

malt extract be examined for diastase; trinitrocellulin be made; acetic aldehyde be fully examined and aldehyde-ammonia be prepared; lactic acid be made; benzoic and salicylic acids and aldehydes be obtained; natural urea be extracted and artificial urea be made; the glucosides be examined; and one or two artificial alkaloids be prepared, etc. Melting-points and boiling-points of pure substances should be taken; and fractional distillation should be applied either to acetic acid with a view to separate glacial acid on the one hand from water or weak aqueous acid on the other, to mixed alcohol and water with the object of attempting their re-separation as far as possible, or to some such mixture. Especially must the operations of quantitative analysis of organic compounds, in due time, be fully and thoroughly performed.

Other Students.—Students who have no occasion to apportion their periods of study in the manner contemplated in the previous two paragraphs are recommended to go through the succeeding sections as they have gone through the foregoing—namely, page by page.

Note.—Students will find that in working at organic chemistry, so called, they are not departing from the method of study hitherto pursued. Hitherto they have concentrated attention on the chief elements, one at a time; they are now about to investigate the compounds of another of those elements; that is all. But it is an element having a far greater range of combining powers than any yet examined. Organic chemistry is the chemistry of the element *carbon*.

ORGANIC CHEMISTRY;*

OR,

THE CHEMISTRY OF CARBON COMPOUNDS.

INTRODUCTION.

EXCEPT alcohol and a few acids, the large number of compounds which have hitherto engaged notice in this Manual have been of mineral origin. But the two other kingdoms of nature, the animal and vegetable, furnish still larger numbers of definite substances. These latter compounds, indeed, when discovered, were producible *only* by organized living structures, and were hence termed *organic* (from *ὄργανον*, *organon*, an organ), and their study was termed *organic chemistry*. A very large number of organic compounds can now, however, be obtained artificially, without the aid of a living organism; hence the particular distinction formerly drawn between organic and inorganic compounds, organic and inorganic chemistry, no longer fully obtains. Another definition, or additional definition, of organic chemistry or the chemistry of animate nature, the laws of which do not differ from those of inanimate nature, is now generally adopted—namely, *the chemistry of carbon compounds*. No doubt two or three kinds of compounds of carbon—carbonic acid gas and carbonates, for example—are met with in the mineral kingdom, and are therefore inorganic compounds; but they are met with in the organic kingdoms too, and therefore are organic compounds also.

Practically, all carbon compounds are organic compounds, and all of the so-called organic compounds are carbon compounds; hence the old term, *organic chemistry*, no longer being etymologically and fully applicable, that of *the chemistry of the carbon compounds* seems natural as well as useful. Moreover, the carbon atoms possess in an altogether exceptional degree a property either not possessed, or only to a slight extent possessed, by those of other elements—namely, the property of combining with one another and forming a sort of chain, to every link of which atoms of other elements can be attached, the result being obviously molecules of almost infinite variety and complexity—a fact which alone suffices to secure for carbon special and separate consideration by chemists. In short, the chemistry of the carbon compounds includes what was formerly as well as what is now known as organic chemistry; or, in other words, the chemistry of organized or animate nature is included in the

* Read the two previous pages of *Advice to Students*.

chemistry of the carbon compounds. Of course, so old and historically interesting a term as *organic chemistry* will continue to be used; and there is no objection to such use, provided students remember that when the term is used as the equivalent of *the chemistry of the carbon compounds*, it is only conventionally and not etymologically accurate. Moreover, the chemistry of a carbon compound includes the chemistry of every element in that compound and the chemistry of the compound as a whole—facts which obtain even more prominence if the chemistry be spoken of by a general word, such as *organic*, rather than by the specific word *carbon*. Indeed, an organic compound sometimes seems to be conditioned as much by its *nitrogen* as its *carbon*. The word *organic* having now in chemistry lost its original specific signification, and having acquired the general signification described, it becomes, by its associations, perhaps the best word that can be chosen as the title of the great division of chemistry now under consideration.

COMPOSITION OF ORGANIC COMPOUNDS.

