragacanth is so far superior to all other dry substances rendered adhesive when moistened that it is almost invariably used. Very small amounts of tragacanth are usually sufficient to render a pill-mass cohesive, when the mass contains enough moisture to develop the adhesive quality of the tragacanth. Tragacanth acts slowly, so that the operator should add it very gradually and take time to observe the results before adding any more. A pill-mass that is but very slightly too soft can generally be rendered firm by the addition of a very small amount of tragacanth. When *acacia* enters into pill-masses and the quantity used is considerable, the result is usually a mass that becomes very hard on drying.

Milk sugar is sometimes introduced into pill-masses to give bulk to them or to dilute some very potent substance, but it is not employed to stiffen soft masses.

The *wet or moist excipients* most common are water, alcohol, glycerin, glucose, syrup and mucilage of tragacanth. When the dry ingredients of a pill-mass contain any substance which becomes adhesive as soon as moistened with its appropriate solvent, then the addition of that solvent is generally sufficient to mass the whole mixture. Extractive matter when moistened is always adhesive. Hence, when the extractive is water-soluble, the addition of a little *water* will suffice to form the mass, or if the extract is alcohol-soluble, we may add *alcohol* or *diluted alcohol*, instead of water, to develop sufficient adhesiveness to make the mass cohesive.

Glycerin is added in pill-masses solely to prevent them from becoming too dry and hard. When too small an amount of glycerin is added and the mass contains water, the water and glycerin evaporate together, and the pill may after all become hard. But a mixture of equal parts of water and glycerin or of two parts of water and one part of glycerin may be advantageously employed, because when the water evaporates enough glycerin will remain to keep the pills from becoming too hard.

Glucose-syrup is so sticky that it is employed in cases where the ingredients of the mass are of such a nature as to form crumbly masses with less adhesive excipients.

The student will understand that moist ingredients require dry excipients, and dry ingredients require moist excipients, and that adhesive materials require only non-adhesive excipients, while non-adhesive materials require adhesive excipients.

522. Pills should never be less than one grain in *weight.* If the materials ordered in a prescription are insufficient to give each pill the requisite weight, inert excipients are added

to increase the mass so that each pill will weigh at least one grain. Pills of the size of from two to three grains are more readily swallowed than either smaller or larger ones.

It occasionally happens that a prescriber inadvertently orders pills too large to be conveniently taken. In such cases, the pharmacist should consult the prescriber and obtain permission to divide the mass into twice as many pills or even three times as many, in order to obviate the difficulty.

Pills weighing only one grain are generally called *granules.*

Pills coated with sugar or various kinds of gelatin coating are now manufactured on a large scale, and all the pills commonly prescribed can be had already prepared and coated. The coatings should either be completely soluble in tepid water or should at least become disintegrated, and the pill-mass itself should also be either soluble or should fall apart when put in tepid water.

523. Cataplasms, or poultices, are not often prepared by the pharmacist. The most common cataplasms are flaxseed poultices and mustard plasters.

Flaxseed poultice is made by first mixing the ground flaxseed with a little cold water, mixing well so as to break up all lumps, then adding the requisite amount of boiling water and heating the mixture until the starch in the flaxseed becomes sufficiently pasty so that the resulting cataplasm has the right consistence.

Mustard plaster is best made by mixing the ground mustard by trituration with tepid water. The water causes the formation of the irritant volatile oil which renders the mustard plaster effective as a rubefacient. If it is desired to make the mustard plaster milder in its action, the ground mustard is diluted with white flour, corn meal, or ground flaxseed before being made into a cataplasm, or a cataplasm of pure ground mustard and tepid water is mixed with a separately prepared poultice of flaxseed or corn meal. In making a mustard plaster, boiling water should never be used, because it coagulates one of the constituents of the mustard which causes the formation of the volatile oil, and moreover causes the volatile oil to vaporize and be lost. Neither should alcohol be used in making mustard plaster, because that, too, coagulates the ferment which causes the formation of the valuable volatile oil.

524. Ointments. Ointments are soft solids intended to be applied externally for the purpose of causing the absorption of certain medicinal agents through the skin, or to soften the skin or protect it, or as a soothing and healing application to denuded surfaces, etc. They are usually made of fatty substances, but they may also be prepared out of soft soap or of glycerite of starch or soft paraffins.

The most common ointment bases are lard, the so-called simple ointment made out of lard and wax, lanolin or sheep's wool fat, petrolatum and glycerite of starch.

Ointments may be divided into two classes, according to their medicinal application; namely, perfectly *bland ointments*, containing no active medicinal agent, and *medicated ointments*.

The *simple ointment* of the pharmacopœia is a mixture of four parts of lard and one part of yellow wax, melted together, and the melted mixture stirred until it congeals.

When fats of low melting point are mixed with fats of high melting point, such as wax and spermaceti, the whole mixture must be stirred during the process of cooling to prevent the separation of the fat of higher fusing point. The stirring not only prevents that separation, but it also makes the ointment bulkier and softer and lighter in color. At the same time the process of stirring undoubtedly introduces air into the finished product, and the presence of air detracts from the keeping qualities of the preparation.

Ointments made by fusion sometimes contain resins added to the fats, and liquid fixed oils are also employed in making certain ointments.

The fusing point of a finished ointment is intended to be very nearly that of the temperature of the body.

525. **Medicated ointments** are usually mixtures made out of the bland ointments with the finely powdered or semi-fluid medicinal agents. *Solid extracts* to be thoroughly incorporated in ointments must first be rendered semi-fluid by trituration with water or diluted alcohol, after which they can be easily mixed with the fatty base or any other soft ointment base.

Solid substances that cannot be reduced to a semi-fluid condition must be in the form of impalpable powder, which is first mixed with a small portion of the ointment base, the remainder of which is afterwards added gradually, and trituration is continued until the mixture is perfectly uniform.

When an ointment is well made, a small amount of it spread very thinly on a piece of white paper with the spatula will show no lack of uniformity, no lumps or streaks. A good ointment feels perfectly smooth when rubbed between the fingers.

One of the essentials in the preparation of good ointments is the employment of perfect materials.

Lard and other fats are so liable to become rancid and irritating that only perfectly fresh lard or fat can be used. Rancid lard applied is much more likely to cause inflammation than to be soothing in its action.

When *soft soap* is used in ointments, no fat is used with it, but sometimes it is necessary to add a little hot water to give the ointment the proper soft consistence.

Glycerite of starch has the advantage of being water-soluble, so that an ointment made with that base is easily washed off with tepid water and, moreover, glycerite of starch does not become rancid or change in any other unfavorable manner.

Petrolatum keeps a long time without alteration, but it is far less suitable for the preparation of ointments than animal fats, because petrolatum does not soften and penetrate the skin, but is suitable only for local dressings.

When watery liquids are to be introduced into ointments, *lanolin* is very useful as an addition to the preparation, because very large quantities of water can be mixed with lanolin and the mixture is sufficiently firm; in fact, when water is added to lanolin, the mixture becomes more and more firm until as much water has been added as the lanolin can hold. Glycerin, also, when added to lanolin makes it stiffer instead of softer.

526. Cerates are altogether like the ointments, with the exception that they have a higher melting point and are somewhat firmer. The simple cerate of the pharmacopœia is a mixture of seven parts of lard and three parts of white wax, mixed together by fusion. Other cerates contain, in addition, resin. Cerates are used mainly as dressings. They may be medicated in the same manner as ointments.

527. Plasters are still firmer external preparations, intended to be applied to circumscribed areas of the body. Plasters are made of metallic oleates, resins, gum-resins and wax.

The most common simple plaster is called *lead plaster*, which consists of a mixture of oleate of lead and stearate of lead. This is made by boiling lead oxide and olive oil together, adding a small quantity of water. The water changes the lead oxide to lead hydroxide, which reacts with the oleate and stearate of glyceryl so that lead oleate and lead stearate are formed, together with glyceryl hydroxide or glycerin The glycerin is then washed out of the finished plaster mass, and the latter is rolled into sticks ready for use in the preparation of medicated and adhesive plasters.

Lead plaster is too hard and non-adhesive to be used alone. To render it adhesive, resins are added, the lead plaster and resin being melted together and the mixture stirred until cold. Wax is also added to adhesive plaster.

When *gum-resins* are introduced into plasters, the best plan is to emulsionize the gum-resin by beating it up with diluted acetic acid until converted into a thick, uniform liquid, free from lumps. This liquid, strained, is then added to the melted plaster and the whole mixture kept warm and liquid, stirring it constantly until the diluted acetic acid has evaporated, so that the plaster becomes sufficiently firm on cooling.

When *soap* is introduced into plasters, the soap is preferably mixed with hot water first, and the uniform soft soap mixture is then added to the plaster and the plaster-mass kept hot until the water added has been evaporated.

When *solid extracts* are added to plasters, the extracts must first be rendered semi-fluid by trituration with water or diluted alcohol, after which they can be added to the melted plaster, which is kept at a temperature barely sufficient to keep it fluid to permit of the requisite stirring.

Plasters made by fusion are always stirred constantly during the process of cooling, until they become so firm that further stirring is impossible. This is to insure uniformity of composition.

When *volatile substances* like camphor or menthol are introduced into plasters, the plaster is first melted and then allowed to cool until barely fluid before the volatile substance is added, after which the mass is diligently stirred and cooled as rapidly as possible, to prevent the loss of any portion of the volatile medicament.

528. **Suppositories** are solid bodies with or without active medicinal ingredients, and they are intended to be introduced into cavities of the body for the purpose of local medication. They are usually made of oil of theobroma, or cacao butter. This substance is peculiarly useful for this purpose, because it is a solid fat which does not soften gradually with an increase of temperature, but remains firm up to very nearly the temperature at which it suddenly liquefies.

When suppositories are ordered to be made with oil of theobroma as the base, the operation is somewhat difficult, because the oil of theobroma liquefies so readily when handled, its melting point being about the temperature of the body. From the nature of the substance, it will be readily understood that it is likely to be either too hard or too soft to be easily formed into cones or globular bodies, such as constitute the so-called suppositories. But no addition must be made to the oil of theobroma to lower its fusing point or increase it, because the superiority of oil of theobroma over all fatty bases that can be used for making suppositories depends upon its property of suddenly liquefying at the right temperature.

Suppositories are made to weigh from one to four grams or from fifteen to sixty grains, according to their uses.

Bougies are long, slender pencils made out of materials similar to those employed in making suppositories, and are also employed for local medication of cavities and passages.

Medicaments to be added to suppositories and bougies should, of course, be in a semi-fluid condition before they are incorporated with the base, or they should be in the form of impalpable powders.

The mass for making suppositories may be mixed on a board with the spatula, or it may be made in a mortar with the pestle, or the oil of theobroma may be melted in a porcelain dish and the medicaments added to the melted base, the mixture being stirred until it congeals, or stirred until barely fluid enough to be poured into suitable molds.

529. Suppositories are formed either by hand or by molding them in special molds. *To make suppositories by hand*, the oil of theobroma may be cut into thin shavings with the spatula and the shavings worked with the spatula on the board until sufficiently soft and plastic and free from lumps, after which the medicaments can be easily incorporated, the mass scraped together, rolled out in a cylinder, and the cylinder cut into the requisite lengths, according to a scale prepared for the purpose.

Rectal suppositories are usually about one inch in length and three-eighths of an inch in diameter at the base, while the apex is bluntly pointed, the shape being nearly conical. In fashioning suppositories in this manner, the mass should come in contact only with the board and spatula; if the mass is touched with the fingers, it is apt to become smeary so that it cannot be formed at all. To prevent the mass from sticking to the board and spatula, a very small amount of lycopodium is dusted on the board, and the mass rolled on the dusted surface.

Molds are made in such a way at present that the mass can be pushed from a cylinder by means of a piston into molds of any shape or size. These suppository machines can be used with a cold mass, and are the best because when the mass is not melted there can be no separation of the ingredients from one another. Molds intended to be used with a melted mass are much more difficult to manage. If the medicaments are not soluble in the melted oil of theobroma and especially if they are solid and heavy, they sink to the bottom of the melted oil and it is difficult even with constant stirring to keep the mixture uniform. Separation cannot be prevented when the stirring ceases and the mixture is poured into the molds. All that can be done is to stir the mixture and allow it to cool off until barely fluid enough to be poured, and to have the molds so well chilled with ice that the mixture congeals rapidly when the molds have been filled. But there is another difficulty attending this operation. If the mold contracts at the low temperature more readily than the contents, and if the congealed mass does not contract in the same ratio, the suppository will be held so firmly in the mold that it cannot be removed, but will be broken in the attempt to extract it.

Test Questions

1. What is meant by a Galenical preparation?

2. By what methods are Galenical preparations made, as distinguished from the methods by which other preparations are made?

3. What is the difference between an organic preparation and an inorganic preparation?

4. How would you mix one milligram of strychnine with one gram of sugar?

5. How would you mix one ounce of opium, one ounce of ipecac and eight ounces of milk sugar?

6. How would you mix five grains of a tough, moist extract with sixty grains of sugar?

7. How would you mix ten grains of a moist, tough extract with ten grains of sugar, the mixture to be divided into ten powders?

8. How would you make a compound powder consisting of two chemical compounds? What precautions are necessary to prevent any chemical changes of the ingredients?

9. How much morphine is contained in one and one-half grain of trituration of morphine?

10. What are the usual ingredients of medicinal confections?

11. What ingredients are common to all kinds of troches?

12. What is an excipient?

13. If a pill-mass is to be made containing four medicinal ingredients, two of which are powders, one a tough, moist solid, and the third a volatile oil, how would you make the mass?

14. What would you add to a solid extract of the consistence of thick honey to make a pill-mass of it?

15. What are the chief differences between acacia and tragacanth as excipients in pill-masses?

16. Which takes the longer time—to stiffen a pill-mass with powdered slippery elm or to stiffen it with starch?

17. What are the essential characteristics of a good pill-mass?

18. When is water used as an excipient in pill-masses?

19. When is alcohol a better excipient than water?

20. Name two of the stickiest moist excipients.

21. Name one of the best absorbent fibrous excipients and one of the best absorbent inorganic excipients.

22. What is a granule?

23. What would you do when a prescription calls for pills and the ingredients prescribed for each pill weigh ten milligrams?

