AN OUTLINE OF THE THEORY OF SOLUTION AND ITS RESULTS: FOR CHEMISTS AND ELECTRICIANS

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AND ITS RESULTS.

FOR CHEMISTS AND ELECTRICIANS.

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AN OUTLINE OF THE THEORY OF SOLUTION AND ITS RESULTS

CHAPTER I.

THE THEORY OF SOLUTION.

THE GAS LAWS.

IN order to understand the rise of the Theory of Solution, it will be necessary for us to review, in brief, the laws for the behavior of gases during the different changes of condition which they may undergo. First we will turn to the *Law of Mariotte*; it may be expressed as follows: *The temperature remaining the same, the volume of a given quantity of gas is inversely proportional to the pressure to which it is exposed.* That is,

$$P' : P :: V : V',$$

where V and V' represent respectively the volumes before and after the pressure is changed from P to P'. Volumes of gases are measured in cubic centimeters at a certain temperature and pressure, while pressures are measured in millimeters of mercury (in a barometer). The *Law of Charles* is: *The pressure remaining the same, the volume of a given quantity of a gas is directly proportional to its absolute temperature.* It has been found that a gas expands (contracts) 1/273 of its volume, at 0° centigrade (C.), for every increase (decrease) in temperature of 1° C.; hence, if a volume of gas, at 0° C., should have its temperature lowered through 273°, the contraction would equal the volume. This point (273° below 0° C.) is called the *absolute zero*, and temperatures reckoned from this point *absolute temperatures*. The proportion then for this law

$$T : T' :: V : V'$$

where T is equal to the centigrade temperature + 273°, and V is as before. The *Law of Dalton* is best expressed, perhaps, in the following form: *The pressure exerted upon the walls of a vessel, containing a mixture of gases, is equal to the sum of the pressures which the single gases would exert, were they alone in the vessel.* The law of Avogadro is of paramount importance. According to it: *All gases, under the same conditions of pressure and temperature, contain in unit volume the same number of molecules.* The law of Mariotte is generally written, when the temperature does not vary,

$$pv = \text{constant},$$

for we know that p and v are inversely proportional, and hence when one increases the other decreases by the same amount, and consequently the product remains constant.

The law of Mariotte and that of Charles are usually united in a form which gives the state of the gas under all conditions. If, for example, we have a gas at a certain volume at 0° and 760 mm. pressure and keep the pressure constant, allowing the temperature to vary, the volume becomes

$$v = v_0(1 + \alpha t).$$

If now, instead of keeping the pressure constant, we vary it and keep the volume constant, then the pressure must increase just as the volume did before. That is,

$$p = p_0(1 + \alpha t).$$

The v_0 and p_0 refer to the standard state (0° and 760 mm. pressure). By uniting these two we obtain

$$pv = p_0 v_0(1 + \alpha t);$$

but

$$t = T - 273$$

and ($\alpha = \frac{1}{273}$) hence

$$pv = p_0 v_0[1 + \tfrac{1}{273}(T - 273)];$$

$$pv = p_0 v_0\left(1 + \frac{T}{273} - 1\right);$$

$$pv = \frac{p_0 v_0}{273} T.$$

As will be seen, this term $\frac{p_0 v_0}{273}$ is a constant. The letter R is usually substituted for it, so that we have, as the equation of state of a perfect gas,

$$pv = RT;$$

or, since R is found, by calculation, to be equal to 84700 centimeter-grams,*

$$pv = 84700 T.$$

This R, which refers to only one mol (molecular weight in grams) of gas, is called the *gas constant.*

According to Avogadro's law, equal volumes of all gases contain the same number of molecules. This gives us a method of determining the molecular weight of substances in gas form, which has been used very largely. By Avogadro's law,

$$\frac{m_1}{d_1} = \frac{m_2}{d_2} = \frac{m_n}{d_n} = \text{constant},$$

where m_1, m_2, m_n, are molecular weights, and d_1, d_2, d_n are the densities of the corresponding gases. If

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* As calculated for one mol of oxygen, but it is the same for one mol of any other gas.' v_0 (1 gr. O at 76 cms. pressure and 0° C.) = 699.25 c.c., p_0 = 76 cms. of a column of mercury 1 cm. in diameter. Sp. gr. of Hg = 13.5. Hence the weight of the column = 76 × 13.5 = 1033.2 grms., $T = 273°$

Therefore $\frac{p_0 v_0}{T}$ for 32 grams (mol) =

$$32 \times \frac{1033.2 \times 699.25}{273} = 84688 \text{ cm. grms.},$$

(84700 in round numbers), i.e., equal to an energy which would lift 84700 grms. 1 cm. in 1 second.

we now take hydrogen as unity, with respect to atomic weight and density, then m_1 (H) will equal 2 (two atoms to one molecule), $d_1 = 1$, and any other molecular weight, m_2, can be found by solving the equation

$$\frac{m_2}{d_2} = \frac{m_1}{d_1} = \frac{2}{1};$$

hence

$$m_2 = 2d_2.$$

That is, *the molecular weight of any substance is equal to twice its density in gas form, hydrogen being unity.*

So much for the laws of gases. I have given them in this short and concise form, for we will have to refer to them very often, and they are all necessary, for, as we will find, they are also, with a few modifications, the laws for solution The dissolved substance acts in its solution just as a gas would when shut into a certain volume, the volume of the solvent being the volume, and the substance itself as the gas. The term which is equivalent to pressure will be developed later.

ABNORMAL RESULTS WITH GASES.

The laws for gases, given in the last section, do not hold strictly for all gases, but do (fairly) for all perfect ones. The vapors of many substances, however, were found to give very strange results; and upon these we will dwell in this section. Thus, long ago, it was found that the vapor of ammonium chloride gave a density which was but one half what it should be, according to its accepted molecular weight. There are but two ways of explaining this abnormal action,