INTRODUCTION.

Stoichiometry is the name given to the art of chemical calculations involving the laws of combining proportions, whether by weight or volume.

It is convenient to consider in this connection certain elementary principles of Physics, such as specific gravity, and the expansion and contraction of gases under change of pressure or temperature.

The present treatise may be used as either text or reference. We here indicate what is supposed to be already familiar to the reader.

It is assumed, then: (1) that he fairly well understands the conventional or provisional meanings attached to the words "element," "compound," "atom," and "molecule." (2) That he has learned the fundamental laws of chemical combination, viz: "definite proportions," "multiple proportions," etc., and the significance of "atomic weights." (3) That he has mastered the elements of nomenclature, and can use symbols and equations intelligently.

A convenient epitome of the most important relations is found in the statement, which may be used when the meaning of "atomic weight" is fully understood:

"Elements combine in the ratios of their atomic weights, or in simple multiples of those ratios."

This is sometimes reversed, and made to serve as a definition:

"The atomic weights of the elements are the proportions in which, or in simple multiples of which, they combine among themselves."

In order to understand clearly the scope of Stoichiometry, or "Chemical Arithmetic," read carefully the following remarks.

Note first, that the definitions above given as to the atomic weights and combining ratios are quite aside from any theory concerning the nature or even the existence of atoms. In fact, while the language of the science is freely employed in the text, Stoichiometry, the "Arithmetic of Chemistry," has little to do with speculative science. Its study may incidentally enable the student to perceive, possibly more clearly than he has ever done before, the essential difference between *facts* which are undisputed, and the *theories*, however well grounded or widely accepted, which have been based upon them.

The discussion of a very simple equation will illustrate how theory and fact may be separated without affecting any result of chemical computation.

$$2H_2SO_4 + Na_2CO_3 = 2NaHSO_4 + H_2O + CO_2$$

We may first describe the terms of this equation in detail, saying that "two atoms of hydrogen, one of sulphur and four of oxygen, form one molecule of sulphuric acid" and so forth. Then we may proceed to state that "two molecules of sulphuric acid and one of secondary sodic carbonate produce two molecules of primary sodic sulphate, one of water and one of carbon dioxide."

But if we had no atomic theory whatever, and no system of conventional symbolism, the reaction would be just as real, and the actual weight relations exactly the same. We could say: "One hundred and ninety-six parts of sulphuric acid plus one hundred and six parts of carbonate of soda produce two hundred and forty parts of acid sulphate of soda, eighteen parts of water, and forty-four parts of carbonic acid gas." (Old nomenclature assumed.)

We might use other numbers, provided they stood in the same ratios, to express the facts.

Chemical reactions were, in fact, described much after this fashion in works printed up to 1825 and even later.

Stoichiometry then, while conveniently employing the adopted terminology, is independent of its theory.

Every strictly stoichiometric problem may be stated as a proportion. The adoption of a fixed order of statement is recommended, not as a matter of necessity, but simply to eliminate one source of possible confusion. It is well always to place the "relative" or "molecular" weights in the first member, and the actual weights (usually including the unknown), in the second.

The student cannot be too strongly impressed with the fact that the table of atomic weights shows only *ratios*, *i.e.*, the *relative* weights in which the elements combine. No amount of investigation of the metal tin would ever disclose the number 119. As to two elements, *e.g.*, carbon and oxygen, it would be just as correct to say that carbon dioxide contained three-elevenths of carbon and eight-elevenths of oxygen, or that it had seventy-five parts of carbon to two hundred of oxygen, as to call the relation twelve to thirty-two.

For reasons foreign to the intent of this text, the relative proportions have been reduced in modern practice to the weights as given in Table I, in which the element oxygen is conventionally assumed as 16, all the other elements assuming numbers *relative* to that one in accordance with numberless experiments, which, from the early work of Berzelius in the first part of the nineteenth century, have been carried on with ever increasing accuracy to the present day.

It is, however, not necessary, in the working of problems for exercise, to use the exact atomic weights. In the table and in the table of factors (II) and percentage composition (III) the exact numbers are used, either directly or as data for computation. But unless otherwise stated, we use in the problems the *nearest whole number* except in the case of chlorine, whose atomic weight is made 35.5 in the computations in which all the other elements are taken to the nearest whole number.

The equality sign is used between the members of a proportion, instead of the old-fashioned "four dots." The student should realize that a ratio is a pure number, and a proportion an expression of the *equality between two pure numbers.*

In the treatment of gas volumes the "two volume" convention is retained for the molecule. It has proved better as a class-room method in the author's experience than the more recent "one volume." It is a matter of small importance as compared with the necessity of recognizing relative volumes upon inspection of the equations, and all other detail following from "Avogadro's rule." This being a matter upon which many technical men quickly become "rusty," some space is devoted to its elementary exposition, before the introduction of problems.

PART I
CHEMICAL ARITHMETIC