24. What is the proper way to make a flaxseed poultice?

25. What is the proper way to make a mustard plaster?

26. How would you make suppositories of oil of theobroma?

27. What is simple ointment?

28. How does simple ointment differ from simple cerate?

29. How would you make an ointment of tar and tallow?

30. How would you make an ointment of cottonseed oil and hard paraffin?

31. What are the principal differences between lard and vaseline as ingredients of ointments?

32. How would you make an ointment of resin, wax and lard?

33. How would you mix lard with a solid extract?

34. How would you test or examine an ointment to see whether or not it is well mixed?

35. What are the advantages of petrolatum over lard as an ointment base?

36. What are ointments used for and what are cerates used for?

37. What is lead plaster?

38. What is adhesive plaster?

39. How would you make a plaster of extract of henbane?

40. How would you mix adhesive plaster, camphor, olive oil and oil of lavender to make an ointment?

41. What are suppositories?

42. Why do the pharmacopœias generally order oil of theobroma as the chief material out of which suppositories should be made?

43. How would you make suppositories of extract of stramonium?

44. How would you make suppositories of camphor?

45. How would you make suppositories containing lead iodide?

LESSON TWENTY-ONE

XXXI

Liquid Preparations Not Made by Processes of Extraction

530. **Water-solutions** of inorganic chemical compounds are to be found in all pharmacopœias. In the American pharmacopœia they are called solutions, in English, and are given the title liquor in the Latinic nomenclature.

The definition of the title liquor most frequently given in text-books is "a water-solution of a non-volatile substance," but mucilages, syrups, infusions and decoctions are also water-solutions of non-volatile substances. Among the "liquores" of our pharmacopœia there are not now any preparations other than water-solutions of non-volatile inorganic chemical compounds, so that this group of preparations is at present well defined.

Some of the official liquores are used only as materials out of which other preparations are made, but most of them are intended for medicinal use, external or internal.

The waters or aquæ of the pharmacopœia are commonly defined as "water-solutions of volatile substances," but while it is true that all of the preparations given the title "aqua" in the American pharmacopœia are really water-solutions of volatile substances, it is equally true that there are other water-solutions of volatile substances not called by that title, as, for instance, several of the acids.

531. A great majority of the **aquæ** are water-solutions of

volatile oils, and a scientific classification of the pharmaceutical preparations would seem to require that the aromatic waters should be made to constitute a class by themselves and should not be grouped together with such solutions as ammonia water, chlorine water and solution of hydrogen dioxide, which are chemical preparations.

The aromatic waters are nearly or quite saturated solutions of volatile oil, made by triturating the volatile oil with talcum or with calcium phosphate and then with water, after which the mixture is filtered, two cubic centimeters of volatile oil being generally used to prepare 1000 cubic centimeters of the finished product.

But rose water and orange flower water are made by distillation, and bitter almond water is made by dissolving the volatile oil of bitter almond in the water without the aid of trituration with calcium phosphate.

Chloroform water is prepared by adding enough chloroform to a convenient quantity of distilled water to maintain an excess of chloroform at the bottom of the bottle, so that when the contents are thoroughly shaken together, the excess of chloroform will sink to the bottom of the bottle and the saturated solution standing over the undissolved chloroform is poured off as required.

The aromatic waters are employed chiefly as flavoring agents or as vehicles for more important substances.

532. Mucilages are water-solutions of vegetable mucilage. The *mucilage of acacia* of the pharmacopœia is made by dissolving 340 grams of acacia in small fragments in enough water to make the finished solution weigh 1000 grams. The acacia is first washed with cold water to remove dust, and then dissolved in the necessary amount of water to form the preparation, which must be kept in completely filled bottles in a cool place, in order to prevent fermentation.

Mucilage of tragacanth is prepared by mixing 6 parts of tragacanth with a mixture of 18 parts of glycerin and 75 parts of water, and letting the mixture stand twenty-four hours, stirring occasionally. The glycerin and water are first mixed and the mixture heated to boiling, after which the tragacanth is added. After twenty-four hours, the mixture is beaten until of uniform consistence and enough water is added to make the whole product weigh 100 grams, and the thick mucilage is forcibly strained through muslin. This mucilage, too, is likely to undergo fermentation and should therefore be prepared in quantities so small that they will be consumed in a short time.

Mucilage of slippery elm bark is made by digesting bruised slippery elm in water over a water bath for one hour, after which the liquid is strained. *Mucilage of sassafras pith* is made by macerating sassafras pith with the prescribed quantity of water for three hours.

All mucilages are liable to undergo fermentation and hence cannot be kept in stock more than a few days.

533. Syrups are water-solutions of medicinal substances, sweetened with considerable quantities of sugar.

The "syrupus," or simple syrup of the pharmacopœia, is a water-solution of sugar made by dissolving 850 grams of coarsely powdered sugar in enough water to make the finished solution measure 1000 cubic centimeters. The sugar is either dissolved with the aid of heat and the solution raised to the boiling point, after which it is strained, or the sugar is dissolved by percolating water through it in an ordinary percolator. Simple syrup has a specific weight of about 1.317, and is an almost saturated solution at ordinary temperatures, so that it crystallizes if placed in a cold room.

Several of the *medicated syrups* of the pharmacopœia contain inorganic chemical compounds, as, for instance, syrup of hydriodic acid, syrup of calcium lactophosphate and syrup of ferrous iodide. Other medicated syrups of the pharmacopœia contain organic medicinal substances, usually added in the form of fluid extracts.

Several of the pharmacopœial syrups are used as flavoring ingredients or agreeable additions to mixtures.

The presence of considerable quantities of inorganic chemical compounds in syrups tends to preserve them, so that such syrups may be made with a smaller quantity of sugar than is necessary to preserve syrups containing fermentable organic matter.

534. **Glycerites** are solutions of pharmaceutical and medicinal substances in glycerin. Glycerin solutions are more permanent than water-solutions of the same substances. Medicated glycerites are few in number, and those contained in the pharmacopœia are the glycerites of carbolic acid, tannic acid, boroglycerin and hydrastis.

The *glycerite of starch* is a thick, translucent, jelly-like preparation made out of 1 part of starch, 1 part of water and 8 parts of glycerin, heated together at the temperature of from 140° to 144° C. It is used mostly as an ointment base.

The *glycerite of yolk of egg*, sometimes called glyconin, is a mixture of yolk of egg and glycerin, intended to be used in preparing emulsion-like mixtures, the yolk of egg acting as an emulsifying agent.

535. **Emulsions** are liquid mixtures containing insoluble substances in a fine state of division, suspended uniformly throughout the whole liquid. The undissolved, finely divided substances may be volatile oils, fixed oils, oleoresins, resins, gum-resins or inorganic powders.

Emulsions may be classified as follows: Seed emulsions, gum-resin emulsions, emulsions of fixed oils, emulsions of volatile oil and oleoresins, quasi-emulsions of inorganic powders.

536. **Emulsions of seeds** are formed when the seeds are beaten and thoroughly triturated with water, because all

seeds contain fixed oils, and they usually contain emulsin, which acts as an emulsifying agent.

The only very common seed emulsion is the *emulsion of almond*, which is prepared as follows: Sweet almonds are blanched by first placing them in tepid water for a few minutes to loosen the seed-coat, which is then easily removed. The seed-coat of almonds can also be loosened by putting the almonds in cold water, but it takes much longer time. Boiling water should never be used, because it unfavorably affects the result, since the emulsin of the almond is coagulated by temperatures exceeding 60° C. The blanched almonds are put in the emulsion mortar and beaten to a coarse powder. Sugar and acacia, previously mixed in the proportions ordered by the pharmacopœia, are then added and mixed with the coarsely crushed almond. Enough water is then added and the whole mixture beaten into a smooth pulp or paste, free from lumps. More water is gradually added and the mixture triturated thoroughly until finally all the water to be used has been added, after which the emulsion is strained and is then finished.

Sweet almond beaten up with water will form an emulsion without the addition of acacia and sugar, but such an emulsion of almond is thin and poor. The amount of fixed oil contained in the almond is so great and the emulsin in the almond is so insufficient as an emulsifying agent, that in order to get a rich emulsion it is necessary to add acacia, which is one of the most effective emulsifying agents we have. Sugar is added to sweeten the preparation.

Emulsion of almond is used sometimes as a "placebo," by which is meant a pharmaceutical preparation ordered by physicians in cases where no active medicinal agent is necessary, the ailment of the patient being one of imagination. Emulsion of almond may also be used as a pleasant vehicle for medicinal substances of not too decided flavor.

A preparation called *hydrocyanated emulsion* is used in several countries of Northern Europe, and occasionally in other countries. This preparation when ordered by a physician is usually prescribed in heroic doses and in cases where life or death depends upon prompt administration of the preparation. Hence, hydrocyanated emulsion must be dispensed by the pharmacist with the least possible delay. It is a mixture of emulsion of sweet almonds with a certain quantity of amygdalin. In order to avoid unnecessary delay, the emulsion of sweet almond required for the preparation of hydrocyanated emulsion is made without first blanching the almonds.

537. **Gum-resin emulsions** are formed when gum-resins are triturated with water. Two such emulsions are contained in the pharmacopœia—emulsion of asafetida and emulsion of ammoniac.

The gum-resin must be clean, and to that end should consist of selected pieces. These are crushed in the mortar, reduced to coarse powder and then beaten with a small amount of water until a perfectly smooth pasty pulp is obtained, free from lumps. More water is gradually added and the trituration continued until all of the water prescribed has been used. The mixture is then strained, and if the work has been well done there should be little if any residue left on the strainer.

538. **Emulsions of fixed oils, volatile oils** and **oleoresins** are made with acacia, according to the so-called "Hager's rules."

Hager's rule fixing the proportions of the materials required to make emulsions of fixed oils is as follows: Take 4 parts of fixed oil, 2 parts of acacia in powder and 3 parts of water of emulsification.

For emulsions of volatile oils and oleoresins, Hager's rule is: Take equal parts, by weight, of the volatile oil or oleoresin, powdered acacia and water of emulsification.

The manipulations are as follows: Mix the oil thoroughly with the powdered acacia, then add the "water of emulsification" all at once, and immediately stir the mixture with the pestle in the mortar as rapidly as possible, until the mixture becomes as light colored as it can be made, thickens and crackles under the pestle, and the globules of oil or oleoresin entirely disappear. The emulsification is then finished. If any additional water is ordered to be added, it must be gradually added after the completion of the emulsification, and finally the emulsion is thoroughly shaken in a bottle.

Another method is to mix the powdered acacia and water first, which requires considerable dexterity and rapidity of motion, to avoid the formation of lumps. When a uniform mixture of the acacia and water has been made, the oil or oleoresin is then added, a little at a time, and the emulsification of each portion completed before another portion is added.

A third method is to put the powdered acacia on the bottom of the mortar in the center, covering the acacia afterwards with the oil or oleoresin, and then adding the water of emulsification so carefully that the layer of oil covering the acacia is not disturbed, in order that the water may not come in contact with the acacia until the trituration begins. If the water should come in contact with the powdered acacia before brisk stirring begins, lumps would be formed, which it is afterwards extremely difficult to crush. Having now all the necessary ingredients in the mortar in the right proportions, the operator grasps the pestle and with an extremely rapid rotary motion in one direction accomplishes the emulsification, after which any additional quantity of water required may be gradually stirred in.

The most common emulsions of fixed oils are made of cod-liver oil, castor oil, olive oil and oil of almond. The most common emulsion of volatile oils is made of oil of turpentine. The only common emulsion of oleoresin is an emulsion of copaiba.

Yolk of egg is also an effective emulsifying agent, employed in making emulsions of fixed oils and occasionally other emulsions. When the yolk of egg is used for this purpose, the oil is mixed with it before the water of emulsification is added.

Powdered tragacanth can also be used, and is quite as effective as powdered acacia, but a much smaller amount of tragacanth will prove sufficient. The tragacanth, however, works slowly, so that it takes a longer time to finish the emulsion, which, however, when finished, holds together remarkably well.

Irish moss jelly is also used as an emulsifying agent for fixed oils, but it is not so effective in reducing the oil to an extremely fine state of division, although the emulsion when finished is comparatively permanent. Unless the Irish moss used in preparing the jelly is carefully selected so that the jelly is nearly colorless, the emulsion made with this emulsifying agent is unsightly, whereas emulsions made with acacia or tragacanth have a much better and cleaner appearance.

Another emulsifying agent sometimes used is *tincture of soap bark*, but tincture of soap bark contains an extremely active medicinal substance called saponin, and hence this emulsifying agent should never be used unless ordered by a physician, and no intelligent physician is ever likely to order it. The only reason why it has been employed is its wonderful emulsifying power and the ease with which the emulsification is effected by it.

539. Chloroform and ether may be incorporated in mixtures with the aid of tragacanth. It is, in fact, a very easy task to make such mixtures. All that is necessary is to place the required quantity of powdered tragacanth in a dry, clean bottle, add the chloroform or ether, and shake the mixture so as to disintegrate any lumps of the powdered gum; then add the water required and shake the bottle vigorously, when a uniform emulsion will soon be formed.

The *emulsion of chloroform* of the American pharmacopœia contains oil of almond as well as chloroform. The best way to make it is to add the chloroform to the oil, then add the powdered tragacanth and finally the water of emulsification, stirring vigorously as in other emulsions and finally shaking the mixture.

The *chalk mixture* of the pharmacopœia is a quasi-emulsion obtained by triturating prepared chalk with acacia and sugar and then with water and cinnamon water. The insoluble prepared chalk is held in suspension in the mixture temporarily by the acacia, which dissolves in the water, but as the chalk is only temporarily suspended, the mixture must be shaken each time it is to be taken.

Precipitated sulphur can also be held in suspension with the aid of acacia, and then triturated a sufficiently long time with the requisite amount of water.

540. Spirits are defined as alcoholic solutions of volatile substances. They are mostly alcoholic solutions of volatile oils, which are very simple preparations.

541. Liquid preparations for external use are generally simple solutions or mechanical mixtures. The ingredients are extremely varied.

Therapeutically, the external liquid preparations are chiefly stimulants, rubefacients, lubricants, astringents and cooling or soothing applications. Antiseptic and disinfectant lotions are also very much used.

Lotions may be water-solutions of inorganic or organic substances, or they may even be alcoholic liquids. Lotions are for local use externally. Eye washes are technically known as *collyria*, while those used for nasal difficulties are called *collunaria.*

Gargles are mostly water-solutions, but they, too, frequently contain alcoholic ingredients. Gargles, technically known as *gargarismata*, are used as washes for the throat.

Injections are so miscellaneous in their character that it is impracticable to give any general description of them. They are aqueous, mucilaginous, oily or even alcoholic. They are injected by means of syringes into the body cavities through the rectum, ear or other openings. A rectal injection is called an *enema.*

Liniments usually contain some fixed oil, volatile oil or soap, but may also be composed of other ingredients in liquid form, as, for instance, tinctures. Liniments are for external use, and are applied as washes or rubbed in by gentle friction.

