SOME BASIC CONCEPTS OF CHEMISTRY
ATOMIC AND MOLECULAR MASSES

❖ ATOMIC AND MOLECULAR MASS

One of the most important concepts derived from Dalton's atomic theory is that of atomic mass, i.e.," each element has a characteristic atomic mass. As atoms are very tiny particles, their absolute masses are difficult to measure. However, it is possible to determine the relative masses of different atoms if a small unit of mass is taken as a standard. For this purpose, mass of one atom

of hydrogen was assumed as unity and was accepted as standard. The be atomic mass of an element can be defined as the be number wbich indicates how many times the be mass of one atom of the element is heavier in comparison to the mass of one atom: of hydrogen.

$$A = \text{Atomic mass of an element}$$

$$= \frac{\text{Mass of an element}}{\text{Mass of one atom of hydrogen}}$$

In 1858, oxygen atom was adopted as a standard on account of the following reasons:

(i) It is much easier to obtain compounds of elements with oxygen than with hydrogen as oxygen is more reactive than hydrogen.

(ii) The atomic masses of most of the elements. Become approximately whole numbers but with hydrogen as standard the atomic masses of most of the elements are fractional. The mass of one atom of natural oxygen was taken to be 16.0. Thus, atomic mass of an element

$$= \frac{\text{Mass of one atom of the element}}{\frac{1}{16}\text{th part of the mass of one atom of oxygen}}$$

$$= \frac{\text{Mas of one atom of the element}}{\text{mass of one atom of oxygen}}$$

By accepting oxygen as a standard, the atomic mass of hydro 6gen comes as 1.008, sodium 22.991 and sulphur 32.066.

In 1961, the International Union of Chemists selected a new unit for expressing the atomic masses. They accepted the stable isotope of carbon (^{12}C) with mass number of 12 as the standard. Atomic mass of an element can be defined as the number which indicates how many times the mass of one atom of the element is heavier in comparison to 1/12 the part of the mass of one atom of carbon-l2 (^{12}C).

$$A = \text{Atomic mass of an element}$$

$$= \frac{\text{Mass of one atom of the element}}{\frac{1}{12}\text{th part of the mass of one atom of carbon} - 12}$$

$$= \frac{\text{Mass of one atom of the element}}{\text{Mass of one atom of carbon} - 12} \times 12$$

[The quantity' A ′was formerly known as atomic weight. However, this term is no longer used as the word 'weight' means gravitational force.]

Atomic mass unit: The quantity ~mass of an atom of 12 carbon-12 (12 C) is known as the atotinc mass unit and is abbreviated as amu. The actual mass of one atom of carbon-l2 is 1.9924 x 10-23 g or 1.99.24 x 10-26 kg.

Thus,

$$1\ \text{amu} = \frac{1.9924 \times 10^{-23}}{12} = 1.66 \times 10^{-24}\ \text{g or } 1.66\ \times 10^{-27}\ \text{kg}$$

$$A = \text{atomic mass of an element}$$

$$= \frac{\text{Mass of one atom of the element}}{1\ \text{amu}}$$

The atomic masses of some elements on the basis ofcarbon-l2 are given below:

Hydrogen	1.008 amu	Iron	55.847 amu
Oxygen	16.00 amu	Sodium	22.989 amu
Chlorine	35.453 amu	Zinc	65.38 amu
Magnesium	24.305 amu	Silver	107.868 amu
Copper	63.546 amu		

The actual mass of an atom of an element the atomic mass of an element in amu x 1.66 x 10-24 g

So, the actual mass of hydrogen atom 1.008 x 1.66 x 10-24 = 1.6736 X 10-24 g Similarly,

the actual mass of oxygen atom 16 x 1.66 x 10-24 = 2.656 X 10-23 g

It is clear from the above list of atomic masses that atomic masses of a number of elements are not nearly whole numbers. Actually, the above values are average relative masses. Most of the elements occur in nature as a mixture of isotopes. (Isotopes-the atoms. of the same element having different atomic masses). With very few exceptions, however, elements have constant mixtures of isotopes. Chlorine is found in nature as a mixture containing two isotopes CI-35 (34.969 amu) and CI-37 (36.966amu). These are found in the ratio of 75.53% (CI-35) and 24.47% (CI-37).

Therefore, the average relative mass of chlorine is calculated as:

(34.969 x 0.7553) + (3'6.966 x 0.2447) = 35.46 amu

Based on the average mass, the atomic mass of chlorine is 35.46 or 35.5 amu but it is never possible to have-an atom having a relative mass 35.5 amu. It can have relative mass of about 35.0 or 37.0 amu depending on the particular isotope. Thus, average relative mass of any naturally occurring sample of chlorine is 35.46 or 35.5 amu as it is a mixture of two isotopes present in definite proportion. The same reasoning applies to all other elements. The average atomic masses of various elements are det~ed by multiplying the atomic mass of each is. tope by its fractional abundance and adding the values thus obtained.

The fractional abundance is determined by· dividing percentage abundance by hundred.