(a) *Qualitative Composition*.—The presence of carbon in a compound is at once shown if the compound blackens when a little is heated on a knife or platinum-foil in a flame. If the substance is heated in a dry, narrow test-tube, and much moisture is condensed on the upper cool part of the tube, the presence of hydrogen and oxygen is reasonably inferred. Nitrogen may be sought by carefully but strongly heating in a test-tube a small portion of the substance with a very small piece of potassium, and, after all action ceases, digesting the residue in water, filtering, and adding to the filtrate a ferrous salt, a ferric salt, and hydrochloric acid; a precipitate of Prussian blue indicates nitrogen. Chlorine, bromine, iodine, sulphur, and phosphorus may be detected by heating the substance with nitric acid and nitrate of silver in a very carefully and strongly sealed tube (in a fume-chamber, with such precautions that if the tube burst no harm to the operator shall ensue), and testing the product for chlorides, bromides, iodides, sulphates; and phosphates by methods already described.

(b) *Quantitative Composition*.—The qualitative composition of an organic substance being ascertained, the quantities of each element are then determined by methods which the student will practise when he is sufficiently advanced to work at the sections on quantitative analysis. The principles of the methods are, however, simple, and may at once be described. For the quantitative estimation of *carbon* and *hydrogen* a carefully weighed portion of the substance is completely burned; the products, which are, of course, carbonic acid gas and water, are collected and accurately weighed. Of every 44 parts of the carbonic acid gas ($\text{CO}_2 = 44$), 12 will be carbon, and of every 18 parts of the water ($\text{H}_2\text{O} = 18$), 2 will be hydrogen; in other words, three-elevenths of the weight of carbonic acid gas obtained will be the carbon of the original substance, while one-ninth of the water obtained will be the hydrogen of the original substance. If *nitrogen* be present, another carefully weighed portion of the sub-

stance is heated with a mixture of soda and lime; the nitrogen then takes up hydrogen and becomes ammonia, which is collected and accurately weighed; of every 17 parts of ammonia ($\text{NH}_3 = 17$), 14 will be nitrogen. The amounts of *chlorine*, *sulphur*, etc.—elements not often present—are obtained by subjecting carefully weighed portions of the original substance to the nitric treatment already alluded to, collecting and weighing the products, and calculating what proportions of the products are chlorine, sulphur, etc. The amount of *oxygen* is ascertained by difference; that is to say, the difference between the sum of the weights of carbon, hydrogen, nitrogen, etc. and the original weight of substance will be the weight of the oxygen in that original weight of substance.

For example, a fluid having well-marked definite properties, and known to contain only carbon, hydrogen, and oxygen, is so burned that 0.3 of a gramme* of it yields 0.5738 of a gramme of carbonic acid gas and 0.3521 of a gramme of water. As three-elevenths of the carbonic acid gas and one-ninth of the water are hydrogen, it follows that the 0.3 of substance contains 0.1565 of carbon and 0.0391 of hydrogen; and the difference between these two figures and 0.3 being 0.1044, it follows that 0.1044 is the amount of oxygen in the 0.3 of original substance. For, $0.5738 \times 3 \div 11 = 0.1565$; and $0.3521 \div 9 = 0.0391$; $0.3 - (0.1565 + 0.0391) = 0.1044$.

(c) *Centesimal Composition*.—It is usual to make at least two such analyses of any organic compound, and as different weights of the original substance will almost necessarily be subjected to combustion (for it is easier to counterpoise by weights a selected quantity than it is to counterpoise with the substance any selected weights), the results of the combustions can only be compared by converting the numbers first obtained into percentages; that is to say, by assuming in, for instance, the present case that not 0.3 parts of substance were operated on, but 100 parts. This is one of the simplest of arithmetical operations. If 0.3 of substance yields 0.1565 of carbon, 100 of substance will yield 52.17 of carbon; if 0.3 of substance yields 0.0391 of hydrogen, 100 of substance will yield 13.03 of hydrogen; and if 0.3 of substance yields 0.1044 of oxygen, 100 of substance will yield 34.80 of oxygen.