Collodions are solutions of so-called soluble guncotton or pyroxylin in a mixture of alcohol and ether. Simple collodion contains nothing else, but medicated collodions contain tannin, cantharidin and various other medicinal substances. When collodion is applied to the skin or to a wound, the alcohol and ether evaporate, leaving a continuous film of the pyroxylin. If the collodion is of suitable density, the film is sufficiently strong and elastic to form an effective covering. The lips of wounds may be held together by applications of collodion, but if the application is too thick, the contraction of the film may be painful. For this reason various additions to collodion are made to render the film elastic so that it may be less painful. The most common additions made for this purpose are glycerin, castor oil and Venice turpentine.

Test Questions

1. Mention several kinds of liquid preparations for external use.

2. What is collodion made of and how is it made elastic?

3. What is the meaning of the title liquor in the American pharmacopœia?

4. What several kinds of water-solutions of non-volatile substances are common in pharmacy?

5. How are the aromatic waters made?

6. How is mucilage of acacia prepared?

7. How is mucilage of tragacanth prepared?

8. What proportions of sugar and water, by weight, are required to make just six pints of simple syrup?

9. How do you find these proportions most easily?

10. What quantity in cubic centimeters of mucilage of acacia can be made from 340 grams of acacia, assuming that the specific weight of the mucilage is 1.31?

11. How much sugar is necessary in a medicated syrup?

12. How is glycerite of starch made?

13. What is an emulsion?

14. What substances will form emulsions when beaten with water without the addition of any other substance?

15. Describe how a good emulsion of almond is made.

16. Describe how a good emulsion of ammoniac is made.

17. What is Hager's rule for the production of fixed oil emulsions?

18. State Hager's rule for making emulsions of oleoresins.

19. What is Hager's rule for the production of emulsions of volatile oils?

20. What are the principal emulsifying agents?

21. How would you make an emulsion containing one-half its volume of almond oil?

22. How would you make an emulsion containing oil of turpentine and olive oil together?

23. How can an emulsion of ether be made?

24. Describe in detail how you would make an emulsion containing one-eighth of its volume of volatile oil of copaiba.

25. What is the object of the acacia in chalk mixture?

26. What would you call an alcoholic solution of oil of peppermint?

LESSON TWENTY-TWO

XXXII

Extracts

542. **Infusions** are ordered by the American pharmacopœia to be made in accordance with the following general directions, unless specially otherwise ordered: "An ordinary infusion, the strength of which is not directed by the physician nor specified by the pharmacopœia, shall be prepared by the following formula: Take of the substance coarsely comminuted 50 grams, boiling water 1000 cubic centimeters. Put the substance into a suitable vessel provided with a cover. Pour upon it the boiling water. Cover the vessel tightly and let it stand for half an hour, then strain and pass enough water through the strainer to make the infusion measure 1000 cubic centimeters." These general directions are followed by a note reading as follows: "Caution.—The strength of infusions of energetic or powerful substances should be specially prescribed by the physician."

Special formulas are given in the pharmacopœia for infusions of cinchona, digitalis and wild cherry and for compound infusion of senna, which preparations are not made in accordance with the general directions.

The *infusion of cinchona*, U. S. P., 1890, was a percolate made with cold water, acidulated with aromatic sulphuric acid.

The *infusion of wild cherry* is also a percolate and is made with cold water.

The *infusion of digitalis* and the *compound infusion of senna* are made with boiling water. But other ingredients besides the drugs after which the infusions are named are added in these preparations, and the strength of each is not 5 per cent, as ordered in the general formula.

In other pharmacopœias of the world, the infusions are generally made of 10 per cent strength. The American pharmacopœia of 1880 ordered infusions of 10 per cent strength, but in the revision of 1890 the strength was changed to one-half of that.

543. Decoctions are ordered by the American pharmacopœia to be made as follows: "An ordinary decoction the strength of which is not directed by the physician nor specified by the pharmacopœia shall be prepared by the following formula: Take of the substance coarsely comminuted 50 grams, water a sufficient quantity. Put the substance into a suitable vessel provided with a cover, pour upon it 1000 cubic centimeters of cold water, cover it well and boil for fifteen minutes. Then let it cool to about 40° C., express, strain the expressed liquid and pass enough cold water through the strainer to make the product measure 1000 cubic centimeters." This general formula is followed by a note similar to that given under the head of infusions, namely: "Caution.—The strength of decoctions of energetic or powerful substances should be specially prescribed by the physician."

According to the pharmacopœia of 1880, decoctions were to be of 10 per cent strength, but the directions of 1890, as will be seen, changed the proportions so as to make these preparations only 5 per cent strength.

Special formulas are given in the pharmacopœia for decoction of Iceland moss and compound decoction of sarsaparilla.

The most common decoctions ordered by physicians are demulcent decoctions or thick, starchy decoctions. The proportion of starchy matter required to make such a decoction must depend upon the percentage of starch in the substance out of which the decoction is made, and for that reason the proportions directed by the general formula of the pharmacopœia are sometimes impracticable.

In most of the pharmacopœias of the world, the decoctions are ordered to be made of 10 per cent strength.

544. Vinegars are liquid extracts made with diluted acetic acid as the menstruum. The Latinic title of a vinegar is "acetum." Many such preparations were used in olden times, but at present the American pharmacopœia contains only two—the vinegar of opium and the vinegar of squill. Both of these are of 10 per cent strength, and they are both made by maceration.

Diluted acetic acid is much stronger than ordinary table vinegar, for the diluted acetic acid of the pharmacopœia contains 6 per cent of absolute hydrogen acetate, while table vinegar usually contains but 4½ per cent. Diluted acetic acid is an effective solvent for many of the active constituents of plant drugs, including alkaloids and many glucosides, especially acrid substances; and diluted acetic acid is also capable of dissolving small quantities of volatile oils and resins.

Medicated vinegars are so disagreeable to the taste that they are seldom used.

545. Tinctures are liquid extracts made with strong or diluted alcohol, but of less strength than the fluid extracts. A few of the preparations called tinctures in the pharmacopœia are alcoholic solutions of resins or alcoholic solutions of inorganic substances.

The common definition given of the title tincture is to the effect that it is "an alcoholic solution of non-volatile" matter, but, of course, the fluid extracts are just as much alcoholic solutions of non-volatile substances. If the title tinctura were restricted to alcoholic and hydroalcoholic liquid extracts of plant drugs, our nomenclature would be in harmony with scientific classification.

A great majority of the tinctures of the American pharmacopœia are directed to be made by percolation, and the period of maceration between the packing of the drug in the percolator and the displacement of the solution is usually twenty-four hours, but in some cases the displacement of the solution formed is proceeded with immediately after packing or without preceding maceration. All tinctures that can possibly be made by percolation are in the American pharmacopœia ordered to be so prepared; in other pharmacopœias of the world the tinctures are almost without exception made by maceration without percolation.

Tinctures of extract-like drugs, such as kino, and of resins, such as benzoin, guaiac and tolu, and of gum-resins, such as asafetida and myrrh, are, of course, not made by percolation, but are made either by simple solution, if the drug is completely soluble in the menstruum, or by maceration if only partially soluble, as in the case of gum-resins.

When a tincture is made of any resin, coarse powder of the resin is used, and all that is necessary is to dissolve the resin in the alcohol. The tincture is finished as soon as the resin has been completely dissolved, and this does not usually require as much as seven days, the period prescribed in the pharmacopœia.

Tincture of iodine is a simple alcoholic solution of iodine.

The *tincture of ferric chloride* is a mixture of solution of ferric chloride with alcohol, which is allowed to stand in a closely covered vessel for at least three months before it is used. The object to be attained by allowing the mixture to stand for at least three months is the formation of certain ethereal compounds by chemical reaction between the ferric chloride and the alcohol.

Most of the tinctures in the pharmacopœia are *simple* *tinctures*, representing but one drug having the medicinal action expected of the preparation. Other tinctures representing but one drug of value are flavored by additions of other substances, and finally there are tinctures called *compound tinctures*, containing more than one active ingredient.

One class of tinctures to which the pharmacopœia makes general reference is the class called "tinctures of fresh herbs." The pharmacopœia gives the following general directions for making the tinctures of fresh herbs: "These tinctures, when not otherwise directed, are to be prepared by the following formula: Take of the fresh herb, bruised or crushed, 500 grams, alcohol 1000 cubic centimeters. Macerate the herb with the alcohol for thirteen days, then express the liquid and filter." Elsewhere in this book the statement has been made that some plant drugs are considered to be more valuable in the fresh condition than after drying, but the plant drugs used in the fresh condition are not all herbs. Some of them are roots and rhizomes, and one fresh drug considerably used is a cactus. Tinctures of all kinds of fresh drugs are made in the same manner as the tinctures of fresh herbs.

The tinctures of the pharmacopœias of the world are not of uniform *strength*. One of the tinctures of the American pharmacopœia, that of aconite, represents about 40 per cent of its weight of the drug. The tincture of veratrum viride represents about 50 per cent of its weight of the drug. The greater number of tinctures represent about 20 per cent; others 15 per cent, others 10 per cent, some only 5 per cent. The strength of each tincture is simply that established by custom, without any system. Doubtless some of the tinctures in use might with great advantage have been made stronger; others might with equal advantage have been made less strong. The authorities having charge of the British pharmacopœia announce that the guiding principle in revising the formulas for tinctures in that book was a greater approach to uniform doses, but great changes in the strength of tinctures commonly employed, especially if the tinctures are made of poisonous drugs, are hazardous, and it has therefore been considered impracticable to change the strengths of tinctures in so radical a way as to bring about anything like uniform dosage. The two strongest tinctures in the American pharmacopœia, those of aconite and veratrum viride, are tinctures of extremely poisonous drugs, and the doses of those tinctures are accordingly extremely small. On the other hand, we have in the American pharmacopœia tinctures of 10 per cent strength made out of a large number of drugs of comparatively small medicinal activity, so that their doses are extremely large.

The *tincture of ipecac and opium* of the pharmacopœia is made out of deodorized tincture of opium, fluid extract of ipecac and diluted alcohol.

The *tincture of nux vomica* is made by dissolving the solid extract of nux vomica in alcohol and water.

Ammoniated tinctures are tinctures prepared by maceration or percolation with aromatic spirit of ammonia as the menstruum. The ammoniated tinctures contained in the American pharmacopœia are the ammoniated tincture of guaiac and that of valerian.

Ethereal tinctures are tinctures made with ether as the menstruum. Such tinctures have been made of lobelia, valerian and other drugs. No ethereal tinctures are contained in our pharmacopœia.

546. Medicated wines are in some respects like the tinctures. They differ, in fact, from the tinctures only in that wine is the menstruum instead of alcohol or diluted alcohol. Wine to be used for the purpose of making the medicated wines must, according to the pharmacopœia, be a white wine containing not less than 10 nor more than 14 per cent, by weight, of absolute alcohol, but in the formulas presented by the pharmacopœia this wine is usually strengthened by the addition of more alcohol.

Any domestic wine having the characteristics described in the pharmacopœia, such as California Riesling, Ohio Catawba, etc., may be used, but in all other countries either sherry or Malaga is used and ordered in the pharmacopœias, and it is quite probable that American pharmacists very generally also use sherry.

The *wine of antimony* of the pharmacopœia consists of wine to which a solution of tartar emetic is added. Bitter *wine of iron* is wine with an addition of citrate of iron and quinine, flavored with tincture of sweet orange peel. *Wine of ferric citrate* is wine with citrate of iron and ammonium added and also flavored with tincture of sweet orange peel. *Wine of ipecac* is a mixture of wine and fluid extract of ipecac. Other medicated wines are made by maceration or percolation of the drug with the wine fortified with alcohol.

547. Fluid extracts are liquid extracts of plant drugs, so prepared that each cubic centimeter of the preparation represents the valuable constituents of one gram of the drug of which the preparation is made. Fluid extracts are extremely numerous in our country and very largely employed. They have not been extensively used in other countries, and in some foreign countries they are not used at all, while some recent foreign pharmacopœias contain less than a dozen kinds.

The uniform standard of strength of fluid extracts is simplicity itself. Every physician or pharmacist knows how much of the drug is represented by any quantity of the preparation without any effort of the memory, but the value of the uniform rule ends there, for the result of such a rule is that the dose of one fluid extract may be less than a drop, while the dose of another fluid extract may be more than five hundred times as great.

Some of the fluid extracts are very nearly saturated solutions of extractive matter; others again contain but very small quantities of extractive in solution. In other words, some fluid extracts are so strong that it would be impracticable to make them any stronger, while others could easily be made several times as strong as they are. The rule which ought to govern in fixing the strength of any medicinal preparation would seem to be to make the preparation as useful and convenient as possible for the particular purposes for which it is to be employed, whether used internally or externally. [To make a whole class of medicinal preparations as numerous as the class of fluid extracts in accordance with a mathematical rule would seem to be too much like making only one size of trousers for a whole army. If the trousers are too long for a short-legged soldier, the trouser legs may be cut shorter, but if they are too short, it would be inconvenient to cut off the soldier's legs to fit the trousers, and when medicinal preparations are arbitrarily made to conform to certain mathematical ratios similar difficulties are sure to arise. It is impossible to make all liquid extracts of such strength that the approximate adult dose for ordinary purposes of each and every such preparation shall be the same as that of every other preparation of the same class, but it is entirely practicable to divide the whole class into a few groups and to make the strength of each member of such a group such that the dose of all members of the same group will be approximately alike.]

Fluid extracts are so difficult to prepare, owing to their concentration, that pharmacists rarely undertake to prepare them. They are usually made only by manufacturing pharmacists.

548. The colors of tinctures and fluid extracts vary considerably, but by far the greater number are of a dark red-brown or yellowish-brown color. Others are greenish-brown or red, green or yellow.

The amount of extractive matter contained in solution in a tincture or a fluid extract is easily found by evaporation of a definite quantity of the preparation. Some fluid extracts can contain but about 3 to 6 per cent of extractive matter, while others, again, may contain between 30 and 50 per cent. The tinctures, of course, contain smaller quantities, according to their percentage strength.

549. Solid extracts are preparations of plant drugs made by separating the soluble matter from the drug by maceration or percolation with the most appropriate solvent, and the subsequent elimination of the solvent by distillation and evaporation. Most of the solid extracts of the American pharmacopœia are ordered to be made of "pilular consistence," or a consistence suitable to the formation of the extract into pills without the addition of any excipient. As a matter of fact, however, the extracts enumerated in the pharmacopœia and ordered to be made of pilular consistence are rarely found to be of that consistence; they are usually either softer or firmer.

