LECTURE NOTES IN CHEMISTRY 1 (HARVARD COLLEGE): DESCRIPTIVE CHEMISTRY

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LECTURE NOTES IN CHEMISTRY 1.

(*HARVARD COLLEGE.*)

DESCRIPTIVE CHEMISTRY.

ARRANGED BY

A. P. LOTHROP AND A. L. HODGES.

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DESCRIPTIVE CHEMISTRY.

Theoretical Chemistry. An *Element* is a substance which cannot by any known process be resolved into simpler substances. A *Compound* is a union of two or more substances, forming a new substance with new properties. A *Mixture* is a mechanical union of two or more substances, retaining the characteristic properties of each.

Law of Definite Proportions: Each compound contains the same elements in the same proportions.

Law of Multiple Proportions: When two compounds consist of the same elements, the proportion in one is a simple multiple of the proportion in the other.

HYDRIC PEROXIDE, H_2O_2, is formed by uniting baric peroxide and hydrochloric acid according to the following reaction:

$$BaO_2 + 2HCl = BaCl_2 + H_2O_2.$$

Similarly we have the reaction of hydrochloric acid on baric oxide forming water:

$$BaO + 2HCl = BaCl_2 + H_2O.$$

These two reactions illustrate the law of multiple proportions. Hydric peroxide contains 2 parts by weight of H and 32 parts of O; while water contains 2 of H and 16 of O. *Properties:* hydric peroxide smells like chlorine and bleaches the skin. When concentrated as much as possible, it is of the consistency of syrup and freezes at — 30°. (Whenever in these notes degrees of temperature are mentioned, Centigrade is to be understood.) It is very unstable, readily giving up O, and is therefore a powerful oxidizer. Substances are attacked by the oxygen from it, when they are not attacked by O in a free state. This is due to the fact that the atoms in the molecule of free Oxygen (O_2) have a strong affinity for each other; but when O is just set free (nascent O), the two atoms have not yet combined and hence unite more easily with other substances. On this property depends its use in restoring pictures. The white lead of the picture, owing to the presence of sulphuretted hydrogen in the air, becomes in time converted into plumbic sulphide (black). By washing with hydric peroxide this is converted into plumbic sulphate (white).

$$PbS + 4H_2O_2 = PbSO_4 + 4H_2O.$$

Hydric peroxide also acts as a reducer, *i. e.* removes Oxygen, as from argentic oxide, thus leaving metallic silver.

$$Ag_2O + H_2O_2 = H_2O + Ag_2 + O_2.$$

Hydric peroxide is used for bleaching hair; it turns it to a greenish-yellow. "Golden Hair Water" is simply H_2O_2 in solution. Hydric peroxide in solution can be detected by adding to the liquid a little ether and a few drops of potassic dichromate. The H_2O_2 will form a perchromate soluble in ether, imparting to it a blue color.

The *Molecule* of *any substance* is the smallest amount of it that can exist in a free state.

The *Atom* of an *Element* is the smallest amount of it that occurs in any *Molecule*. In other words, when any substance is divided as far as possible by physical means, it is separated into molecules, which retain the qualities of the original substance. On carrying the division farther by chemical means, these molecules are split up into the atoms of the constituent elements. These definitions are a consequence of the *Atomic Theory*, which regards all substances as made up of atoms which unite to form molecules. The laws of definite and multiple proportions, which rest on experimental proof, are explained only by the assumption of some such theory as the atomic theory.

The determination of molecular weights depends on Avogadro's law: Equal volumes of all gases under the same conditions contain the same number of molecules. Hence the relative weights of these molecules must be the same as the relative weights of the equal gas volumes. By taking some one gas as the unit, all others can be referred to it. Since it is the lightest gas known, hydrogen is taken as the unit. The vapor density of a substance, therefore, is the weight of a volume of its gas referred to an equal volume of hydrogen gas; and the weight of the molecule of a substance referred to the hydrogen molecule is the same as the vapor density of that substance. But in determining molecular weights the hydrogen *atom* is taken as the unit. Since the H molecule contains 2 atoms, the molecular wt. of a substance = its density $\times$ 2. The weight of a molecule is of course equal to the sum of the weights of the constituent atoms.

The methods of determining atomic weight will be explained near the end of these notes.

There are three classes of reactions; analytical, synthetical, and metathetical. An *Analytical* reaction is when a compound breaks up into simpler substances, *e. g.*

$$2H_2O = 2H_2 + O_2. \quad \text{(Decompos. of water.)}$$

Decomposition is almost the only example of this class of reactions. A *Synthetical* reaction is when simpler substances unite to form a more complex, *e. g.*

$$2H_2 + O_2 = 2H_2O. \quad \text{(Combustion of hydrogen.)}$$

Combustion is almost the only case of this class. A *Metathetical* reaction consists in the interchange of radicals, *e. g.*

$$BaO + 2HCl = BaCl_2 + H_2O.$$

Metathetical reactions are by far the most common. *Stochiometry* is the branch of chemistry that treats of weights: for example, required the amount of $BaCl_2$ formed from 10g. of BaO. The reaction is given above.

$$\left.\begin{array}{l} \text{at. wt. Ba} = 137 \\ \text{" \ " \ O} = 16 \\ \text{" \ " \ Cl} = 35.5 \end{array}\right\} \qquad \begin{array}{l} BaO = 137 + 16 = 153 \\ BaCl_2 = 137 + 71 = 208 \end{array}$$

Forming a proportion, 153 : 208 = 10 : wt. required. If volume is required instead of weight, it must be remembered that

$$\text{volume} = \frac{\text{wt.}}{\text{sp. gr.}}$$

Berthollet's law: When two substances can form a substance insoluble or volatile under the conditions of the reaction, that insoluble or volatile substance will be formed till one of the factors is exhausted.