(d) *Chemically Empirical Composition*.—But the chemist further desires to know, not so much what percentages or ordinary unit-weights of elements are contained in the compound, but what relative number of chemical unit-weights or atomic weights are present—how many parts of carbon each weighing twelve, how many parts of hydrogen each weighing one, how many parts of oxygen each weighing sixteen, how many parts of nitrogen each weighing fourteen, etc. This, too, is one of the simplest of arithmetical operations. Divide the percentage of carbon by 12, of hydrogen by 1, of oxygen by 16, of nitrogen by 14, etc. Thus, in the present case: $52.17 \div 12 = 4.347$ atomic weights of carbon; $13.03 \div 1 = 13.03$ atomic

* If the reader is not already familiar with the metric system of weights and measures, he is referred to the section on that subject in the latter part of the Manual. (*Vide* Index, "Metric System.")

weights of hydrogen; and $34.80 \div 16 = 2.171$ atomic weights of oxygen. Reducing these three fractional numbers of atomic weights to the lowest whole numbers (by assuming that the lowest of the three will represent 1 atomic weight—that is, by dividing the two higher of the three by the lowest), we find that the compound is composed of 2 atomic weights of carbon, 6 of hydrogen, and 1 of oxygen, thus: $4.347 \div 2.171 = 2$ of carbon; $13.03 \div 2.171 = 6$ of hydrogen; $2.171 \div 2.171 = 1$ of oxygen. The result is, that of proportions of carbon each weighing 12, the substance contains 2; of proportions of hydrogen each weighing 1, the compound contains 6; and of proportion of oxygen each weighing 16, the compound contains 1. Finally, instead of the words "proportion of carbon weighing 12," the simple capital letter C may be used, which, as the reader now well knows, is not only the short-hand or symbol for the word carbon, but stands for 12 parts of carbon. Similarly, H may stand for 1 part of hydrogen, and O for 16 parts of oxygen; whence we arrive at C_2H_6O as the simplest chemically empirical expression, or *empirical formula*, of the substance under consideration.

(e) *Chemically Rational Composition*.—From the *empirical formula* of a substance we pass to a *two-volume formula*; that is to say, in accordance with the practice of chemists the formula must, if possible, represent two volumes of the substance when in the state of vapor (see pp. 53 and 57). Two parts of hydrogen gas, or seventeen of ammonia gas, or eighteen similar parts of water vapor, or forty-four of carbonic acid gas, or thirty-six and a half parts of hydrochloric acid gas, etc., occupy, if all are at the same temperature and under the same pressure, the same volume; whence we derive the formulæ H_2 , NH_3 , H_2O , HCl , and CO_2 as formulæ comparable with each other. If, now, the vessel which held these quantities of the respective substances be filled with the vapor of the substance supposed to be under examination at the same temperature and pressure, and the vessel and contents be weighed, the contents will be found to weigh 46 similar parts. C_2H_6O will be found, on adding up the atomic weights, to represent 46 parts by weight. Therefore C_2H_6O is the two-volume formula as well as the empirical formula, and thus the first step has been taken from the formula chiefly obtained by chemical art, an *empirical formula*, toward one largely obtained by and that satisfies the reason, or a *rational formula* or *structural constitutional formula*. Had the weight been found to be 92, the two-volume formula would have been $C_4H_{12}O_2$. The actual method of taking these weights of equal volumes of gases and vapors (specific gravity and vapor-density) will be described in the paragraphs on quantitative analysis.

(f) *Molecular Composition*.—Equal volumes of gases and vapors, being similarly affected by temperature and pressure, must be similarly constituted (Avogadro and Ampère's conclusion, pp. 52 and 53). Whatever the number of molecules in such equal volumes may be, it must be the same in each. Therefore the weights of equal bulk of gases and vapors under like conditions represent the relative weights of the respective molecules. Hence, 2, 17, 18, 44, and 36.5 respectively represent the weight of one molecule of each of the

substances hydrogen, ammonia gas, water vapor, carbonic acid gas, and hydrochloric acid gas; and 46 represents the molecular weight of the substance under consideration. C_2H_6O therefore represents the composition of a molecule of the substance. C_2H_6O is the *molecular formula* of the substance. (The substance is common alcohol.)