But some of the extracts of the pharmacopœia are ordered to be entirely dry, and some of the extracts which are ordered to be made dry are also ordered to be reduced to powder for greater convenience. Doubtless all extracts that can without injury be made perfectly dry should also be powdered.

A good and very familiar example of a hard, dry extract is the common black stick-licorice. The stick-licorice varies as to the amount of moisture it contains, some of it being sufficiently moist to render the stick more or less flexible, so that it can be bent more or less without breaking; other sticks of black licorice are so hard and dry as not to be in any degree flexible. Some black licorice is so hard and dry that it can not only be crushed, but easily triturated to powder. When dissolved in water, it forms a sticky solution, the density of which depends upon the proportion of extract dissolved. Whenever the black licorice is at all wetted it at once becomes sticky. The color of extract of licorice, or stick-licorice, is a dark reddish-yellowish brown, much like the color of most of the solid extracts, and stick licorice is, in fact, in every respect a solid extract.

The solid extracts differ in composition according to the drug from which they are made and according to the menstruum employed in making them. The method by which the extracts are generally prepared consists of two parts. The first part of the process is like that by which fluid extracts are made. It consists in the extraction of soluble matter by maceration or percolation. The second part of the process consists in the separation of the menstruum from the dissolved matter.

Solid extracts are not of uniform strength with reference to the drug out of which they are made. Some extracts may be more than thirty times the strength of the drug, while others may be only twice the strength of the drug. That, of course, is determined by the total amount of soluble matter given up by the drug to the menstruum used, and also by the degree to which the extract is dried.

The direction to evaporate an extract to a pilular consistence renders the strength of any one such extract more or less uncertain, because the expression "pilular consistence" may mean one thing to one operator and quite another thing to another.

In cases where it is practicable to determine accurately the percentage of active constituents in the drug or the extract, the product can be made of absolutely uniform potency by dilution with the requisite quantity of sugar of milk or of glycerin. Dry and powdered extracts of uniform strength may be made by dilution with sugar of milk, and soft or semi-fluid extracts of definite strength may be made by dilution with glycerin. Dry and powdered extracts are the most convenient for the preparation of compound powders, troches, pills and certain other solid preparations; but soft or semi-fluid extracts are most convenient for the preparation of ointments, plasters, suppositories and liquid mixtures.

The strength of a solid extract may be made to bear a simple relation to the drug it is made from, as follows: The total amount of extract produced may be made to exceed the natural yield of extractive and a sufficient amount of diluent added to bring about that result. The extracts of drugs yielding less than 10 per cent of extractive matter may be made to represent ten times their weight of the drug. Extracts from drugs yielding from 10 to 20 per cent of extractive can be made to represent five times their weight of the drug, etc. Another plan for making the extracts as convenient and useful as possible would be to regulate the yield according to the dose so as to form a few classes of extracts, each member of one class having approximately the same dose.

In all cases where it is practicable to determine the potency of a drug by assay, the extract made from the drug can be made of absolutely definite value in the same manner. Thus, in the American pharmacopœia the extract of opium is a dry powder diluted with milk sugar, used in such proportion that the final product contains precisely 20 per cent of morphine, and the extract of nux vomica is a dry powder also diluted with milk sugar to obtain a product containing exactly 5 per cent of strychnine. Assayed extracts can also be prepared of a number of other alkaloidal drugs and of drugs containing resins.

550. Oleoresins are ethereal extracts, and of these the American pharmacopœia contains six. A typical example is the oleoresin of male fern. The aspidium or male fern is put into a cylindrical glass percolator provided with a stopcock and arranged with cover and receptacle suitable for volatile liquids. The drug is pressed down firmly and ether is slowly percolated through it; the ether being added in successive portions and the percolation continued until the drug is exhausted. The greater part of the ether is then recovered from the percolate by distillation over a water bath, the residue is transferred to a capsule or porcelain dish and the ether remaining is allowed to evaporate spontaneously. The product remaining after all the ether has been evaporated constitutes the oleoresin.

The oleoresins of the pharmacopœia are semi-fluid.

551. Precipitated resins are prepared from jalap, podophyllum and scammony.

Resin of jalap is made from finely powdered jalap, which is percolated with undiluted alcohol until the drug is exhausted or until the end-percolate no longer produces more than a slight turbidity when dropped into water. The alcohol is then distilled off until the liquid is reduced to a certain degree of concentration and the concentrated liquid is poured into a large amount of water with constant stirring. The resin then precipitates. The precipitate is washed twice with water and is then collected on a strainer, allowed to drain, and then pressed, after which the resin is dried. The *resin of podophyllum* is made in a similar manner, but in this case 1 per cent of hydrochloric acid is added to the water employed to precipitate the resin and the water must be previously cooled to a temperature below 10° C., in order th t the precipitation may be made as complete as possible and to prevent the resin from forming lumps. *Resin of scammony* is made by digesting the powdered scammony with boiling alcohol, used in successive portions until no more alcohol-soluble matter remains in the marc. The alcohol is then distilled off until the remaining liquid has been reduced to a syrupy consistence, and is then added to a large amount of water, after which the precipitated resin is washed and dried.

Test Questions

1. Name the aqueous liquid extracts mentioned in the pharmacopœia.
2. What are the differences between a decoction and an infusion of the same drug?
3. Under what circumstances are infusions and decoctions made of a different strength from that prescribed for "ordinary" infusions and decoctions?
4. What is the pharmacopœial strength of a medicated vinegar?
5. What is the percentage of acetic acid contained in a pharmacopœial vinegar?
6. What are the medicinal constituents usually contained in the medicated vinegars?
7. Define the title tincture.
8. What is the difference between a tincture and a fluid extract of the same drug?
9. What menstruum is employed in the preparation of tinctures?
10. What is their percentage strength?
11. How are tinctures made?
12. Are all the tinctures liquid extracts? If not, mention some tinctures that are not properly called extracts.
13. In what respects do the tinctures and fluid extracts resemble each other?
14. How would you prepare a tincture of an undried or fresh root?
15. When it is stated that a tincture of veratrum viride is of 50 per cent strength, what does that statement really mean? Does it mean that 100 grams of the preparation

represents all the activity of 50 grams of veratrum viride? If so, why? If not, why not?

16. What tincture in the American pharmacopœia is made out of a solid extract?

17. What is meant by a hydroalcoholic tincture?

18. What is an ethereal tincture?

19. What is the menstruum used in the making of an ammoniated tincture?

20. What is the percentage of alcohol contained in a medicated wine?

21. What name would you give to a liquid extract so prepared that one liter of it represents 200 grams of a plant drug?

22. What is a fluid extract?

23. What quantity of solid matter is obtained from the evaporation of 100 cubic centimeters of a fluid extract?

24. What is the standard of strength prescribed for solid extracts by the American pharmacopœia?

25. How can the strength of a fluid extract, solid extract or tincture be made absolutely uniform?

26. What is the difference between an extract and an oleoresin?

27. What menstruum is employed for making oleoresins?

28. Why is glycerin prescribed to be mixed with some of the solid extracts?

29. For what purpose is sugar of milk added to some extracts?

30. Out of what kinds of drugs can oleoresins be made?

31. What is the consistence of a solid extract?

32. What is the consistence of oleoresins?

33. What is the consistence of precipitated resin?

34. What is the difference between an oleoresin soluble in diluted alcohol and one soluble only in ether?

LESSON TWENTY-THREE

XXXIII

Pharmacopœias

552. Pharmacopœias are authoritative books containing the titles, definitions, descriptions and standards of purity and strength of commonly employed medicinal substances, together with directions for preparing simple and rational medicinal preparations such as physicians employ.

Nearly every civilized nation has its own pharmacopœia, and that pharmacopœia has the authority of law. It is generally prepared by a governmental commission.

The American Pharmacopœia is, however, not prepared by the Government, but by a committee appointed by a delegate convention called the **Pharmacopœial Convention.** This national convention for revising the pharmacopœia meets decennially. The first convention met January 1, 1820, and the eighth decennial convention met May 1, 1900. The meetings of the convention are always held in the city of Washington. The membership of the convention is made up of not more than three delegates from each of the medical and pharmaceutical associations and colleges in the country, and the medical departments of the Army, the Navy and the Marine Hospital Service. This large convention elects a **Committee of Revision** of the pharmacopœia, and that committee does the work of revision. Instructions are given by the convention to its Committee of Revision concerning the general features of the work and the principles to govern its scope. They may instruct the committee concerning the language of the text, the system of weights and measures to be employed, the extent to which definite standards of strength may be fixed for plant drugs and their preparations, etc., but all details are of necessity entrusted to the Revision Committee. The Committee of Revision appointed by the decennial convention of 1880 and those appointed by the conventions of 1890 and 1900 all consisted of twenty-five members, about half of them physicians and the remainder pharmacists.

The work of revising the pharmacopœia usually occupies from two to four years, and when that work is completed, the officers of the convention make arrangements for its publication.

553. The medicinal substances included in the pharmacopœia are those which in the judgment of the members of the Committee of Revision are of **sufficient importance** and sufficiently **commonly employed** to require that their identity, quality, purity and strength shall be regulated. But it may be said in a general way that simple drugs and substances of definite chemical composition are those entitled to a place in any pharmacopœia, and that complex mixtures are generally excluded. The fact that a certain preparation is extensively used does not entitle it to a place in the pharmacopœia, unless it is a rational preparation such as educated men licensed to practice medicine may consider useful. Nearly all pharmacopœias still retain a small number of mixed nostrums which gained admission to the pharmacopœias a long time ago, when the scientific principles along which pharmacopœial revision should proceed had not yet taken form. [One of the pharmacopœias, for instance, still retains a preparation containing over fifty different ingredients, the sole reason for its retension in that pharmacopœia being that the preparation is still occasionally called for at the drug stores by ignorant people. The presence of such compounds in any pharmacopœia seriously detracts from its dignity and character, and it is evident that any preparation for which there is a demand may be made and sold whether it is contained in the pharmacopœia or not. In the American Pharmacopœia there are forty or fifty preparations of a complex character or of doubtful utility that should be transferred to the National Formulary as unworthy of a place in the National Pharmacopœia. These preparations include Lady Webster's dinner pills, Plummer's pills, Morrison's pills, paregoric, compound cathartic pills, Griffith's mixture, etc., all of which preparations disfigure the pages of any scientific pharmacopœia.]

554. As to the **plant drugs** contained in the pharmacopœia, the Revision Committee is largely guided by what is known concerning the constituents found in them *by chemical investigation.* Any drug containing an alkaloid is necessarily a potent medicinal agent and might well be included in the pharmacopœia, even if it is comparatively little used, whereas a plant known not to contain appreciable quantities of any of the classes of plant constituents to which medicinal value may be attributed should be excluded from the pharmacopœia, unless other evidence of its utility is conclusive.

Whenever any plant drug is introduced into the pharmacopœia, provision should also be made for suitable preparations of it, for physicians do not order crude plant drugs to be taken in substance. Such preparations as fluidextracts, tinctures, extracts and other rational pharmaceutical concentrations or solutions are, therefore, introduced into the pharmacopœia as the character of each drug may require. This rule has not been strictly observed in the past, for we find in the pharmacopœia of 1890 such drugs, for instance, as wormwood and pokeberries, without any preparations of these drugs.

In past generations it was held that the pharmacopœia should not recognize any *new* medicinal agent, but that the utility of a medicinal substance should be thoroughly demonstrated by many years of experience and observation before it could be consistently included among the official medicines. It was also held that any medicinal substance already introduced in the pharmacopœia ought not to be dropped unless its use had been discontinued. However, more rational ideas prevail at present.

555. Any substance of **definite chemical composition** may be rationally introduced into the pharmacopœia as soon as it is evident that it possesses physiological and medicinal effects indicating that it deserves to be tried in the practice of medicine.

556. It is no longer held that the presence of any given medicinal substance in the pharmacopœia constitutes evidence of its value, nor is it held that the absence of any medicinal substance from the pharmacopœia indicates that it does not deserve to be used, for it is now recognized that the functions of the pharmacopœia are not to recommend or condemn medicinal agents, but simply to provide means by which their identity, purity and strength may be fixed, so that physicians may attain reasonably uniform results from their use.

557. If there were no pharmacopœia or other means of establishing uniformity in medicinal agents, safe and scientific medication would be impossible. The tincture of digitalis dispensed in one drug store should be of precisely the same potency as in another. In the pharmacopœia of 1870 it was provided that opium in powder should contain not less than 10 per cent of morphine, but nothing was said about the maximum amount of morphine which powdered opium may contain without rendering it unsafe. Some samples of powdered opium contain about 20 per cent of morphine.

Hence under that pharmacopœia it was possible for one pharmacist to dispense a powdered opium twice as strong as that dispensed by another pharmacist. Clearly, that pharmacopœia failed in establishing a proper standard of strength for that drug. In 1880 the pharmacopœia ordered that powdered opium should contain not less than 12 per cent nor more than 16 per cent of morphine, and it was, therefore, possible while that pharmacopœia was in force to obtain powdered opium in one drug store that was one-third stronger than the powdered opium dispensed in another drug store. In 1890 the Revision Committee introduced in the pharmacopœia our present standard of morphine strength for powdered opium, which provides that the drug shall contain not less than 13 nor more than 15 per cent, but clearly the most proper standardization of powdered opium would be one requiring an absolutely fixed percentage of morphine, above or below which no deviation should be permitted, since it is as easy to enforce such a rigid and uniform standard as it is to enforce variable standards, for, in order to fix the morphine strength of opium in any manner, the opium must first be assayed, after which poorer and richer opiums are mixed until the average complies with the pharmacopœial requirements. Then the product can quite easily be made to have an absolutely fixed morphine strength. The Pharmacopœia of 1900 makes the strength of opium from 12 to 12½ per cent of morphine.

558. With reference to **tests for purity**, absolute freedom from all impurities is not insisted upon, unless necessary, because small amounts of other substances may be present in medicinal agents without impairing their medicinal value, and in such cases the purity tests are so framed as to insure satisfactory results without imposing hypercritical standards which cannot be attained without great difficulty.

559. The essential distinctive features of the text of the pharmacopœia are as follows: The *titles*, the *definitions* of the titles, the *descriptions*, the *identity tests*, the *purity tests*, the *potency tests* or quantitative tests, the *working formulas*, the directions for the preservation of the medicinal substances, the *general directions*, and the *tables*.

