from *unus*, one, and *valens*). Barium, strontium, calcium, magnesium, zinc, cadmium, mercury, and copper, like oxygen, are bivalent. Phosphorus, arsenium, antimony, and bismuth, like nitrogen, usually exhibit trivalent properties; but the composition of certain compounds of these five elements shows that the several atoms are sometimes quinquivalent (quin-quiv′-a-lent; *quinquies*, five times, and *valens*). Gold and boron are trivalent. Silicon (the characteristic element of flint and sand), tin, aluminium, platinum, and lead resemble carbon in being quadrivalent. Sulphur, chromium, manganese, iron, cobalt, and nickel are sexivalent (sex-iv′-a-lent; from *sex*, six, or *sexies*, six times, and *valens*), but frequently exert only bivalent, trivalent, or quadrivalent activity. This *quantivalence* (quant-iv′-a-lence; from *quantitas*, quantity, and *valens*), also termed *atomicity* (maximum quantivalence), *dynamicity*, and *equivalence* of elements, may be ascertained at any time on referring to the table of the Elements at the end of this volume, where Roman numerals, I, II, III, IV, V, VI, are attached to the symbols of each element to indicate atomic univalence, bivalence, trivalence, quadrivalence, quinquivalence, or sexivalence. Dashes (H', O'', N''') similar to those used in accentuating words are often used instead of figures in expressing quantivalence. The quantivalence of elements, as they one after another come under notice, should be carefully committed to memory; for the composition of compounds can often be thereby predicated with accuracy and remembered with ease. For instance, the hydrogen compounds of chlorine, Cl', oxygen, O'', nitrogen, N''', and carbon, C'''', will be respectively $H'Cl'$, H'_2O'', H'_3N''', and H'_4C'''',—one univalent atom, H', balancing or saturating one univalent atom, Cl'; two univalent atoms, H'_2, and one bivalent atom, O'', saturating each other; three univalent atoms, H'_3, and one atom having trivalent activity, N''', saturating each other; and four univalent atoms, H'_4, and one quadrivalent atom, C'''', saturating each other. Carbonic acid gas, $C^{iv}O^{ii}_2$, again, is a saturated molecule containing one quadrivalent and two bivalent atoms.

The subject of quantivalence will be further explained after the first six metals have been studied, when abundant illustrations of it will have occurred.

DEFINITIONS.

Chemistry is the study of the chemical force.

The Chemical Force, like other forces, cannot itself be described, for, like them, it is only known by its effects. It is distinguished from other forces by the facts that (*a*) it produces an entire change of properties in the bodies on which it is exerted, and that (*b*) it is exerted only between definite weights and volumes of matter. Like the *force of cohesion*, which is the name given to the attraction which molecules have for each other, and which is great in solids, small in liquids, and apparently absent in gases, and like the *force of adhesion*, which is the name given to the attraction which a mass of molecules has for another mass, *the chemical force* acts only within immeasurable distances: indeed, inasmuch as the chemical force appears to reside in atoms, that is to say, is exerted inside a molecule, while all other forces affect entire molecules, the chemical force may be said to be distinguished (*c*) by being exerted within a smaller distance than that at which any other force is exerted.

An Element is a substance which cannot by any known means be resolved into any simpler form of matter.

An Atom of any element is a particle so small that it undergoes no further subdivision in chemical transformations.

A Molecule is the smallest particle of matter that can exist in a free state.

A mere Mixture of substances is one in which each ingredient retains its properties.

A Chemical Compound is one in which definite weights of constituents have combined, and during combination have undergone an entire change of properties. A "compound" in pharmacy is an intimate mixture of substances, but still only a mixture; it is not a *chemical* compound, the ingredients have not entered into *chemical* union or combination.

Combustion is a variety of chemical combination, a variety in which the chemical union is sufficiently intense to produce heat and, generally, light.

The Law of Diffusion is one under which gases mix with each other at a rate which is in inverse proportion to the square root of their relative weights; that is, irrespective of and even in spite of their comparative lightness or heaviness.

A Chemical Symbol is a capital letter, or a capital and one small letter. It has four functions, namely:—

1. It is short-hand for the *name* of the element.
2. It represents one *atom* of the element.
3. It stands for a constant *weight* of the element—the atomic weight or combining weight.
4. Symbols represent single and equal *volumes* of gaseous elements.