Check on Composition.—If the formula found is, even so far, the true formula of the substance, the centesimal composition found by experiment ought to be practically the same—the same within the limits of experimental error—as the centesimal composition obtained by calculation from the formula, thus:—

	Calculated.	Found.
$C_2 = 24 =$	52.174	52.170
$H_6 = 6 =$	13.043	13.036
$O = 16 =$	34.783	34.800
$46 =$	100.000	100.000

From *composition* we now pass to *constitution*. What we know of the composition of a substance is reflected in its *empirical formula*. A step in advance is recorded in the *molecular formula*. What is afterward learned about *constitution* is exhibited in the *structural formula*.

CONSTITUTION OF ORGANIC COMPOUNDS.

In the molecule of an organic compound how are the atoms arranged? This is perhaps the greatest problem the chemist has to solve. Like the toy-puzzles of our youth, these chemical puzzles have to be attacked analytically and synthetically. How to separate into its constituent bars of wood that apparently solid cube given to us by a friend in old days was not an ungenial task, but, once accomplished, how to put those bars together again was a still more fascinating if more difficult labor. How to separate the groups of atoms or radicals in molecules of chemical substances, or at least how to find out the positions of those groups in a molecule, is a most difficult yet fascinating task for the skilled enthusiast in chemistry; and how to so marshal those groups (drawn perhaps from several different sources, and visible and tangible only in a state of combination and in mass) that he shall produce by art the compound originally only furnished by nature, is still more difficult, but also more fascinating. More fascinating, firstly, because it will furnish proof that his synthetical work was sound; secondly, because by artificially and perhaps cheaply producing a rare color, a rare perfume, a rare flavor, or a previously costly medicine, he may become a benefactor to his fellow-man; and thirdly, because he may gain the honor of unveiling for all time one more of the truths of nature.

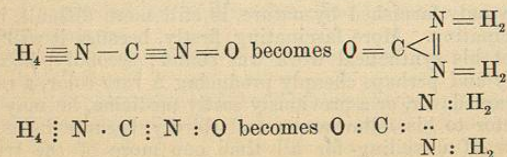
In practically attacking the problem of the constitution of a compound the chemist proceeds to note whether the substance is acid,

alkaline, or neutral; to attack it with a base of known constitution if it is an acid, or with an acid of known constitution if it is a base, and to analyze the produced salts; to oxidize it; to deoxidize it; to chlorinize it; to remove or add hydroxyl (HO), carbonyl (CO), etc.; to substitute hydrogen by a compound radical, and *vice versa*; to heat it; to electrolyze it; and, generally, to perform many such operations, in the hope that the lines of chemical cleavage in the molecule will be detected, the essential groupings of atoms in the molecule be discovered, and even the positions of atoms or groups of atoms in relation to each other be reasonably inferred.

For example, urea, which was the first organic body produced artificially, was obtained by Wöhler in 1828 on heating solution of cyanate of ammonium; H_4NCNO became $\text{OC}(\text{NH}_2)_2$, the mere change in the position of the constituent atoms—that is, in the *structure* of the molecules (indicated roughly, but to the best of our judgment, by the change in the position of the letters in the two formulæ just given)—accounting for the differences in the properties of the two substances, just as the differences in the position of a given number of stone blocks which at first were put together to form a bridge, but afterward were put together to form a house—that is, the differences in the *structure* of the edifices—fully account for the differences in their properties.

NOTATION OF ORGANIC COMPOUNDS.

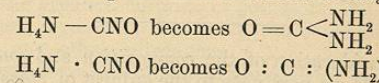
In order that we may convey to one another our conclusions respecting the constitution of organic compounds, notation has to be carried somewhat farther in organic than has already been shown to be necessary in inorganic chemistry. (See pages 41 and 55). The position of atoms and groups of atoms in a molecule may be indicated by placing the symbolic letters above or beneath one another as well as on one line, and the quantivalence of atoms, as well as the directions in which we conclude they are joined in the molecule, may be indicated by lines ($-$ or \equiv) or dots (\cdot or $:$) either completely or only partially employed throughout the formula; each dot, and, especially, each line or "bond," representing such union between two neighboring atoms or radicals as would be represented by the extended arms of two persons shaking hands. For instance, the statement just made that cyanate of ammonium (H_4NCNO) becomes urea [empirically $\text{CH}_4\text{N}_2\text{O}$, or rationally $\text{OC}(\text{NH}_2)_2$] might be represented by either of the following forms of equation:—