560. The **titles** of the medicinal substances in the pharmacopœia are of two kinds—the Latinic title and the technical English title. The Latinic title is not Latin, except in a minority of cases; it is simply Latinic in form. The reason for retaining at this day in the pharmacopœia Latinic titles for the medicinal substances is the ease with which scientific technical titles can be constructed having a Latinic form, and the great difficulty which is encountered in the effort to construct scientific technical titles of any other kind. The Latinic titles are in most cases arbitrarily coined words, and their meaning is specific and fixed.

In many pharmacopœias the Latinic titles of plant drugs are their only technical titles, for the other titles of the plant drugs are merely the popular names current among the people. A great change has been made in the American Pharmacopœia in this respect. Our pharmacopœia formerly employed such titles as "deadly nightshade," "dandelion," "foxglove" and "German chamomile." It now substitutes for those names the technical titles *belladonna*, *taraxacum*, *digitalis* and *matricaria*. Much remains to be done, however, to complete this commendable reform. There seems to be no good reason why in pharmacy and medicine we should not substitute the technical titles *myristica* for nutmeg, *viburnum prunifolium* for black haw (just as we have substituted *viburnum opulus* for cramp bark), *ulmus* for elm, *galla* for nutgall, *coccus* for cochineal, *allium* for garlic, etc.

The technical titles of plant drugs are usually the genus names of the plants from which the drugs are derived. In some cases they are old genus names now discarded by botanists, and in other cases they are species names now or formerly in use. The title of rhubarb is *rheum*, which is the botanical genus name of the plant yielding the root called rhubarb. The Latinic title of sweet flag is *calamus*, which is the species name of the plant *acorus calamus*, which yields the drug.

But in some cases the Latinic titles have no connection with the botanical names; they are arbitrarily adopted and purely pharmaceutical titles. The word *buchu* is used as a Latinic title and also as the English technical title for one of our much used drugs, but buchu is the name employed by the Hottentots to designate the drug. *Tragacantha* is the Latinic title of the gum which in English we call tragacanth, but the word tragacantha is not a botanical title.

In some pharmacopœias the Latinic titles of the plant drugs are generally made up of two words, one indicating the botanical source of the drug and the other the plant-organ or plant-part employed. For instance, the title of rhubarb is in such a pharmacopœia *rhei radix*, which translated into English means the root of rheum, whereas in the American Pharmacopœia rhubarb is given the Latinic title *rheum*, which is considered sufficient, because the root is the only part of rheum that is medicinally employed. But when two different organs of the same plant are separately employed as drugs it is, of course, necessary that the pharmacopœia should distinguish between them in the titles. Thus, our pharmacopœia gives belladonna root the title *belladonnæ radix* and belladonna leaves the title *belladonnæ folia.*

In cases where two or more different species of the same plant genus furnish drugs, the genus name is, of course, insufficient to designate each drug. In such cases, the species name is used together with the genus name. The Latinic title of peppermint is therefore *mentha piperita*, and the title of spearmint *mentha viridis.*

In naming Indian cannabis, which consists of the flowering tops of *cannabis sativa* grown in the East Indies, it is necessary to call it *Cannabis Indica*, because *cannabis sativa* grown in other countries does not constitute the drug.

Sometimes the botanical titles of plants yielding drugs are modified in their endings to transform them into specific titles for the drugs. The botanical title of the almond tree is *prunus amygdalus*, but the seed or almond is called *amygdala*. In the British Pharmacopœia the title for cloves is *caryophyllum*, derived from the old botanical name "caryophyllus."

The titles of pharmaceutical preparations are generally made up of two words, one indicating the character of the preparation and the other giving the name of the drug of which the preparation is made. Tincture of rhubarb is, for instance, called *tinctura rhei*, and the extract of rhubarb, *extractum rhei*. [The next chapter of this book will be devoted to Pharmaceutical Nomenclature.] After giving the Latinic title and then the English technical title, the pharmacopœia next names in brackets any very common or recently used English name or names. In speaking of gum arabic, the pharmacopœia, for instance, puts the text as follows:

ACACIA

Acacia

[*Gum Arabic*]

In this case it will be seen that the Latinic title and the English title are identical, as is the case with very many of the drugs of the pharmacopœia.

561. After the titles and common names of crude drugs and chemicals, we find next the **definition** of the title.

The definitions of *plant drugs* are very brief. They state what part of the plant constitutes the drug, the name of the plant itself, and the botanical family to which it belongs. The definition of the title *althæa* is: "The dried root of *Althæa officinalis*, Linné (Fam. *Malvaceæ*)." Aloe Socotrina is defined as, "The inspissated juice of the leaves of *Aloe Perryi*, Baker, *Aloe vera* (Linné), Webb, *Aloe Chinensis*, Baker, or other species of *Aloe* (Fam. *Liliaceæ*)." The definition of Cambogia is, "A gum-resin obtained from *Garcinia Hanburii*, Hooker filius (Fam. *Guttiferæ*)." The definition of Eucalyptus is, "The leaves of *Eucalyptus globulus*, Labillardiere (Fam. *Myrtaceæ*), collected from the older parts of the tree." That of Frangula is, "The dried bark of *Rhamnus Frangula*, Linné (Fam. *Rhamnaceæ*), collected at least one year before being used."

The definitions of chemical compounds are their molecular formulas, but these are sometimes supplemented by additional notes when the molecular formulas are not sufficiently definitive. Under the title of Hyoscyamine Hydrobromate, the molecular formula is given, but as hyoscyamine and atropine have the same molecular formula, it is necessary to add the statement that hyoscyamine hydrobromate is the hydrobromate of an alkaloid obtained from hyoscyamus.

Definitions are not given of the titles of pharmaceutical preparations, because the title itself and the directions given for making the preparation render a definition unnecessary.

562. After the definitions, the pharmacopœia gives necessary technical **descriptions.** These descriptions are framed in accordance with a general plan. They begin with the description of the most striking external features of the substances named, such as size, shape and color, afterwards mentioning such features and properties as require closer examination, as, for instance, the internal structure, odor and taste, solubility in common solvents, and specific weight, etc. Whenever practicable and useful, the pharmacopœia also calls attention to certain common signs of inferiority, and directs that drugs possessing certain stated evidences of unfitness shall not be used.

The following description of colchicum seed will serve to illustrate the general style:

"Subglobular, about 2 mm. in diameter, very slightly pointed at the hilum; externally reddish-brown, finely pitted; internally whitish; tough and of almost bony hardness; nearly inodorous; taste bitter and somewhat acrid."

The student will see that the descriptions are amplifications of definitions and are necessary to the intelligent selection of good drugs. When the pharmacopœia directs that leaves of the second year's growth constitute the drug, the first year's leaves must, of course, not be used. When the drug is to consist of the inner bark, the outer bark must be separated from it, and the inner bark must not be accompanied by any of the wood. When root-bark is ordered, stem-bark should not accompany it, nor should the whole root be used. Flowering tops should not be made to include the whole plant, and when the drug is defined and described as consisting of leaves, stems and stalks must be removed. Roots and rhizomes must be free from adhering dirt, etc.

A drug which has the fresh, natural color belonging to it when well cured and preserved, and which possesses in a high degree and unaltered the peculiar odor and taste which characterize it, will generally be found of satisfactory medicinal quality; but a drug which is discolored or the odor or taste of which is impaired cannot be of good quality.

Some of the drugs imported from distant parts of the world are found to require thorough garbling before they are fit for use. By garbling is meant the removal from a drug of admixtures, impurities, decayed portions, and other things that do not belong to it, under the pharmacopœial definitions and descriptions. Occasionally these admixtures and impurities amount to a considerable proportion; 20 per cent of sand is not uncommon in asafetida, and more than 20 per cent of stems and stalks, legumes and other admixtures in Alexandrian senna.

The following description of morphine sulphate will serve as an example of descriptions of *organic chemical compounds:*

"White, feathery, acicular crystals of a silky luster; odorless and having a bitter taste; permanent in the air.

"Soluble at 15° C. in 21 parts of water and in 702 parts of alcohol, in 0.75 part of boiling water, and in 144 parts of boiling alcohol; almost insoluble in ether.

"When heated for some time at 100° C., the salt loses three molecules (7.12 per cent) of water of crystallization; the remaining two molecules (4.75 per cent) are gradually expelled by raising the temperature to 130° C. At 255° C. the salt melts and upon ignition it is consumed, leaving no residue.

"The salt is neutral to litmus paper."

In reading this description, the student will observe how the various properties and behavior of the compound are mentioned in the order in which they may be most readily determined. To find the solubilities of substances, practical trials would be necessary, if the solubilities are to be employed as means of identification. The effects of various degrees of temperature must, of course, also be determined experimentally, and the reaction of a substance upon test paper ascertained by actual trial. But the color, form, odor and taste are more readily ascertained and are therefore mentioned first.

Descriptions of *inorganic chemical compounds* are exemplified by that given under the title potassium iodide:

"Colorless, transparent or translucent cubical crystals (the white, opaque commercial variety being crystallized from an alkaline solution and less pure), or a white granular powder having a peculiar, faint, iodine-like odor and a pungent, saline, afterwards bitter taste; permanent in dry air and but slightly deliquescent in moist air.

"Soluble at 15° C. in 0.75 part of water, and in 18 parts of alcohol, in 0.5 part of boiling water and in 6 parts of boiling alcohol; also soluble in 2.5 parts of glycerin.

"When heated the salt decrepitates. At a low red heat it fuses and at a bright red heat it is volatilized without decomposition.

"Its aqueous solution is neutral, or has at most a scarcely perceptible alkaline reaction upon litmus paper."

Descriptions of *pharmaceutical preparations* are rarely given in the American Pharmacopœia, but are not uncommon in other pharmacopœias. It may be assumed that when a pharmaceutical preparation is made out of proper materials which correspond to the descriptions given in the pharmacopœia and the directions are carefully carried out, the product will be uniformly of satisfactory character. But if the operator who makes the preparation uses improper materials or does not exercise sufficient care and skill, the product may be an unfit one, and it may be practicable to detect the unfit character of a pharmaceutical preparation even by its physical properties. Descriptions of pharmaceutical preparations therefore have practical value. An unfit tincture or fluidextract or oleoresin may, for instance, exhibit a color which deviates so far from the proper color of a good product that it may be immediately rejected solely on that sufficient evidence of unfitness. To illustrate, we may mention that tincture of *Cannabis Indica* made from a good drug and in the manner described in the pharmacopœia has a vividly green color, and if the pharmacopœia should mention that color, any tincture of *Cannabis Indica* not havingthat color would at once be recognized as not in accordance with the pharmacopœial requirements.

563. After the descriptions, the pharmacopœial text gives a series of tests called **identity tests**. These are applicable to chemicals. One of the tests by which sodium sulphite may be identified is that "when strongly heated, the compound emits vapors of sulphur and of sulphur dioxide and leaves a residue of sodium sulphate," although these facts alone are not sufficient for its identification. An additional identity test for sodium bisulphite is as follows: "On the addition of hydrochloric or sulphuric acid, the aqueous solution of the salt evolves sulphur dioxide, which is recognized by its odor and by its blackening a strip of paper dipped in mercurous nitrate test solution and held over the escaping gas." The description and identity tests applicable to ferric chloride are as follows:

"Orange-yellow, crystalline pieces; odorless or having a faint odor of hydrochloric acid and a strongly styptic taste; very deliquescent in moist air.

"Freely and completely soluble in water and in alcohol; also in a mixture of 1 part of ether and 3 parts of alcohol.

"At 35.5° C. the salt melts, forming a reddish-brown liquid. When strongly heated, it decomposes with the loss of water and hydrochloric acid, while the inodorous salt sublimes, leaving a residue of ferric oxide.

"The dilute aqueous solution of the salt is acid to litmus paper and yields a brownish-red precipitate with ammonia water, a blue one with potassium ferricyanide and, with silver nitrate, a white one insoluble in nitric acid."

564. Following the identity tests, the pharmacopœia next gives **tests for purity**. Under the head of ferric chloride, the purity tests are as follows:

"If the iron be completely precipitated from a solution of the salt by an excess of ammonia water, the filtrate should be colorless and should not yield either a white or a dark colored precipitate with hydrogen sulphide (absence of zinc or copper); nor should it leave a fixed residue on evaporation and gentle ignition (absence of salts of the fixed alkalies).

"On adding a clear crystal of ferrous sulphate to a cooled mixture of equal volumes of concentrated sulphuric acid and a moderately dilute solution of the salt, the crystal should not become colored brown nor should there be a brownish-black color developed around it (absence of nitric acid).

"If to a dilute solution of the salt a few drops of freshly prepared potassium ferricyanide solution be added, a pure brown color should be produced, without a tinge of green or greenish-blue (absence of ferrous salt).

"A 1 per cent aqueous solution of the salt when boiled in a test tube should remain clear (absence of oxychloride)."

565. The student will observe that the impurities which the tests are intended to disclose are indicated in parenthesis after each test. The impurities for which tests are prescribed are, of course, those which might naturally be expected to be found present in view of the materials employed in making the medicinal preparation and the manner in which those materials are used. When certain small amounts of impurities are tolerated, the tests prescribed establish the limits of toleration. This is illustrated by the following tests under the head of sodium carbonate:

"If 5 cc. of the aqueous solution be slightly supersaturated with acetic acid, the addition of 0.5 cc. of sodium cobaltic nitrite should not render it turbid within one hour (limit of potassium).

"If 1.2 gm. of the salt be dissolved in 10 cc. of diluted nitric acid, then 0.5 cc. of decinormal silver nitrate solution added and the precipitate, if any, removed by filtration, the clear filtrate should remain unaffected by the further addition of silver nitrate solution (limit of chloride).

"If 2.5 gm. of the salt be dissolved in 10 cc. of diluted hydrochloric acid and 0.1 cc. of nitric acid and 0.1 cc. of barium chloride solution added and the precipitate, if any, removed by filtration, the clear filtrate should remain unaffected by the further addition of barium chloride solution (limit of sulphate, sulphite and hyposulphite)."

566. After the purity tests, we find the **quantitative tests.** Under sodium carbonate the quantitative test is as follows: "To neutralize 1 gm. of inodorous sodium carbonate (deprived of its water of crystallization by heat immediately before being weighed) should require not less than 18.7 cc. of normal sulphuric acid (corresponding to not less than 98.9 per cent of the pure salt)."

