MOLE CONCEPT

1. Mole

- One of the most important unit in chemistry is the mole.
- Scientists use the mole to make counting large numbers of particles easier.
- The number of particles in a mole is called Avogadro's Number.
- Avogadro's number is $6.02214199 \times 10^{23}$ units/mole.
- We call $6.02x10^{23}$ particles as 1 mole.

2. Avagadro's Number

- The mole is used to count out a given number of particles, whether they are atoms, molecules, formula units, ions, or electrons.
- The mole is just one kind of counting unit:
  1 dozen = 12 objects
  1 hour = 3600 seconds
  1 mole = 6.022×10^{23} particles
- 602,000,000,000,000,000,000,000 is a very large number, known as Avagadro's number, abbreviated as N_A.
- A mole is the number of atoms in exactly 12 grams of carbon-12.
- 1 g Hydrogen = 6.02 x 10^{23} atoms = 1 mol H atom.
- 12 g Carbon = 6.02 x 10^{23} atoms = 1 mol C atom.
- 18 g Water = 6.02 x 10^{23} molecules = 1 mol H_2O molecules.
- The mass of 1 mol of a substance in grams is defined as its molar mass.

1 mol of N = 14 g = 6.02 x 10^{23} N atoms.
1 mol of Cu = 63.5 g = 6.02 x 10^{23} Cu atoms.
1 mol of CH_4 = 16 g = 6.02 x 10^{23} CH_4 molecules.
Shortly,

M_{He}= 4 g/mol,
M_{NaOH} = 40 g/mol

3. Molar Mass (M)

Molar mass of compounds are calculated by using molar masses of their consisting elements

M_{H2O} = 2x(mass of H atom) + 1x(mass of O atom)
=2x1 + 1x16
= 18 g/mol

M_{Al2O3} = 2x27 + 3x16
=102 g/mol

Example 1

Find the molar masses of the following substances
a. Co b. CaO c. $KMnO_4$ d. $C_6H_{12}O_6$
Solution

a. M_{Co} = 59 g/mol
b. M_{CaO} = 40 + 16 = 56 g/mol
c. M_{KMnO4}= 39 + 55 + 4x16 = 158 g/mol
d. $M_{C6H12O6}$ = 6x12 + 12x1 + 6x16 = 180 g/mol

4. Molar Volume of Gases

The volume of 1 mol of gas is called the molar volume
At a standard temperature and pressure (STP), one mole of any gas occupies 22.4 L volume. STP: 0°C and 1 atm
For example,
1 mol Ne gas = 22.4 L at STP.
1 mol N_2 gas = 22.4 L at STP.
1 mol O_3 gas = 22.4 L at STP.
1 mol of SO_2 gas = 22.4 L at STP.

Example 2

Find the volumes of the following gases at STP
a. 0.2 mol of O_2 b. 3 mol of NH_3
Solution

a. V_{O2} = 0.2 x 22.4 = 4.48 L
b. V_{NH3} = 3 x 22.4 = 67.2 L

Example 3

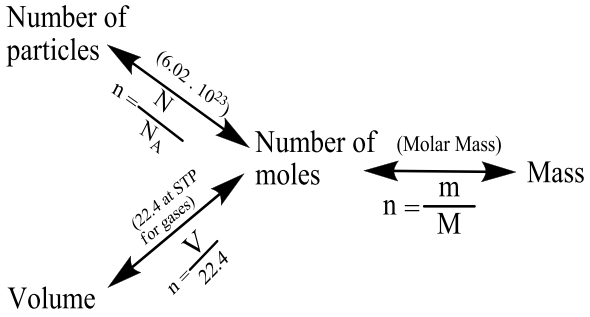
Find the moles of the following gases at STP
a. 11.2 L of CO_2 b. 44.8 L of N_2H_4
Solution

a. 1 mol of CO_2 — 22.4 L
x mol of CO_2 — 11.2 L
x . 22.4 = 1 . 11.2
x = 0.5 mol

b. 1 mol of N_2H_4 — 22.4 L
x mol of N_2H_4 — 44.8 L
x . 22.4 = 1 . 44.8
x = 2 mol

5.Mole Concept Calculation

Mole number, n, is related to the number of particles, mass or volume of substances.



