Molecular mass from vapour density

The density of a gas relative to that of hydrogen at the same temperature and pressure is known as the vapour density or the hydrogen density of the gas.

$$\text{Thus, the vapour density of a gas} = \frac{\text{density of the gas at a given P and T}}{\text{density of hydrogen at the same P and T}}$$

$$= \frac{\text{mass of given volume of the gas at a given P and T}}{\text{mass of the same volume of hydrogen at the same P and T}}$$

$$= \frac{\text{mass of 22.4 L of the gas at STP}}{\text{mass of 22.4 L of hydrogen at STP}}$$

$$= \frac{\text{1 gram} - \text{molecule mass of the gas}}{\text{2 g}}$$

$\therefore$ the relative molecular mass of a gas = 2 x vapour density.

The vapour densities of gases can be determined experimentally. So can those of many other substance like methanol, ethanol and acetone, which can be completely volatilized. Thus, it is easy to calculate the relative molecular masses of such substances.

Substance	Vapour density	Relative molecular mass (= 2 x vapour density)	Molecular formula
Nitrogen	14	28	N_2
Oxygen	16	32	O_2
Chlorine	35.5	71	Cl_2
Methane	8	16	CH_4
Ethane	15	30	C_2H_6
Carbon dioxide	22	44	CO_2
Methanol	16	32	CH_3OH
Ethanol	23	46	C_2H_5OH
Acetone	29	58	$(CH_3)_2CO$

Atomicity

The atomicity of a gaseous element can be easily calculated if we know its vapour density and atomic mass.

$$\text{Atomicity} = \frac{\text{molecular mass}}{\text{atomic mass}} = \frac{\text{2 x vapour density}}{\text{atomic mass}}.$$

For example, the vapour density of nitrogen is 14 and so its molecular mass = 2 x 14=28

As the atomic mass of nitrogen is 14, its atomicity $= \frac{28}{14} = 2$.

Hence the molecular formula N_2.

Percentage Composition

The percentage composition of a compound in terms of the different elements constituting it can be easily calculated if we know the molecular or the empirical formula of the compound and the atomic masses of its constituents.

Illustration 6: ***What is the percentage of Ca is $CaCO_3$? (Ca = 40, C = 12, O =16)***

Solution: The relative molecular mass of $CaCO_3$ = 40 + 12 + 3 x 16 = 100.

100 g of $CaCO_3$ contain 40 g of Ca.

$\therefore$ the percentage of Ca in $CaCO_3$ = 40.

Exercise 10: Calculate the percentages of H and O in H_2O. (H = 1, O = 16)

Ans. 11.11 % of H, 88.89 % of O.

Exercise 11: Calculate the percentage of Cu and water of crystallisation in blue vitriol $CuSO_4 . 5H_2O$).

(Cu = 63.5, S = 32, O = 16, H = 1)

Ans. 25.45 % of Cu, 76.07 % of H_2O

Exercise 12: Calculate the percentage composition of ethanol (C_2H_5OH) in terms of all the elements present

in the compound.

Ans. **52.17 % of C, 13.04 % of H, 34.78 % of O**