Under the head of diluted hydrocyanic acid, the pharmacopœia states:

"To ascertain the percentage strength, mix in a flask of the capacity of about 100 cc. 0.27 gm. of hydrocyanic acid (obtained by the official process of preparation), with sufficient water and magnesia to make an opaque mixture of about 10 cc. Add to this two or three drops of potassium chromate solution and then from a burette decinormal silver nitrate solution until a red tint is produced, which does not again disappear by shaking. Each cc. of silver nitrate solution used indicates 1 per cent of absolute hydrocyanic acid.

"After ascertaining the strength of the distillate, dilute it with distilled water so as to bring it to the strength of 2 per cent of absolute acid. Lastly, test the finished product again, when 1.35 gm. of it should require for complete precipitation 10 cc. of decinormal silver nitrate solution."

In this case it is, of course, intended that any diluted hydrocyanic acid, in order to be fit for medicinal use, should be of exactly 2 per cent strength, and that consequently 1.35 gm. of it should require for complete precipitation no more and no less than 10 cc. of decinormal silver nitrate solution. The importance of this test will be appreciated from the fact that the pharmacist who dispenses the diluted hydrocyanic acid is responsible for its strength, no matter by whom the preparation may have been made, and that a diluted hydrocyanic acid materially deficient in strength, as well as a diluted hydrocyanic acid much too strong, may cause the loss of human life.

The solution of potassium arsenite of the pharmacopœia is a pharmaceutical preparation for which purity tests are unnecessary and impracticable, but for which a quantitative test is prescribed as follows: "If 24.7 cc. of the solution be boiled for a few minutes with 2 gm. of sodium bicarbonate and the liquor when cold diluted with water to 100 cc. and mixed with a little starch solution, it should require from 49.4 to 50 cc. of decinormal iodine solution to produce the blue tint of iodide of starch (corresponding to 1 gm. of arsenous acid in 100 cc. of the solution)."

567. The student will appreciate the fact that these several kinds of tests prescribed by the pharmacopœia must be intelligently applied; that pharmacists are responsible for the identity, purity and strength of the preparations they dispense, and that accordingly sufficient scientific training is a necessary preliminary to the practice of pharmacy. All the apparatus, reagents and other facilities necessary to the proper application of the pharmacopœial tests must be found in every properly equipped pharmacy, and a disregard of the pharmacopœial requirements in these particulars is treated as a violation of law, punishable according to the gravity of the case. No pharmacopœia in the world is more precise and careful in establishing just and proper tests of identity, purity and strength of medicinal substances than the American Pharmacopœia, but in no other country are the requirements of the pharmacopœia less generally respected. This neglect cannot continue much longer without jeopardizing the very existence of pharmacy as a distinct scientific technical occupation.

568. **Working formulas** are given by the pharmacopœia for preparations the character of which depends upon the materials and manipulations almost entirely, but the pharmacopœia does not give working processes for substances of definite chemical composition which may be made in various ways, and the character of which can be readily ascertained by tests.

The best assurance that tincture of rhubarb is in every way right would be derived from the use of perfect rhubarb and the conscientious and skillful application of the pharmacopœial directions in making it. If the pharmacist makes the preparation himself and possesses the requisite knowledge and skill, he will know of his own knowledge that the preparation is what it ought to be; but if he buys tincture of rhubarb made by some one else, there are no tests known by which the quality of the preparation can be certainly verified by himself, and he is then reduced to the necessity of depending upon the skill and knowledge of the manufacturer, and must take for granted that no mistake has been made nor any omission. The pharmacist who makes no pharmaceutical preparations, but simply dispenses the products of others, is not in a position to guarantee the satisfactory character of his materials. Every detail mentioned in the pharmacopœial directions for making any given preparation must be assumed to be necessary, and any modification or disobedience of directions usually results in failure to a greater or less extent.

569. All pharmacopœias contain certain **general directions**, usually placed in front of the body of the text enumerating the medicinal substances. To illustrate the general principles or rules, the following extracts from the Norwegian Pharmacopœia will serve our purpose: The introductory to the Norwegian Pharmacopœia requires that the metric system shall be used, and it says that whenever the word *parts* is

employed in working formulas, it shall be interpreted to mean parts by weight.

It orders that the thermometer of Celsius shall be used, and that the expression "common temperature" must be understood to be about 15°.

It orders that the specific weight of liquids be taken at a temperature of 15° and that the number employed to designate the specific weight shall refer to water of the same temperature as the unit of expression.

It explains that maceration is to be conducted at a temperature of from 15° to 25° and digestion at a temperature of from 30° to 45°.

It orders that wherever water is directed to be used, distilled water only shall be employed.

It gives directions for the collection, drying and preservation of plant substances, saying that unless otherwise directed, roots, rhizomes and tubers shall be collected in the spring before the leaves are fully developed, or in the fall when the plants whither, and that such drugs shall be freed from adhering dirt and other foreign substances before being dried. Barks are ordered to be preferably collected in the spring. Roots and herbs are to be collected when fully developed and, as a rule, at the time the flowers begin to expand. Flowers are to be collected when fully developed, and fruits and seeds when full-grown and mature. It orders that all plant drugs be collected in dry weather. It gives directions for drying the plant drugs at a temperature not exceeding 65°, and orders that these drugs be kept in well closed receptacles and protected against light and moisture.

It gives directions concerning the comminution and powdering of drugs.

It orders that every pharmacy must be provided with the facilities, apparatus and reagents necessary in carrying out the directions of the pharmacopœia for the preparation, preservation and testing of all medicinal substances.

It orders that all containers in the pharmacy shall be provided with labels conforming to the pharmacopœial Latinic nomenclature; that containers in which poisonous remedies are kept shall have labels with red letters and all others labels with black lettering.

It provides that substances which are volatile, or which are liable to attract moisture or to become altered under the influence of air or light, must be preserved in well closed receptacles, impervious to light.

It says that the table of maximum doses given in the pharmacopœia must be understood to refer to doses safe when administered to adults.

It finally declares that all medicinal substances must be in satisfactory conformity to all the requirements of the pharmacopœia, and that medicinal preparations for which the pharmacopœia gives detailed directions of preparation must be made by the pharmacists themselves and not obtained from manufacturers.

Test Questions

1. When did the third national convention for revising the American Pharmacopœia meet, and in what State?
2. How is the Pharmacopœial Convention constituted?
3. When did the convention meet last?
4. What is the difference between the Pharmacopœial Convention and the Pharmacopœial Committee of Revision?
5. Of how many members does the Revision Committee consist and how are those members selected?
6. What is the scope of a pharmacopœia?
7. What kinds of simple substances may be properly described in a pharmacopœia?
8. What substances of definite chemical composition may

it properly include, and what kinds of pharmaceutical preparations are legitimate in a pharmacopœia?

9. What kinds of medicines in common use are unfit to be included in a pharmacopœia?

10. Is there any reason for including in a pharmacopœia an entirely new remedy not yet sufficiently tried to establish its value?

11. What is the principal object of a pharmacopœia?

12. How is that object attained?

13. Is it possible to fix the strength of a pharmaceutical preparation made out of a plant drug? If so, how?

14. In analyzing the text of the pharmacopœia, how can the different parts of the text be classified with regard to their uses?

15. What is the origin of the Latinic titles of the plant drugs of the pharmacopœia?

16. How are the English technical titles of plant drugs obtained?

17. In what cases are the Latinic titles of plant drugs made to consist of more than one word?

18. State briefly the character of the definition of a plant drug.

19. What definitions are given for chemical compounds?

20. What are the objects of the descriptions?

21. In what cases of official medicines are the definitions and descriptions absent from the pharmacopœial text?

22. How are the tests in the pharmacopœia classified?

23. For what kinds of preparations does the pharmacopœia give explicit methods of production?

LESSON TWENTY-FOUR

XXXIV

The Latinic Nomenclature of the Pharmacopœia

570. About five hundred words have furnished the one thousand titles in the United States Pharmacopœia, and of these five hundred words, about one hundred are simply modifications or derivatives of other words included in the five hundred. Most of these words are derived from Greek roots, others from Latin roots, or from Arabic, and others again from different languages and names of places and men. All of the titles so far as practicable have been given a Latinic form by changing their endings.

A knowledge of the Latin language is not necessary to understand the Latinic nomenclature; in fact, some of the real Latin words used in the technical terminology of pharmacy do not have at all the same meaning when so used as they had or have in the Latin language; but to learn the construction of the pharmacopœial nomenclature and how to use it and abbreviate it correctly requires a knowledge of Latin declensions and of certain rules of abbreviation and other rules.

571. The most common endings of the Latinic titles are *us*, *a*, *um*, *as* and *is*. These nominative endings follow the Latin declensions.

The only title now at all used which follows the *fifth declension* is the word species. This is plural and its genitive is specierum.

There are five titles following the *fourth declension.* These are cornus, ficus, quercus, fructus and spiritus. Their genitives are identical with their nominatives.

All titles ending in *a* in the nominative follow the *first declension* and their genitive ending is *æ*, except that titles of Greek origin ending in *ma* in the nominative follow the third declension, having the genitive ending *matis*, as, for instance, gramma, gram′matis; physostigma, physostig′matis; aspidosperma, aspidosper′matis; theobroma, theobro′matis; enema, ene′matis.

All titles ending in *us* or *um* follow the *second declension* and have the ending *i* in the genitive. Certain words of Greek origin ending in *os* and *on* are treated as if their endings were *us* or *um.* The following examples of titles following the second declension will suffice: oxidum, oxidi; rubus, rubi; prinos, prini; hæmatoxylon, hæmatoxyli.

All words that do not follow the declensions already mentioned must, of course, follow the *third declension* if they are declined at all. Words following the third declension have very many different endings. Many of them have the nominative endings *as* and *is*, as, for instance, sulphas, nitras, sulphis, nitris. Other examples of words following the third declension are as follows:

lotio
tuber
radix
flos
semen
borax
calx

pix
adeps
juglans
piper
mel
mas
lac

The genitive ending of words following the third declension is *is.* It is easy to change the nominative to the genitive except in the third declension, where it is frequently necessary to introduce additional letters or to change both consonants and vowels of the nominative in order to make the genitive form sound euphonious. The following titles following the third declension are among those contained in the American Pharmacopœia:

Nominative	*Genitive*	*English Name*
adeps	adipis	lard
æther	ætheris	ether
alumen	aluminis	alum
anthemis	anthemidis	Roman chamomile
calx	calcis	lime
cannabis	cannabis	hemp
cantharis	cantharidis	Spanish fly
carbo	carbonis	charcoal
colocynthis	colocynthidis	colocynth
confectio	confectionis	confection
digitalis	digitalis	foxglove
fel	fellis	bile
hamamelis	hamamelis	witch hazel
hydrastis	hydrastis	golden seal
iris	iridis	blue flag
juglans	juglandis	butternut
limon	limonis	lemon
liquor	liquoris	liquid
macis	macidis	mace
mel	mellis	honey
mucilago	mucilaginis	mucilage
nux	nucis	nut
sinapis	sinapis	mustard
theobroma	theobromatis	chocolate
pepo	peponis	pumpkin
physostigma	physostigmatis	Calobar bean
piper	piperis	pepper
pix	picis	tar
pulvis	pulveris	powder
rhus	rhois	sumach
rumex	rumicis	yellow dock
sapo	saponis	soap

Nominative	*Genitive*	*English Name*
sassafras	sassafras	sassafras
styrax	styracis	storax
sulphur	sulphuris	sulphur
trituratio	triturationis	trituration
acetas	acetatis	acetate
arsenis	arsenitis	arsenite
benzoas	benzoatis	benzoate
boras	boratis	borate
carbolas	carbolatis	carbolate
chromas	chromatis	chromate
citras	citratis	citrate
hydrobromas	hydrobromatis	hydrobromate
hydrochloras	hydrochloratis	hydrochlorate
hypophosphis	hypophosphitis	hypophosphite
lactas	lactatis	lactate
nitras	nitratis	nitrate
nitris	nitritis	nitrite
oleas	oleatis	oleate
phosphas	phosphatis	phosphate
pyrophosphas	pyrophosphatis	pyrophosphate
salicylas	salicylatis	salicylate
sulphas	sulphatis	sulphate
sulphis	sulphitis	sulphite
tartras	tartratis	tartrate
cortex	corticis	bark
flores	florum	flowers
radix	radicis	root
semen	seminis	seed
semina	seminum	seeds

572. The Latinic titles of the *inorganic chemical compounds* are, of course, constructed out of the names of the elements. These names of the elements in Latinic form will be found on pages 46-48 of this book. It will be noticed that the Latinic names of all the elements of which any compounds are employed in pharmacy have the ending *um* or *ium* in the nominative, and that they accordingly must follow the second declension, except the name phosphorus

with the genitive phosphori, and the name sulphur with the genitive sulphuris.

In constructing Latinic titles for *binary compounds* the English ending *ide* is simply changed to *idum*, or, in other words, the final *e* is changed to *um*. Thus, a chloride is called *chloridum;* a bromide, *bromidum;* an iodide, *iodidum;* an oxide, *oxidum;* a sulphide, *sulphidum*, etc.

The Latinic titles of true *salts* are constructed by simply changing the English ending *ate* to *as* and the English ending *ite* to *is*. Thus, arsenate is called *arsenas;* arsenite, *arsenis;* carbonate, *carbonas;* chlorate, *chloras;* bicarbonate, *bicarbonas;* hypophosphite, *hypophosphis;* subsulphate, *subsulphas;* permanganate, *permanganas;* thio-sulphate, *thiosulphas*, etc. The student will readily understand that these arbitrarily constructed Latinic titles are in no sense Latin words.

573. Having learned how to construct the Latinic *generic titles* for *classes* of binary compounds and of salts, we may now construct the complete titles of specific substances. We do this as follows: As in naming a binary compound in English we first mention the positive element and then the generic title of the compound constructed out of the negative element with the ending *ide*, so, in constructing the Latinic title, we give the Latinic name of the positive element with its genitive ending and then the Latinic name of the generic title of the compound named; as, for instance, in naming iron chloride, we would say *ferri chloridum;* potassium hydroxide would be *potassii hydroxidum;* sodium iodide would be *sodii iodidum;* copper sulphate would be *cupri sulphas;* magnesium sulphite would be *magnesii sulphis;* sodium bicarbonate would be *sodii bicarbonas;* calcium hypochlorite would be *calcii hypochloris*, etc.