When the conditions of the law are not fulfilled, we shall have, besides the new substances formed, some of the original substances remaining uncombined.

$$NaCl + H_2SO_4 = NaHSO_4 + HCl.$$

The products being soluble, some NaCl and H_2SO_4 will remain uncombined.

A *Radical* is an atom, or any group of atoms that behaves like a single atom. Na is a simple radical; NH_4, a compound radical. A *Basic Radical* is a metal, or any radical that behaves like a metal. Na and NH_4 are both basic radicals. An *Acid* is a substance containing H which can be replaced by a basic radical. A *Salt* is formed from an acid by replacing its H by a basic radical. Thus in HCl, hydrochloric acid, the H can be replaced by Na, forming NaCl. An *Acid Salt* is a salt containing H that can be replaced by a basic radical. Thus in $NaHSO_4$, acid sodic sulphate, the H can be replaced by Na, forming Na_2SO_4. A *Hydrate* is formed from water by replacing one-half its H by a radical. A *Base*, or *Basic Hydrate*, is formed from water by replacing one half its H by a Basic radical, *e. g.* water HOH, sodic hydrate NaOH. Bases have properties directly opposite to those of acids. An *Alkali* is a base soluble in water. An *Alkaline Earth* is a base only slightly soluble in water. The neutralization of an acid by a base or a base by an acid forms a salt, *e. g.*

$$NaOH + HCl = NaCl + H_2O.$$

The *Basicity of an Acid* is the number of atoms of H it contains which can be replaced by a basic radical. HCl is monobasic; Sulphuric acid, H_2SO_4, is di-basic, and can form both an acid and a neutral salt; Acetic acid, $HC_2H_3O_2$, is monobasic, as only one of its H atoms can be replaced. The *Quanticalence* of an atom or a radical is its combining capacity as measured by the number of H atoms which it will replace. Na is univalent, HCl,—NaCl; Ca is bivalent, 2HCl,—$CaCl_2$.

HYDROCLORIC ACID, HCl, is usually made by the action of sulphuric acid on common salt.

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

Properties: it is a strong acid, turning blue litmus paper red. It is a colorless gas, heavier than air, and fumes in moist air; very soluble in water, condensed by cold into a liquid. The acid dissolves some metals, giving up its H. Its salts are called chlorides.

NITRIC ACID, HNO_3 can be formed by action of sulphuric acid on potassic nitrate.

$$KNO_3 + H_2SO_4 = KHSO_4 + HNO_3.$$

But the commercial nitric acid is obtained from Sodic Nitrate.

$$2NaNO_3 + H_2SO_4 = 2HNO_3 + Na_2SO_4.$$

Properties: when pure, it is called *Fuming Nitric Acid* and is a colorless gas, very corrosive. It corrodes by giving up its oxygen, and is used as an oxidizer. It stains a bright yellow. It is soluble in water and the solution is usually yellow owing to impurities. It has a boiling point of 184°, and a specific gravity of 1.52. It dissolves Zinc, setting free H, which decomposes the acid so that we do not obtain free H. Its salts are called nitrates.

SULPHURIC ACID, H_2SO_4, is made by burning sulphur, and then making the product take up more H and water. *Properties:* this is a strong acid and has a great affinity for water. When mixed with water, it gives out heat and precipitates an impurity, plumbic sulphate, which it takes up in preparation. Its salts are called sulphates.

HYDRO-SULPHURIC ACID or Sulphuretted Hydrogen, H_2S, is usually made from ferrous sulphide and sulphuric acid.

$$FeS + H_2SO_4 = H_2S + FeSO_4.$$

Properties: H_2S is a gas resembling HCl, with the odor of rotten eggs. It is poisonous when pure and in large quantities; harmless when mixed with air. It is slightly soluble in water and has a weak acid reaction, turning litmus paper a pinkish red. Its H cannot be replaced by Zinc unless the Zinc is in solution. It is a reducing agent and its salts are called sulphides.

The symbol of H_2S may be written in a graphical form, thus: H—S—H. The graphical symbol of H_2SO_4 is

$$\begin{matrix} H—O— \\ H—O— \end{matrix} S \begin{matrix} = O \\ = O. \end{matrix}$$

This makes S sexivalent. Some chemists, however, maintain that the quantivalence of an element is always the same, whatever the compound in which it occurs. Thus, since S is bivalent in H_2S, they would make it bivalent in H_2SO_4, with the graphical symbol H—O—O—S—O—O—H. This view is probably incorrect.