Example 11. Boron has two isotopes boron-1O and boron-II whose percentage abundances are 19.6% and 80.4% respectively. What is the average atomic mass of boron?

Solution:

Contribution of boron-1O 10.0 X0.196 = 1.96amu

Contribution of boron-II =ll. Ox 0.804 = 8.844amu

Adding both =1.96+8.844=10.804amu

Thus, the average atomic mass of boron is 10.804 amu. Gram-atomic Mass or Gram Atom

When numerical value of atomic mass of an element is expressed in grams, the value becomes gram-atomic mass or gram atom. The atomic mass of oxygen is 16 while gram-atomic mass or gram atom of oxygen is 16 g. Similarly, the gram-atomic masses of hydrogen, chlorine and nitrogen are 1.008 g, 35.5 g and 14.0 g respectively; Gram atomic. mass or gram. Atom of every element consists of same number of atoms. This number is called Avogadro's number. The value of Avogadro's number is 6.02 x 1023. Absolute mass of one oxygen atom

= 16amu =16x 1.66 x 10-24 g

Therefore, the mass of 6.02 x 1023 atoms of oxygen will be

= 16x 1.66 x 10-24 x 6.02 X 1023

16g (gram-: atomic mass)

Thus, gram-atomic mass can be defined as the absolute mass in grams of 6.02 x 1023 atoms of any element. Number of gram atoms of any element can be calculated with the help of the following formula:

$$\text{No. of gram atoms} = \frac{\text{Mass of the element in grams}}{\text{Atomiv mass of the element in grams}}$$

Molecular Mass:

Like an atom, a molecule of substance is also a very small particle possessing a mass of the order of lO-24 to 10-22 g. Similar to atomic mass, molecular mass is also expressed as a relative mass with respect to the mass of the standard substance which is an atom of hydrogen or an atom of oxygen or an atom of carbon-12. The molecular mass of a substance may be defined as the mass of a molecule of a substance relative to the mass of an atom of hydrogen as 1.008 or of oxygen taken as 16.00 or the mass of one atom of carbon taken as 12. Molecular mass is a number which indicates how many times one molecule of a substance is heavier in comparison to 1/16th of the mass of oxygen atom or 1/12th of the mass of one atom of carbon-12.

$$M = \text{Molecular mass}$$

$$= \frac{\text{Mass of one molecule of the substance}}{\frac{1}{12}\text{th mass of one atom of carbon}-12}$$

The mass of a molecule is equal to sum of the masses of the atoms present in a molecule. One molecule of water consists of 2 atoms of hydrogen and one atom of oxygen. Thus, molecular. mass of water (2 x 1.008) + 16.06 18.016amu. One molecule of H2 S04 (sulphuric acid) consists of 2 atoms of hydrogen, one atom of sulphur and four atoms of oxygen. Thus, the molecular mass of sulphuric acid is

= (2x 1.008) + 32.00 + (4 x 16.00)

= 98.0160r 98.016amu

Gram-molecular Mass or Gram Molecule A quantity. of substance whose. mass. in grams is numerically equal to its molecular mass' is called gram molecular mass. In other words; molecular mass of a substance

expressed in grams is called gram-molecular mass to gram molecule. For example, the molecular mass of chlorine is 71 and, therefore, its gram-molecular mass or gram molecule is 71 g. Similarly, molecular mass of oxygen (02) is 32, i. e.,

2x 16= 32amu.

Gram-molecular mass of oxygen 32g Molecular mass of nitric acid (HN03) is 63, i. *e.,*

$$= 1 + 14 + 3 \text{ x } 16 = 63 \text{ amu}$$

Gram-molecular mass of nitric acid = 63 g

Gram-molecular mass should not be confused with the mass of one molecule of the substance in grams. The mass of one molecule of a substance is known as its actual mass.

For example, the actual mass of one molecule of oxygen is equal to.

32x 1.66 x 10-24 g, i.e., 5.32 x 10-23 g.

The number of gram molecules of a substance present in a given mass of a substance can be determined by the application of following formula:

$$\text{No. of gram molecules} = \frac{\text{Mass of a Substance in grams}}{\text{Molecular mass of the substance in grams}}$$

$$\text{Mass of single molecule} = \frac{\text{Molar mass in grams}}{6.023 \times 10^{23}}$$

$$= \text{Molar mass in amu} \times 1.66 \times 10^{-24} \text{ grams}$$

Calculate the mass of 2.5-gram atoms of oxygen.

Solution: We know that,

$$\text{No. of gram atoms} = \frac{\text{Mass of the element in grams}}{\text{Atomic mass of the element in grams}}$$

So, Mass of oxygen = 2.5 x 32 80.0g

Calculate the mass of 1.5-gram molecule of sulphuric acid.

Solution: Molecular mass of H

2S04 =2x 1+ 32+ 4 x 16= 98.0amu

ram-molecular mass of H2S04 =98.0g

Mass of 1.5-gram molecule of H2S04=98.0x 1.5=147.0g