Here, bars, in the first equation, and dots in the second, show not only the quantivalence, but especially the distribution of the

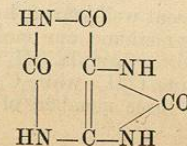
chemical power or affinity expressed by the quantivalence, of each atom. Thus the first four bars or dots not only indicate the univalence of each of the four hydrogen atoms on the one hand, and four-fifths of the quantivalence of the first nitrogen atom on the other hand, the next bar or dot showing the remaining fifth, but the five bars or dots also indicate that, of the total power or affinity of the nitrogen atom, four-fifths are engaged with a corresponding amount of attraction offered by four univalent hydrogen atoms, while the other fifth is engaged with one-fourth of the total power of the adjacent carbon atom. And so on with the quadrivalence of the carbon atom, the quinquivalence of the second nitrogen atom, and the bivalence of the oxygen atom.

But it is unnecessary, indeed undesirable, thus to indicate the quantivalence of *each* atom in a molecule, the closeness of union of groups of atoms (radicals) within a molecule being best indicated by putting the symbolic letters in a formula as close together as written characters or printer's types will allow; moreover, an atom, such as that of nitrogen, may often pass from one degree of activity to another during a reaction. The following therefore are better arrangements:—



Indeed, after a time the chemical student will find that his own imagination will often best supply that which is intended to be indicated by the lines or dots in the formulæ of organic compounds, actual lines or dots only being employed where their use tends to promote clearness in a formula. For printed lines look like bars, and these, and even dots, are liable to suggest separation, whereas in a chemical formula they should suggest the union of the atoms and radicals in the molecule of which the formula is the crude picture. While suggesting links and bonds, however, and the power (quantivalence or atomicity) of the atoms, they must be regarded as indicating lines of force rather than anything more substantial. Again, symbols and formulæ, written or printed, are necessarily exhibited on surfaces, whereas the conception of a molecule should be that of a sphere—that of grapes on a bunch, or apples on a tree, rather than balls on a billiard-table; or, still better, that of moons round a planet and planets round a sun, all kept in their places by force rather than by anything material.

Finally, bars, dots, or what not must only be placed in a formula where actual experiment warrants, unless the statement is distinctly made or understood that the suggested formula is only hypothetical. The use of the following graphic *rational formula* or *constitutional* or *structural formula*, for example (for uric acid), is fully justified by a series of well-defined experiments:—



Here, not only is the univalence of each of the hydrogen atoms, the bivalence of oxygen atoms, the trivalent character of each of the nitrogen atoms, and the quadrivalent nature of each carbon atom shown, either directly by bars attached to the symbols or suggestively by the position of a symbol of recognized quantivalence next to another symbol of recognized quantivalence, but the positions which experiment warrants us in believing that radicals occupy within the molecule are indicated in the formula by the position of the symbols for those radicals (HN, imidogen; CO, carbonyl) round central atoms of carbon.

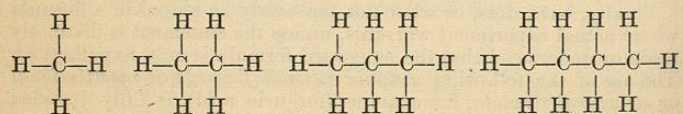
To the student the great advantage of extended formulæ, whether ordinary or graphic, consists in the relationships which they clearly exhibit between compounds which otherwise are not readily shown to be related to one another.

The structural formulæ characteristic of modern chemistry may be regarded as pictures of our idea of architecture in nature's molecules. The first sketches are seen in such formulæ as $\text{HC}_2\text{H}_3\text{O}_2$. Among the earlier, mid-century, artists were Gerhardt, Williamson, Frankland, and especially, from 1858 onward, Kekulé.

From the consideration of the *composition* and *constitution* of organic compounds we now pass to the subject of *classification*.

HYDROCARBONS: NEUTRAL OR NORMAL, AND BASYLOUS.