In constructing titles for *preparations* of the inorganic compounds, we must, of course, use the genitive of the entire title of the compound. Thus, solution of potassium hydroxide is called *liquor potassii hydroxidi;* solution of chloride of iron becomes *liquor ferri chloridi;* solution of nitrate of mercury is called *liquor hydrargyri nitratis;* syrup of iodide of iron is called *syrupus ferri iodidi;* compound syrup of the hypophosphites is called *syrupus hypophosphitum compositus.*

574. The Latinic title for acid is *acidum.* To this title we add an adjective indicating the *kind* of acid. The English adjectives ending in *ic* have corresponding Latinic equivalents ending in *icus* or *ica* or *icum*, according to the gender. English adjectives ending in *ous* have Latinic equivalents ending in *osus*, *osa*, *osum.* As the word acidum is neuter, the adjective used in naming acids must also be neuter. Hence, acetic acid is called *acidum aceticum;* arsenous acid is called *acidum arsenosum;* benzoic acid is called *acidum benzoicum;* boric acid, *acidum boricum;* citric acid, *acidum citricum;* gallic acid, *acidum gallicum;* hydriodic acid, *acidum hydriodicum;* hydrobromic acid, *acidum hydrobromicum;* hydrochloric acid, *acidum hydrochloricum;* hydrocyanic acid, *acidum hydrocyanicum;* hypophosphorous acid, *acidum hypophosphorosum;* lactic acid, *acidum lacticum;* nitric acid, *acidum nitricum;* nitrohydrochloric acid, *acidum nitrohydrochloricum;* oleic acid, *acidum oleicum;* phosphoric acid, *acidum phosphoricum;* salicylic acid, *acidum salicylicum;* sulphuric acid, *acidum sulphuricum;* sulphurous acid, *acidum sulphurosum;* tannic acid, *acidum tannicum;* tartaric acid, *acidum tartaricum.*

575. In naming pharmaceutical preparations of plant drugs and other medicinal substances, the generic title of the class to which the preparation belongs is always given first. We may say in English "compound solution of iodine," but in giving the Latinic title of that preparation we would not put the adjective first, but last. The title liquor is

placed first and so the title of the compound solution of iodine becomes *liquor iodi compositus.* We say "aromatic spirit of ammonia" in English, but in Latin the title is *spiritus ammoniæ aromaticus.* We say "heavy magnesia" in English, but we say *magnesia ponderosa* in Latin, because we always put the adjective last in any Latinic title. In naming extracts, tinctures, pills, powders, etc., we put these generic titles first and then give in the genitive the name of the drug or drugs from which the preparation is made. Hence, the title of extract of rhubarb must be *extractum rhei*, and of tincture of rhubarb *tinctura rhei.*

576. The Latinic titles of classes of pharmaceutical preparations in the American Pharmacopœia are as follows:

acetum	vinegar
aqua	water
ceratum	cerate
charta	paper
confectio	confection
decoctum	decoction
emplastrum	plaster
emulsum	emulsion
extractum	extract
fluidextractum	fluidextract
glyceritum	glycerite
infusum	infusion
linimentum	liniment
liquor	liquor ("solution")
massa	mass
mistura	mixture
mucilago	mucilage
oleatum	oleate
oleoresina	oleoresin
oleum	oil
pilula	pill
pilulae	pills
pulvis	powder
resina	resin
spiritus	spirit

suppositorium	suppository
suppositoria	suppositories
syrupus	syrup
tinctura	tincture
trituratio	trituration
trochiscus	troche
trochisci	troches
unguentum	ointment
vinum	wine

577. Certain Latinic **adjectives** are employed in pharmaceutical nomenclature to so great an extent that the student must learn them. They are the following:

English Form	Latinic Forms		
	Masculine	*Feminine*	*Neuter*
animal	animalis	animalis	animale
vegetable	vegetabilis	vegetabilis	vegetabile
soft	mollis	mollis	molle
flexible	flexilis	flexilis	flexile
mild	mitis	mitis	mite
volatile	volatilis	volatilis	volatile
green	viridis	viridis	viride
sweet	dulcis	dulcis	dulce
strong	fortis	fortis	forte
common	communis	communis	commune
glacial	glacialis	glacialis	glaciale
antimonial	antimonialis	antimonialis	antimoniale
simple	simplex	simplex	simplex
compound	compositus	composita	compositum
cut	incisus	incisa	incisum
contused	contusus	contusa	contusum
hard	durus	dura	durum
fluid	fluidus	fluida	fluidum
liquid	liquidus	liquida	liquidum
fused	fusus	fusa	fusum
heavy	ponderosus	ponderosa	ponderosum
dry	siccus	sicca	siccum
dried	exsiccatus	exsiccata	exsiccatum
white	albus	alba	album
yellow	flavus	flava	flavum
red	ruber	rubra	rubrum

English Form	Latinic Forms		
	Masculine	*Feminine*	*Neuter*
black	niger	nigra	nigrum
decolorized	decoloratus	decolorata	decoloratum
deodorized	deodoratus	deodorata	deodoratum
bitter	amarus	amara	amarum
aromatic	aromaticus	aromatica	aromaticum
absolute	absolutus	absoluta	absolutum
concentrated	concentratus	concentrata	concentratum
diluted	dilutus	diluta	dilutum
inspissated	inspissatus	inspissata	inspissatum
crude	crudus	cruda	crudum
pure	purus	pura	purum
impure	impurus	impura	impurum
purified	purificatus	purificata	purificatum
washed	lotus	lota	lotum
skinned	despumatus	despumata	despumatum
expressed	expressus	expressa	expressum
prepared	præparatus	præparata	præparatum
granulated	granulatus	granulata	granulatum
crystallized	crystallisatus	crystallisata	crystallisatum
sublimed	sublimatus	sublimata	sublimatum
distilled	destillatus	destillata	destillatum
rectified	rectificatus	rectificata	rectificatum
corrosive	corrosivus	corrosiva	corrosivum
aqueous	aquosus	aquosa	aquosum
alcoholic	alcoholicus	alcoholica	alcoholicum
reduced	reductus	reducta	reductum
sulphurated	sulphuratus	sulphurata	sulphuratum
monobromated	monobromatus	monobromata	monobromatum
ferric	ferricus	ferrica	ferricum
mercuric	hydrargyricus	hydrargyrica	hydrargyricum
nitrous	nitrosus	nitrosa	nitrosum
ferrous	ferrosus	ferrosa	ferrosum
mercurous	mercurosus	mercurosa	mercurosum
effervescent	effervescens	effervescens	effervescens
deliquescent	deliquescens	deliquescens	deliquescens

578. In naming pills, the pharmacopœia uses the plural in the Latinic title. Compound cathartic pills are therefore called *pilulæ catharticæ compositæ.* The genitive of this title is *pilularum catharticarum compositarum*, because the genitive plural in the first declension ends in *arum*.

579. Very few, if any, of the Latinic labels found upon the shop bottles in the drug stores are correctly abbreviated, if abbreviated in any way. Latin abbreviations do not follow the same rules as English abbreviations. The rules for abbreviations of Latin words are as follows:

No word should be abbreviated at all unless at least three letters are omitted, and all letters omitted in any abbreviation should be at the end of the word. The last letter written should always be a consonant, and the first letter omitted should always be a vowel. The letter *u* is treated as a vowel if it stands before a consonant; it is treated as if it were the consonant *v* if it stands in front of the vowel *e* or the vowel *i*, or whenever pronounced like *v*. Hence, the word unguentum can be abbreviated ungu., but it cannot be abbreviated ung. The following examples of correct and incorrect abbreviations will illustrate the rules:

Words in Full	*Correct Abbreviations*	*Incorrect Abbreviations*
tinctura	tinct.	tin. tinc.
emplastrum	empl.	emp. emplas.
extractum	extr.	ext.
acetatis	acet.	acetat
potassii	pot.	potas.
spiritus	spir.	sp. spirit.
syrupus	syr.	syru.

580. Among the words that should never be abbreviated are acidum, aqua, æther, iodum, cerium, opium, oleum, aloes, aurum, barium, bromum, calcium, ferrum, cuprum, lithium, zincum, plumbum, acacia, cera, scilla, rheum, etc., for reasons understood from the rules given.

Abbreviations which are ambiguous should never be made. The title aqua acidi carb. if written upon a prescription may stand for carbolic acid water or for carbonic acid water. The abbreviation chlor. hydr. may mean chloral hydrate or calomel or corrosive sublimate. Sodii chlor. may mean either sodium chloride or sodium chlorate. Cal. may mean calumba or it may mean calendula or calycanthus. Col. may mean colchicum or columbo or collinsonia, since it is well known that abbreviations are more frequently incorrect than correct. The abbreviation aq. am. may be a poor attempt at abbreviating aqua ammoniæ or aqua amygdalæ; sulph. may be an abbreviation of sulphatis or it may be an abbreviation of sulphidi; elat. may be an abbreviation of elaterium or an abbreviation of elaterinum.

581. Several of the titles of drugs are indeclinable. All words ending in *ol*, *yl*, *al* and *ul* are generally treated as indeclinable, as, for example, alcohol, menthol, phenol, thymol, benzol, amyl, æthyl, methyl, phenyl, chloral and sumbul. Other indeclinable words are some that have been derived from the languages of savage tribes and cannot be conveniently given a Latinic form, as, for example, azedarach, buchu, catechu, coca, curare, elemi, jaborandi, kamala, kino, kousso, matico and sago.

Test Questions

1. Why are the principal titles of the pharmacopœial drugs and preparations said to be Latinic?
2. Name the Latinic titles following the fifth declension.
3. Name those following the fourth declension.
4. State what titles follow the first declension.
5. What titles follow the second declension?
6. What titles follow the third declension?
7. What are the nominative and genitive endings of the respective declensions?

8. Give the genitives of the following titles: Sal, berberis, cortex, nitras, sulphis, borax, rumex, juglans, zingiber, gargarisma, cannabis, liquor, flores, semina, folia.

9. Write in full the Latinic titles of the following articles, also the proper abbreviations of those Latinic titles: tincture of aconite, lard oil, oleoresin of male fern, fluidextract of buchu, extract of Cannabis Indica, cerate of cantharides, infusion of digitalis, licorice root, wine of aloes, fluidextract of nux vomica, spirit of myristica, extract of physostigma, emulsion of almond, oleoresin of pepper, resin of podophyllum, syrup of wild cherry, oak bark, glycerite of hydrastis, decoction of sarsaparilla, vinegar of squill, compound infusion of senna, extract of stramonium seed, ammoniated tincture of valerian, fluidextract of veratrum viride, aromatic spirit of ammonia, the seed of aspidosperma, herb of tussilago, vegetable cathartic pills, suppositories of opium, ointment of nitrate of mercury, nitrate of silver, acetate of lead, oxide of mercury, chloride of gold, sulphate of copper, dioxide of manganese, iodide of arsenic, hydrochloric acid, hydrocyanic acid, boric acid, arsenous acid, sulphurous acid, aromatic sulphuric acid, zinc carbonate, zinc phosphide, oxide of calcium, hydroxide of aluminum, red oxide of mercury, yellow iodide of mercury, black sulphide of antimony, sodium hydroxide, ferric hydroxide, ferrous sulphate, ferric sulphate, ammonium chloride, potassium bromate, solution of chloride of iron, solution of ferric sulphate, mild chloride of mercury, corrosive chloride of mercury, syrup of ferrous iodide, chlorate of potassium, valerate of zinc, dried sulphate of iron, saccharated carbonate of iron, bicarbonate of sodium, permanganate of potassium, syrup of lactophosphate of calcium, compound syrup of the hypophosphites, chlorine, bromine, iodine, carbon, antimony, carbonic acid water, solution of hydrogen dioxide, glacial

acetic acid, calcium hypochlorite, sodium thio-sulphate, potassium chromate, bitartrate of potassium, oxalate of iron, chloride of gold and sodium, tartrate of potassium and sodium, saccharated iodide of iron, sulphurated potassa, sulphurated antimony, yellow subsulphate of mercury, aluminum and ammonium sulphate, alum, dried alum, precipitated phosphate of calcium, granulated sulphate of copper, crystallized nitrate of silver, fused nitrate of silver, diluted hypophosphorous acid, soluble phosphate of iron, dried sodium carbonate, subnitrate of bismuth, potassium dichromate, solution of potassium arsenite, solution of arsenous acid, solution of iodide of mercury and arsenic, oleate of mercury, tartrate of iron and potassium, citrate of iron and quinine, solution of citrate of magnesium, mercury with chalk, pure hydrochloric acid, purified antimony sulphide, deodorized alcohol, hard soap, soft soap, sublimed calomel, distilled water, expressed oil of nutmeg, volatile oil of mustard, alcohol, extract of belladonna, washed sulphur, prepared chalk, prepared calcium carbonate, sublimed sulphur, heavy magnesia, precipitated oxide of mercury, precipitated sulphate of iron, strychnine, morphine, cocaine, salicin, lupulin, aconitine, ether, acetic ether, absolute alcohol, glycerin, pepsin, sugar, milk sugar, chloral, purified chloroform, quinine sulphate, quinine hydrochloride, morphine hydrochloride, physostigmine salicylate, hyoscine hydrobromide, syrup of hydriodic acid, solution of acetate of ammonium, lime solution, compound solution of iodine, solution of chlorinated soda, ointment of subacetate of lead, confection of senna, resin of jalap, powder of ipecac and opium, trituration of morphine sulphate, troches of licorice and opium, mercury mass, potassium nitrate paper, compound iron mixture, peppermint water, mucilage of tragacanth, compound tincture of cinchona, compound morphine powder, camphorated soap liniment, chlorine water, aqueous extract of aloes, aromatic fluidextract, fluidextract of bitter orange peel, fluidextract of colchicum seed, saccharated pepsin, antimonial powder, spirit of nitrous ether, tincture of arnica flowers, tincture of kino, deodorized tincture of opium, tincture of deodorized opium, tincture of green soap, ointment of ammoniated mercury, effervescent citrate of magnesium.

LESSON TWENTY-FIVE

XXXV

The Pharmacopoeia of the United States Eighth Revision—A.

In order to acquire sufficient familiarity with the style, scope and contents of the pharmacopoeia, the student should study certain portions of it as indicated in the following suggestions:

Read the titles and definitions, including the percentage strength, of acetic acid, diluted acetic acid, glacial acetic acid, diluted hydriodic acid, diluted hydrobromic acid, hydrochloric acid, diluted hydrochloric acid, diluted hydrocyanic acid, hypophosphorous acid, diluted hypophosphorous acid, lactic acid, nitric acid, diluted nitric acid, phosphoric acid, diluted phosphoric acid, sulphuric acid, diluted sulphuric acid, sulphurous acid.

