Avogadro's Law.

By John Waddell, Ph.D.

The importance of Avogadro's law is indicated by the papers in chemistry set at the provincial examinations of Nova Scotia last July. There were three questions out of a total of fourteen in which the principles involved were a feature. Avogadro's law should more strictly be called an hypothesis, not being like Gay Lussac's law regarding the proportion by volume in which gases unite, a generalization of facts. So many facts, however, can be easily understood if Avogadro's hypothesis is assumed to be correct, that it is scarcely looked upon as an hypothesis. It was, to a certain extent, a lucky guess on the part of Avogadro, because he had a very limited knowledge of the facts bearing upon the case. The guess was, on this very account, to a certain extent, unlucky, because Avogadro applied this law to cases where it was not applicable, and so for nearly fifty years the law was neglected, and it was only when its limitations were properly recognized that its usefulness became evident.

The law in modern form is: "Equal volumes of all gases under the same conditions of temperature and pressure contain the same number of molecules."

The *existence* of *molecules* is assumed, though nobody has ever seen a molecule. Setting out with certain assumptions regarding the character and motion of molecules, Avogadro's law follows as a mathematical consequence, but of course the mathematical deduction is no more valid than the hypothetical premises.

On the assumption that Avogadro's lucky guess represents the facts, let us see some of the consequences.

In the first place there is no distinction made between elementary gases and compound gases. In a given volume, say a cubic foot of hydrogen, there is the same number of molecules as in a cubic foot of hydrochloric acid gas; in a litre of nitrogen there is the same number of molecules as in a litre of ammonia in ten liters of carbon monoxide or carbon dioxide there is the same number of molecules as in ten liters of oxygen, or hydrogen, or of chlorine.

This leads, in the second place, to the result that the relative weights of equal volumes of different gases give the relative weights of the molecules; for if a litre of ammonia containing, let us say, a million, million, million molecules of ammonia weighs 8½ times as much as a litre of hydrogen, which, according to the law, would also contain a million, million, million molecules, it follows that one molecule of ammonia must weigh 8½ times as much as one molecule of hydrogen. We do not know the absolute weight of a molecule of hydrogen, or of a molecule of ammonia, but it follows from what has been said above that an ounce, or a pound, or a gramme of hydrogen will occupy the same volume as 8½ ounces, or pounds, or grammes of ammonia, the same conditions of temperature and pressure being maintained in both cases.

Hence, in the third place, it follows that the *formula* given to gases may represent a definite volume of the gases, and that the formula which represents the *molecule* may also represent a perfectly definite *volume,* which will be the same for all gases.

The question now arises: *What* volume is to be represented by the formula of a gas? The volume may be chosen as the volume occupied by an ounce, or a pound, or a ton of some particular gas, say hydrogen. None of these volumes is chosen, however; in ordinary chemical work the French system of measurement being more common. The volume occupied by a gramme of hydrogen might be employed, and this was in fact used for some time. But if this volume is used as the standard, the formula representing ammonia should represent 8½ grammes, of carbon monoxide 14 grammes, of hydrochloric acid 18.25 grammes. The usual formula for ammonia is, however, NH_3, nd if H represents one gramme, N will necessarily represent 14, and NH_3 will represent 17, or twice the number of grammes in the volume chosen. In the same way the formula CO usually given to carbon monoxide, and the formula HCl given to hydrochloric acid would represent *twice* the weight of the gases contained in the volume chosen. If we are to retain these formulæ it will be necessary to adopt as the standard volume the volume occupied, not by *one* gramme of hydrogen, but by *two* grammes. The formula for hydrogen, then, would be H_2, of nitrogen, N_2, and of oxygen, O_2. Avogadro's law would thus lead to the result that the molecule of hydrogen consists of two atoms, and the same would hold for a number of other elementary gases.

Avogadro's law may be applied in another way to arrive at this result. It is found by experiment that *one* volume of hydrogen uniting with *one* volume of chlorine gives *two* volumes of hydrochloric acid gas. According to Avogadro's law there must be therefore twice as many molecules