Neutral or Normal Hydrocarbons.—The simplest compounds of carbon are those with hydrogen, and as the atom of carbon is quadrivalent and the atom of hydrogen univalent, it follows that if a single atom of carbon be fully saturated with hydrogen, the formula of the resulting molecule must be CH_4 . But, as before stated, carbon is of all elements that which is peculiarly and specially liable to unite with itself, so far, at all events, as a portion of the attractive power of its atom is concerned, the other portions of its power attracting and being attracted by other atoms (as magnets attract each other); the result being, possibly, molecules of great complexity. The following graphic formulæ will illustrate this point:—

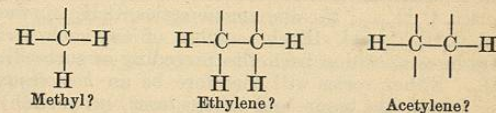


These formulæ represent well-known hydrocarbons, the first being common marsh gas or methane, one molecule of which is otherwise represented by the shorter formula, CH_4 ; the next represents ethane, C_2H_6 ; the third, propane, C_3H_8 ; while C_4H_{10} is the formula of butane or tetraene. The first three members of the series are gases; those

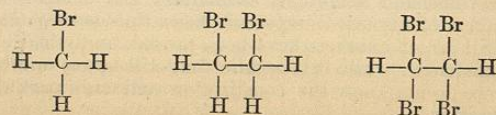
which immediately follow are liquids, C_5H_{12} , C_6H_{14} , etc.; while the highest members are solids, several of which form the mixture of hydrocarbons known as common paraffin; indeed, the whole series is distinguished as the *paraffin series* of hydrocarbons. It will be observed that the four units of affinity of the carbon atom are, in the molecule of each substance, fully saturated either by the affinities of adjacent hydrogen atoms or by that of another carbon atom. The substances are illustrations of *saturated hydrocarbons* or neutral or normal hydrocarbons. They differ in composition by CH_2 ; add CH_2 to the first, and you obtain the second; add CH_2 to the second, and you obtain the third; and so on. The members of this series resemble each other in containing, to a given number of carbon atoms, twice that number, with two added, of hydrogen atoms. Representing "any number" by the letter n , the *general* formula for members of this neutral series of hydrocarbons will be $\text{C}_n\text{H}_{2n+2}$. Like neutral inorganic salts, their elements have saturated each other's affinities; hence the molecules refuse further to unite by direct or indirect addition with atoms having attractive powers. Potassium is powerfully basylous, chlorine powerfully acidulous, each has great affinity for the other; but the product, chloride of potassium, KCl , is neutral or normal: saturated hydrocarbons are in the same case, for they do not unite with any other substances.

Basyulous Hydrocarbons.—Many hydrocarbon groups, such as "methyl," CH_3 , and "ethyl," C_2H_5 , apparently have strong basylous affinities, because in compounds they appear to play the part which in inorganic compounds is performed by those basylous metals, etc. (K , NH_4 , Fe , etc.) which are commonly called inorganic radicals. Indeed, such hydrocarbon groups are often termed *organic radicals*, and to hold the theory that they exist is convenient; but any attempt to isolate them results in the production of neutral hydrocarbons, C_2H_6 , C_4H_{10} , etc.

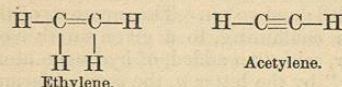
Some hydrocarbons, however, which can quite easily be isolated are basylous, such as ethylene, C_2H_4 , and other bivalent radicals having the general formula C_nH_{2n} ; and acetylene, C_2H_2 , and other quadrivalent radicals having the general formula $\text{C}_n\text{H}_{2n-2}$. Such radicals are sometimes termed *unsaturated hydrocarbons*.



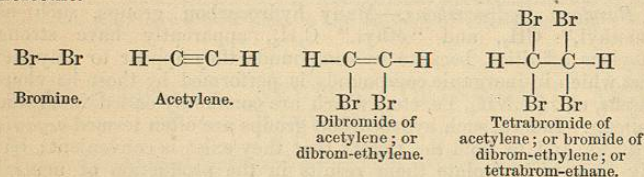
their compounds with, for example, bromine, being thus formulated:—



But the first is probably methane, in which one atom of hydrogen is substituted by one of bromine, other salts containing the supposed non-isolable radicals being normal hydrocarbons in which atoms of hydrogen are substituted by atoms of acidulous elements or acidulous radicals, the residual hydrocarbon being the so-called basylous radical. And as regards the basylous hydrocarbons which can be isolated, they too probably are neutral hydrocarbons in which the carbon atoms are united to the extent of half or even three-fourths of their affinities, thus:—



Bring bromine into contact with these so-called free basylous radicals, and in the case of ethylene one pair of carbon "arms" may be considered to unclasp, each of the two free arms clasping a one-armed bromine atom; while in the case of acetylene first one pair of arms unclasp and take in two bromine individuals, and then another pair unclasp and take in two more individuals of a bromine molecule.



