Basis of the Mole Concept

Postulate: If two samples of two different elements contain the same number of atoms, their masses must be in the same ratio as the atomic weights of the elements.

Corollary: If the masses of two samples of different elements are in the same ratio as their atomic weights, they both must contain the same number of atoms.

Defining a Mole

A mole is the amount of substance that contains as many elementary units (atoms, molecules, formula units, etc.) as there are atoms in exactly 12 grams of an isotopically pure sample of ^{12}C.

Moles of Atoms in a Sample of an Element

A sample of an element with a mass in grams numerically equal to its atomic weight in atomic mass units contains a mole of atoms of the element.

16.00 g O = 1 mol O atoms

12.01 g C = 1 mol C atoms

12 g (exactly) ^{12}C = 1 mol ^{12}C atoms

✏ This amount of an element is called the **molar mass** of the element (formerly called a gram-atomic weight of the element).

Avogadro's Number

The number of fundamental units in a mole of substance, called Avogadro's number, N_A, has been determined to be

$$N_A = 6.0221367 \times 10^{23}$$

For our purposes, $N_A = 6.022 \times 10^{23}$.

1 mol atoms of element = at. wt. in grams = 6.022×10^{23} atoms

Molar Mass and Molecular Weight

✏ The mass in grams of one mole of substance is its **molar mass**.

For an element or compound composed of molecules, the molar mass in grams is numerically equal to its molecular weight in atomic mass units.

The molar mass of a molecular substance contains an Avogadro's number of molecules of the substance.

m.w. CO_2 = 44.01 u

1 mol CO_2 = 44.01 g CO_2

= 6.022×10^{23} CO_2 molecules

m.w. O_2 = 32.00 u

1 mol O_2 = 32.00 g O_2

= 6.022×10^{23} O_2 molecules

Molar Mass and Formula Weight

For a compound described by an empirical formula (e.g., ionic compound, network solid, empirical formula unit of a molecular compound), the molar mass in grams is numerically equal to the formula weight in atomic mass units.

The molar mass based on a formula weight contains an Avogadro's number of formula units of the substance.

f.w. NaCl = 58.44 u
1 mol NaCl = 58.44 g NaCl
= 6.022×10^{23} NaCl formula units

f.w. SiO_2 = 60.08 u
1 mol SiO_2 = 60.08 g SiO_2
= 6.022×10^{23} SiO_2 formula units

Mole Relations

Example: Consider exactly 1 mol C_2H_6
(m.w. = 30.08 u)

- ✓ Weighs 30.08 g

- ✓ Contains 6.022×10^{23} C_2H_6 molecules

- ✓ Contains 2 mol C
  - ✓ Contains 2 x 12.01g C = 24.02 g C
  - ✓ Contains $2 \times 6.022 \times 10^{23}$ C atoms = 1.204×10^{24} C atoms

- ✓ Contains 6 mol H
  - ✓ Contains 6 x 1.01 g H = 6.06 g H
  - ✓ Contains $6 \times 6.022 \times 10^{23}$ H atoms = 3.613×10^{24} H atoms

- ✓ Contains 2 mol of CH_3 formula units
  - ✓ Contains $2 \times 6.022 \times 10^{23}$ formula units