Learn the definitions and percentage strength of ether, acetic ether, alcohol, absolute alcohol, diluted alcohol, ammonia water, stronger ammonia water, solution of arsenous acid, solution of ammonium acetate, solution of arsenous and mercuric iodides, lime water, chlorine water, solution of ferric chloride, solution of ferric subsulphate, solution of ferric sulphate, solution of formaldehyde, solution of mercuric nitrate, compound solution of iodine, solution of lead subsulphate, diluted solution of lead subsulphate, solution of potassium arsenite, solution of potassium hydroxide, solution of sodium arsenate, solution of sodium hydroxide and solution of zinc chloride.

Read the methods of preparation of vinegar of opium and vinegar of squill.

Read the general paragraph concerning waters on page 49 and the methods of preparation of the aromatic waters, from bitter almond water to rose water.

Study the formulas for the preparation of cerates on pages 93-95.

Read the processes of preparation of the collodions on pages 113 and 114, and look up the definition of pyroxylin in the proper place.

Read the formulas for confections on page 115; the general directions for the preparation of decoctions and infusions, suppositories and tinctures of fresh drugs.

Read the formulas for plasters on pages 124-127.

Study the emulsions, pages 127-130.

Test Questions

1. What is the percentage strength of the diluted acids of the pharmacopoeia?

2. Does the percentage strength of any one of the pharmacopoeial acids bear a simple relation to the molecular weight?

3. How many pounds of diluted hypophosphorous acid can be made from ten pounds of hypophosphorous acid?

4. What is the difference between the undiluted nitric acid of the pharmacopoeia and absolute nitric acid?

5. What is the difference between absolute ether and official ether?

6. Give the molecular formulas of ether, acetic ether and alcohol.

7. How is diluted alcohol made?

8. What is the percentage strength of diluted alcohol and the percentage strength of alcohol?

9. In what proportions would you mix official alcohol

and official diluted alcohol to produce an alcohol of 60% strength?

10. What is them olecular weight of ammonia, and what is the molecular weight of ammonium hydroxide?

11. What percentage of ammonium hydroxide is contained in a solution containing 10% of ammonia?

12. How much stronger ammonia water is necessary to make twenty-eight pounds of ammonia water?

13. What is the difference between arsenous oxide and arsenous acid?

14. How much arsenous acid is contained in one hundred parts of a solution made out of one part of arsenous oxide?

15. What percentage of acetic acid is contained in the official solution of ammonium acetate?

16. What percentage of the element arsenic is contained in the solution of arsenous and mercuric iodides, and what percentage of mercury?

17. How much calcium hydroxide will be formed by twelve grams of lime?

18. What is chlorine water, according to the new pharmacopoeia?

19. Crystallized ferric chloride is $FeCl_3 + 6H_2O$. How much crystallized ferric cholride can be made from one hundred parts of the official solution?

20. What is the principal difference between solution of ferric subsulphate and solution of ferric sulphate, as shown by the proportions of the materials employed in their preparation?

21. What is pharmacopoeial formaldehyde solution?

22. What is formed besides mercuric nitrate when mercuric oxide is dissolved in nitric acid?

23. What is compound solution of iodine?

24. What is solution of magnesium citrate?

25. How many ounces of diluted solution of lead subace-

tate can be made out of one ounce of the official solution of lead subacetate?

26. What is the percentage of As in solution of potassium arsenite?

27. How do you reconcile the proportions of potassium hydroxide and water in the formula for the preparation of solution of potassium hydroxide with the official statement of percentage strength of that solution?

28. What proportions of sodium hydroxide and water are necessary to make one kilogram of a 5% solution?

29. What is the percentage of Zn in the official solution of zinc chloride?

30. By what process are the official vinegars made?

31. In what respect does the process for the preparation of bitter almond water differ from the methods directed for the preparation of other aromatic waters?

32. How would you make a saturated solution of chloroform in water?

33. What aromatic waters of the pharmacopoeia are made by distillation?

34. How is a saturated solution of camphor in water prepared?

35. What waters of the pharmacopoeia are not aromatic waters?

36. What resemblance do you find between the composition of cantharides cerate and resin cerate?

37. What cerates of the pharmacopoeia contain white petrolatum?

38. Why is wool fat contained in the cerate of lead subacetate?

39. What constitutes the body of the official collodions?

40. How is the painful contraction of the collodion film left upon evaporation of an application of collodion prevented?

41. What confections are retained in the pharmacopoeia?

42. State how decoctions are made.

43. How are infusions made?

44. What are the general directions of the pharmacopoeia relative to the preparation of suppositories?

45. What is the general method directed by the pharmacopoeia for the preparation of tinctures of fresh vegetable drugs?

46. What is adhesive plaster, according to the new pharmacopoeia?

47. What official plasters are made from solid extracts?

48. What is the new process for the preparation of lead plasters?

49. Name the fixed oil emulsions, volatile oil emulsions, gum resin emulsions and seed emulsions of the pharmacopoeia.

50. How is the emulsion of cod liver oil made?

51. What resemblance do you note between the process for preparing emulsion of oil of turpentine and that for preparing emulsion of chloroform?

LESSON TWENTY-SIX

XXXVI

The Pharmacopoeia of the United States—B.

Study the working formulas for the preparation of solid extracts, pages 133-150. In studying these extracts, observe that some of them are made with water, others with undiluted alcohol, others with a mixture containing more alcohol than water, others with equal parts of alcohol and water, and still others with a menstruum consisting of more water than alcohol. Note which of these extracts are of pilular consistence and which of them are dry; also which of the dry extracts are ordered to be powdered. Note that some of them are diluted with powdered sugar of milk and others with powdered licorice root. Note, also, that some of the solid extracts are of definite potency, being adjusted to a fixed percentage of alkaloidal contents. Learn, also, which of the solid extracts are prepared by the evaporation of fluid extracts.

Next study the fluid extracts. Note which of them are made with undiluted alcohol and which are made with mixtures of alcohol and water, containing either more alcohol than water, more water than alcohol, or equal volumes of alcohol and water. Also note which of the fluid extracts are ordered by the pharmacopoeia to be assayed and adjusted to a fixed standard of strength.

Learn how the glycerites are made, as described on pages 224-226.

Read the formulas for infusions on pages 247 and 248 and compare those formulas with the general directions beginning at the foot of page 246.

Read and compare with each other the formulas for liniments on pages 255-257.

Examine the formulas for masses on page 286.

Read the formulas for mixtures on pages 292 and 293, then study the mucilages on pages 296 and 297.

Study the oleates on pages 300 and 301 and note that they are not preparations of definite chemical composition, but simply solutions of alkaloids in oleic acid and olive oil, except the oleate of mercury, which is a solution of oleate of mercury in oleic acid.

Examine the formulas for oleoresins on pages 202-204 and observe that this class of preparations has been materially changed in the new revision of the pharmacopoeia, being now prepared with acetone instead of with ether.

Read the titles and definitions of the oils. Note which of them are fixed oils and which are volatile oils, and which of them are not oils at all, although bearing that title.

Compare the standards of strength of powdered opium, opium, deodorized opium and granulated opium on pages 328-331.

Read the definition and description of pepsin and of pancreatin.

Study the formulas for pills on pages 345-350.

Study the formulas for compound powders on pages 368-371.

Read the processes for the preparation of precipitated resins on pages 378-381.

Read the formulas for spirits on pages 413-421. Note which of them are solutions of volatile oils in alcohol, which of them are alcoholic solutions of ether compounds, which of them are solutions of gases and which of them are well-known liquors.

Read the formula for syrups, pages 435-448. Note which of them contain active medicinal agents and which of them are merely flavoring media. Also note which of the syrups are solutions of inorganic substances.

Study the formulas for the preparation of tinctures on pages 453-485. Observe which of these tinctures are made with undiluted alcohol and which are made with mixtures of alcohol and water, containing more alcohol than water, those made with more water than alcohol and those made with official diluted alcohol. Also note what tinctures are made with aromatic spirit of ammonia. Learn which tinctures contain inorganic active constituents. Learn what tinctures are made from fluid extracts, and learn also what tinctures are assayed and adjusted to a definite standard of strength by that means. Learn what tinctures are of 5% and which are of 10%, 15% and 20% strength or other standards of strength, with reference to the kind of drug used.

Read the general formula for triturations and the formula for trituration of elaterin.

Study the formulas for troches on pages 486-489.

Make yourself acquainted with ointments of the pharmacopoeia by reading the formulas for their preparation on pages 490-497.

Read the formulas for the official wines on pages 501-503.

Test Questions

1. How much belladonna leaves is represented approximately by one gram of the extract?

2. What menstruum is used in the preparation of extract of aloes?

3. What menstruum is used in preparing extract of cannabis indica?

4. What is compound extract of colocynth?

5. Enumerate the aqueous extracts of the pharmacopoeia.

6. What solid extracts are prepared from fluid extracts?

7. What extracts of the pharmacopoeia are prepared with acetic acid?

8. How much powdered opium equals one gram of extract of opium?

9. What powdered extracts are contained in the pharmacopoeia?

10. Which of the official extracts are assayed?

11. What fluid extracts are assayed?

12. Are any of the official fluid extracts prepared with water?

13. What fluid extracts are prepared with undiluted alcohol?

14. Are there any fluid extracts in the pharmacopoeia which deviate from the rule that one cubic centimeter represents the activity of one gram of the drug? If so, which of them?

15. In what fluid extracts is acetic acid contained?

16. What is glycerite of starch?

17. What is boroglycerin?

18. In what respect does glycerite of hydrastis resemble the fluid extract of hydrastis?

19. What glycerites of the pharmacopoeia are liquid glycerin solutions?

20. How is infusion of digitalis made?

21. In what respect does the formula for infusion of wild cherry deviate from the general directions for the preparation of infusions?

22. What is lime liniment?

23. What is ammonia liniment?

24. How is soap liniment prepared?

25. Is the mass of ferrous carbonate a galenical or a chemical preparation?

26. How much mercury is contained in a pound of mercury mass?

27. How is compound iron mixture made?

28. Which of the official mucilages are liquid and which are solid?

29. How much olive oil is contained in oleate of veratrine?

30. In what respect do the methods of preparation ordered for oleoresin of cubeb and oleoresin of pepper differ from the directions given for the preparation of other oleoresins?

31. Mention five fixed oils and ten volatile oils.

32. What is the official standard of strength of pepsin?

33. In which of the official pills is soap an ingredient?

34. In which of the official pills is aloes contained?

35. Which of the official pills contain iron?

36. In what official pills do chemical reactions attend the method of preparation?

37. What is aromatic powder?

38. What are the most notable differences between the several processes for the preparation of the precipitated resins of the pharmacopoeia?

39. Which of the spirits of the pharmacopoeia are not solutions of volatile oils?

40. Which of the official syrups contain inorganic substances?

41. Which of them are made from fluid extracts?

42. Enumerate the tinctures which are approximately of 5% strength.

43. Is it strictly true that when 100 Cc. of tincture is made from 20 grams of drug, that tincture is of 20% strength? If not, why not?

44. How much tincture of nux vomica represents 1 Cc. of the fluid extract?

45. What tinctures of the pharmacopoeia are mere mixtures of the fluid extract with more or less diluted alcohol?

46. What is the percentage strength of tincture of aconite of the new pharmacopoeia?

47. What is the percentage strength of the new tincture of veratrum?

48. How would you make trituration of strychnine?

49. What is the most common adhesive excipient ordered in the preparation of the troches of the pharmacopoeia?

50. What is the maximum weight and the minimum weight of each of the official troches?

51. What is "ointment"?

52. What is diachylon ointment?

53. How is rose water ointment made?

54. What is the difference between mercurial ointment and blue ointment?

55. Which of the official ointments are made of solid extracts?

56. What official wines are made of fluid extracts?

57. What official wines contain inorganic substances?

LESSON TWENTY-SEVEN

XXXVII

The Pharmacopoeia of the United States—C.

Learn the Latinic and English titles of the vegetable drugs of the pharmacopoeia by reading their titles and definitions, and note which of them are provided with an official standard of strength. Make separate lists of the vegetable drugs, consisting of (1) herbs, (2) leaves, (3) flowering tops, (4) flowers, (5) fruits, (6) seeds, (7) stems and barks, (8) woods, (9) rhizomes, bulbs and corms and (10) roots.

Read the formulas for the preparation of benzoinated lard, purified aloes, molded silver nitrate, medicated silver nitrate, citrated caffeine, effervescent citrated caffeine, cataplasm of kaolin, mustard paper, adjuvant elixir, aromatic elixir, elixir of iron, quinine and strychnine, purified oxgall, glycerinated gelatin, effervescent lithium citrate, effervescent magnesium sulphate, clarified honey, honey of rose, soft soap, effervescent sodium phosphate, purified talc.

To learn doses, make tables or lists of all the official remedies for which the pharmacopoeia gives doses, dividing the medicinal substances into groups according to the size of the doses, as follows:

(*a*) Doses of less than 1 milligram.
(*b*) 1 to 3 milligrams.
(*c*) 4 to 10 milligrams.
(*d*) 10 to 30 milligrams.
(*e*) 30 to 100 milligrams.

(*f*) 100 to 300 milligrams.
(*g*) 300 to 1000 milligrams.
(*h*) 1 to 3 grams.
(*i*) 4 to 8 grams.
(*j*) All substances having doses exceeding 8 grams.

Test Questions

1. What crude vegetable drugs of the pharmacopoeia are directed to be assayed?
2. What is aconite?
3. What is althaea?
4. What is manna?
5. What is spermaceti?
6. What is cardamom?
7. What is buchu?
8. What is eucalyptus?
9. What is valerian?
10. What is copaiba?
11. What is aspidium?
12. What is lupulin?
13. What is jalap?
14. What is podophyllin and podophyllum?
15. What is cannabis indica?
16. What is myrrh?
17. What is rhubarb?
18. What is senega?
19. What is squill?
20. What is frangula?
21. What is senna?
22. What is digitalis?
23. What is colocynth?
24. What is aloes?
25. What is ergot?
26. What is catechu?

27. What is gambir?
28. What is kino?
29. What is opium?
30. What is hyoscyamus?
31. What is conium?
32. What is nux vomica?
33. What is veratrum?
34. What is ipecacuanha?
35. What is prunus virginiana?
36. How is purified aloes made?
37. How are the effervescent salts of the pharmacopoeia made?
38. Describe the preparation of purified oxgall?
39. What is glycerinated gelatin?
40. State the doses of aconitine, strychnine, morphine, diluted hydrocyanic acid, tincture of aconite, extract of nux vomica, extract of Calabar bean, extract of belladonna, fluid extract of colchicum, extract of conium, tincture of hyoscyamus, aloin, elaterin, resin of podophyllum, extract of digitalis, tincture of cannabis indica, oil of turpentine, hydrated chloral.

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