Series of Hydrocarbons.—Three distinct series of hydrocarbons have now been alluded to—namely, the paraffin series, $\text{C}_n\text{H}_{2n+2}$; the olefine series, C_nH_{2n} ; and the acetylene series, $\text{C}_n\text{H}_{2n-2}$. Twelve or fourteen other series are known, as, the terpene series, $\text{C}_n\text{H}_{2n-4}$; the benzene series, $\text{C}_n\text{H}_{2n-6}$; the cinnamene series, $\text{C}_n\text{H}_{2n-8}$; the anthracene series, $\text{C}_n\text{H}_{2n-10}$, etc. Each member of any such series obviously differs in composition from the preceding or succeeding member by CH_2 . Either series will therefore be an *homologous* series (from *ὁμός*, *homos*, the same, and *λόγος*, *logos*, proportion) of compounds.

Substitution.—The atoms of hydrogen in any member of either of the series of hydrocarbons may be substituted by radicals of all kinds—basylous and acidulous, elementary and compound. Very large numbers of organic compounds have thus been obtained artificially; still larger numbers have been proved, analytically, to have distinct existence; while it is certain that still larger numbers exist of which we do not know the constitution and only partially know the composition.

Several of these series of hydrocarbons and their substitutional derivatives will now be described, special notice being given to the compounds of medical and pharmaceutical interest. Some members of the paraffin, olefine, acetylene, terpene, benzene, naphthalene, and anthracene series will be treated of, together with their haloid, nitrous, and acetic derivatives; the alcohols or hydroxyl substitution compounds will then be noticed as a class; and, afterward, the carbohydrates, amyloids, aldehydes, acids, glucosides, and alkaloids.

A very large number of compounds of carbon will thus be brought under notice, far larger than that of any other element. The mere number, however, need not dismay the student. The relation of the derivatives of one hydrocarbon to that hydrocarbon will be found to obtain between the next set of derivatives studied with their hydrocarbon, and so on; hence, as the student progresses he is soon looking for compounds which he already expects to exist, instead of finding his mind overburdened with what at first sight he might fear would be an intricate and endless subject.

The methods of examining morbid urine will afterward be experimentally considered. There will then remain to be studied by the medical and pharmaceutical pupil, but by aid of some other guide than the author's, certain galenical as distinguished from chemical substances, solid and liquid, which can only be fairly regarded from a pharmacist's rather than a chemist's point of view, and a still larger number, doubtless, not yet brought within the grasp of chemist or pharmacist, and of which, therefore, we must at present be content to remain in ignorance. An opportunity, however, will be afforded of noticing the effect of such indefinite organic matter as a vomit or the contents of a stomach in masking or preventing the reaction by which mineral and vegetable poisons are detected.

A section on quantitative analysis will complete the Manual.

QUESTIONS AND EXERCISES.

669. What do you understand by Organic Chemistry?
670. Give methods of ascertaining the presence of carbon, hydrogen, and nitrogen in organic compounds.
671. Give an outline of the methods by which the quantities of carbon, hydrogen, oxygen, and nitrogen are determined in organic compounds.
672. How would you convert centesimal into "atomic" composition?
673. Define *empirical*, *molecular*, and *rational* formulæ.
674. How is the constitution of an organic compound ascertained?
675. What do you understand by graphic chemical formulæ?
676. Give graphic formulæ of two or three saturated hydrocarbons.
677. What do you mean by an organic radical? Give illustrations.
678. Give the general formulæ of different series of hydrocarbons, with special illustrations.
679. Define *substitution* as understood in organic chemistry.