A Chemical Formula represents *a molecule* either of an element or of a compound. It has four other functions:—

1. It indicates at a glance the *names* of the elements in the molecule.
2. Its symbol or symbols, together with a small figure attached to the foot of any symbol, show the *number of atoms* in the molecule.
3. It stands for a constant weight of a compound—the molecular weight—the sum of the combining *weights* or of the weights of the atoms in the molecule.
4. It represents *two volumes* of the substance, if volatilizable, in the state of gas or vapor, and the number of volumes of gaseous elements from which two volumes of any gaseous compound were obtained.

A Chemical Equation or *a Chemical Diagram* is a collection of formulæ and symbols so placed on paper as to form a picture or illustration of the state of things before and after that metathesis (interchange of atoms) of molecules which results in the formation of molecules of new substances.

A Solid is a substance the molecules of which are more or less immobile, though probably not in absolute contact.

A Liquid is a substance the molecules of which so freely move about each other that it readily assumes and retains the form of any vessel in which it is placed.

A Gas is a substance the molecules of which are so far apart that they seem to have lost all attraction for each other, and, indeed, to have acquired the property of repulsion to such an extent that they are only prevented from receding to a still greater extent by the pressure of surrounding matter. Motion is especially characteristic of gaseous fluids.

The Three Laws regulating Chemical Combination (either by weight or volume).

First. A definite compound always contains the same elements and the same proportions of those elements—by weight or volume.

Second. When two elements unite in more than one proportion, they do so in simple multiples of that proportion.

Third. The proportions in which two elements unite with a third are the proportions in which they unite with each other.

Atomic Weights are, first, the proportions in which elements are found to combine with each other by weight. (The figures showing these proportions are purely relative, but all chemists agree to make this relation fixed by giving the number 1 to hydrogen.) Secondly, they are the weights of equal volumes of elements in the state of gas (relative to 1 of hydrogen).

Molecular Weights.—These are the weights of equal volumes of gases or vapors, under equal circumstances of temperature and pressure, and relative not to 1 but to 2 of hydrogen. In the case of non-volatile bodies, molecular weight is deduced from the observed analogies of the bodies with those whose molecular weight admits of proof. The molecular weight of a compound is the sum of the atomic weights.

Quantivalence of Atoms.—The observed power, force, or value for work of an atom—relative to 1 of hydrogen.

THE LEARNER IS RECOMMENDED TO READ THE FOREGOING PARAGRAPHS ON THE GENERAL PRINCIPLES OF CHEMICAL PHILOSOPHY CAREFULLY ONCE OR TWICE, THEN TO STUDY (EXPERIMENTALLY, IF POSSIBLE) THE FOLLOWING PAGES, RETURNING TO AND READING OVER THE GENERAL PRINCIPLES FROM TIME TO TIME UNTIL THEY ARE THOROUGHLY COMPREHENDED.

Minor Principles and Generalizations will be found scattered throughout the following pages.

Students of pure chemistry, especially when fairly well acquainted with chemical facts, will also find the Principles of Chemistry, including the probable Constitution as distinguished from the mere Composition of Chemical Substances, amply set forth in Tilden's "Chemical Philosophy," one of Longman's series of "Text-books of Science."

QUESTIONS AND EXERCISES.

42. What do you understand by *chemical* action? Give examples.
43. How is chemical force distinguished from other forces?
44. Adduce evidence that elements exist in compounds; that sulphide of iron, for instance, still contains particles of sulphur and iron, though it possesses properties so different from those elements.
45. Define the term atom.
46. What condition is essential for the manifestations of chemical force?
47. Can an atom exist in an uncombined state? and when are the atoms of an element most potent to enter into chemical combination?
48. What is a molecule?
49. How may the results of chemical reactions be expressed on paper?
50. Enumerate the functions of a symbol.
51. Give the additional functions of a chemical formula.
52. Describe by a diagram or an equation the reaction which ensues when red-hot charcoal is plunged into oxygen gas.
53. Draw diagrams representing the formation of P_2O_5, SO_2, and FeI_2 respectively.
54. Enumerate the differences in the physical conditions of the molecules in a solid, a liquid, and a gas.
55. State the law of constant proportions.
56. State the law of multiple proportions.
57. State the law of reciprocal proportions.
58. Give illustrations of the above laws.
59. Describe the origin and use of the atomic theory.
60. What do you understand by the atomic weight, and the molecular weight of an element?
61. Representing the weight of an atom of hydrogen as 1, what will be the atomic weights of carbon, sulphur, nitrogen, and iodine? Give reasons for considering the stated weights to be correct.
62. In what proportion, by volume, do elements in the gaseous state chemically combine?
63. What relation exists between the combining volumes of elements in the gaseous state and their atomic weights? Give the explanation for this.
64. Is there any difference between the molecular volume of a simple or of a compound gas?
65. Define isomorphism.
66. Explain the value of isomorphism as evidence of atomic weight.