A. Mole-Number of Particles Relationship

$$\text{Number of Moles} = \frac{\text{Number of Particles}}{6.02x10^{23}}$$

$$n = \frac{N}{N_A}$$

Example 4

What is the number of moles of $3.01x10^{23}$ atoms of Fe?
Solution

N = $3.01x10^{23}$ N_A = $6.02x10^{23}$ n = ?
n = N/N_A n = 0.5 mol

B. Mole-Mass Relationship

$$\text{Number of Moles} = \frac{\text{Mass}}{\text{Molar Mass}}$$

$$n = \frac{m}{M}$$

Example 5

What is the number of moles of 20 g of $CaCO_3$?

Solution

m = 20 g M = 100 g/mol n = ?

n = m/M n = 0.2 mol

C. Mole-Volume Relationship

$$\text{Number of Moles} = \frac{\text{Volume}}{22.4}$$

$$n = \frac{V}{22.4}$$

Example 5

What is the number of moles of 5.6 L of O_2 gas at STP?

Solution

V= 5.6 L n = ?

n = V/22.4 n = 0.25 mol

6.Several Types of Problems

A. Finding Density of A Gas at STP

In general, the unit of density of a gas is given in g/L instead of g/mL or g/cm^3.

Example 6

What is the density of 4 mol of NO_2 gas at STP? (N: 14, O: 16)

Solution

n = 4 M = 14+2x16 = 46 g/mol m = ?

n = m/M 4 = m/46 m = 4x46 = 184 g

n = 4 V = ?

n = V/22.4 4 = V/46 V = 4x22.4 = 89.6 L

d = m/V d = 184/89.6 = 2.05 g/L

B. Mass-Percentage of Elements in a Compound

Example 7

What is the mass percentages of each element in $C_6H_{12}O_6$? (C: 12, H:1, O: 16)

Solution

M = 6x12 + 12x1 + 6x16 = 72 + 12 + 96 = 180 g/mol

$$\%\,C = \frac{m_C}{M} x\ 100 = \frac{72}{180} x\ 100 = 40\%$$

$$\%\,H = \frac{m_H}{M} x\ 100 = \frac{12}{180} x\ 100 = 6.7\%$$

$$\%\,O = \frac{m_O}{M} x\ 100 = \frac{96}{180} x\ 100 = 53.7\%$$

C. Calculation of Empirical formula by Mass percentages

Example 8

What is the empirical formula of 2.8 g of a carbon-hydrogen compound that contains 0.4 g of hydrogen? (C: 12, H:1, O: 16)

Solution

m_C = 2.8 – 0.4 = 2.4 g ,n_C = 2.4/12 = 0.2 mol, n_H = 0.4/1 = 0.4 mol

$$C_{0.2}H_{0.4} \Rightarrow C_{\frac{0.2}{0.2}}H_{\frac{0.4}{0.2}} \Rightarrow C_1H_2 \Rightarrow CH_2$$

D. Determining Molecular Formula

$$\text{ratio} = \frac{\text{molar mass of molecular formula}}{\text{molar mass of empirical formula}}$$

Example 9

What is the molecular formula of 92 g of compound which has an empirical formula of NO_2? (N: 14, O: 16)

Solution

M_{NO2} = 14 + 2x16 = 46 g/mol.

ratio = 92/46 = 2

ratio x (NO_2) = N_2O_4 (molecular formula)

E. Mixture Problems

Example 10

A 8.96 L mixture of CO and CO_2 gases at STP is 16 g. Calculate the mass of CO in the mixture? (C: 12, O: 16)

Solution

n_{mix} = 8.96/22.4 = 0.4 mol n_{CO} = x mol then n_{CO2} =0.4 - x

m_{CO}= n.M = x.28 g m_{CO2}= 44.(0.4 – x) g

28x + 44.(0.4 - x) = 16

28x + 17.6 – 44x = 16

1.6 = 16x

x = 0.1 mol

m_{CO} = nxM = 0.1x28 = 2.8 g