67. What is to be understood by the quantivalence of an element? Give examples of univalent, bivalent, trivalent, and quadrivalent atoms.

68. How may the quantivalence of an element be expressed in its atomic symbol?

69. Give the formulæ of two or three compounds in which the quantivalence of one atom is saturated by the combined quantivalence of others.

The reader is also recommended to question himself, or be questioned, on the "definitions" given on pages 56, 57, and 58.

THE ELEMENTS AND THEIR COMPOUNDS.

Having thus obtained a general idea of the nature of such elements as have especial interest for the medical and pharmaceutical student, and which indeed are all with which any student of chemistry should at present occupy his attention, we may pass on to consider in detail the relations of the elements to each other. The elements themselves, in the free condition, are seldom used in medicine, being nearly always associated—bound together by the chemical force; in this combined condition, therefore, they must be studied, inorganic combinations first, organic afterwards. The inorganic compounds may, as a rule, be regarded as containing two parts or roots, two radicals; the one usually metallic, or, to speak more generally, basylous; the other commonly a non-metallic, simple or complex, acidulous radical. The basylous radicals, or metals, will be considered in the immediately succeeding pages, then the acidulous radicals. Each radical will be studied from two points of view, the synthetical and the analytical; that is to say, the properties of an element on which the preparation of its compounds depends will be illustrated by descriptions of actual experiments, and thus the principles of chemistry, and their application to medicine and pharmacy, be simultaneously learnt; then the reactions by which the element is detected, though combined with other substances, will be performed, and so the student will be instructed in qualitative analysis. Synthetical and analytical reactions are, in truth, frequently identical, the object with which they are performed giving them synthetical interest on the one hand, or analytical interest on the other.

A good knowledge of chemistry may be acquired synthetically by preparing considerable quantities of the salts of the different metals, or analytically by going through a course of pure qualitative analysis. But the former plan demands a larger expenditure of time than most students have to spare, while under the latter system they generally lose sight of the synthetical interest which attaches to analytical reactions. Hence the more useful system, now offered, of studying each metal, etc., from both points of view, time being economized by the operator preparing only small specimens of compounds.

Chemical synthesis and analysis, thoughtfully and conscientiously followed, without hurry and mere superficial consideration, but, of course, without undue expenditure of time, will insensibly carry the principles of chemistry into the mind, and fix them there indelibly.

THE BASYLOUS RADICALS.

POTASSIUM.

Symbol K. Atomic weight 39.

Formula K_2. Probable molecular weight 78.

Memoranda.—The chief sources of the potassium salts* are the chloride, found at Stassfurt, in Prussia, in the form of the mineral *Carnallite* ($KCl,MgCl_2 6H_2O$); the nitrate, found in soils, especially in warm countries; and the compounds of potassium, existing in plants. *Kainite*, a double sulphate of potassium and magnesium, also occurs among the Stassfurt minerals. The vegetable salts of potassium are converted into carbonate (other salts are present) when the wood or other parts are burned to ashes. If the ashes be lixiviated with water, and the solution evaporated to dryness, the residue, when fused, constitutes *crude potashes.* The residue, calcined on the hearth of a reverberatory furnace till white, gives the product termed *pearlash.* Large quantities of carbonate are thus produced in North America and Russia, and, latterly, from the sugar-beet marc, in France. From the native chloride and from the carbonate purified by treating the pearlash with its own weight of distilled water, filtering and evaporating the solution until it thickens, and stirring constantly, "so as to form a granular salt" (*Potassii Carbonas*, U. S. P.), nearly all other compounds of potassium are made. Exceptions occur in cream of tartar (*Potassii Bitartras*, U. S. P.), which is the more or less purified natural potassium salt of the grape-vine, and in nitrate of potassium. Potassium is a constituent of between forty and fifty chemical or Galenical preparations of the Pharmacopœias.

Carbonate of potassium is a white crystalline or granular powder, insoluble in alcohol, very soluble in water, rapidly liquefying in the air through absorption of moisture, alkaline and caustic to the taste. It loses all water at a red heat. *Potassii Carbonas Purus*, U. S. P., is obtained by heating the bicarbonate to redness: the resulting white anhydrous carbonate is converted into hydrous granular carbonate by solution in water and evaporation until a dry granular salt remains.

Preparation.—Potassium itself is isolated with some difficulty by distilling a mixture of its carbonate and charcoal. It rapidly oxidizes in the air, and hence is always kept below the surface of min-

* The ill-defined term *salt* includes most solid chemical substances, but more especially those which assume a crystalline form.