Stoichiometry-1

SAP-4

Atom → Atom is a smallest fundamental particle of an element.

Representation of atom →

$$_{Z}X^{A} \quad \text{or} \quad ^{A}_{Z}X$$

X = Notation of atom

Z = Atomic no.

A = mass no. (no. of nucleons)

Ex. $^{23}_{11}Na$ atomic no. = 11
mass no. = 23

* No. of Protons in an atom = Z
* No. of neutrons in an atom = $A - Z$
* No. of electrons in a neutral atom = No. of Protons

— " ———— in a charged species
= No. of Protons − charge

Ex. O^{2-} (oxide ion) $\left(_{8}O^{16} \right)$

No. of Protons = 8

No. of neutrons = 16 − 8 = 8

No. of electrons $= 8 - (-2) = 10$

Ex. NH_4^+ (Ammonium ion)

$^{14}_{7}N \quad ^{1}_{1}H$

No. of Protons $= 7 + (4 \times 1) = 11$

No. of neutrons $= 7 + (4 \times 0) = 7$

No. of electrons $= 11 - 1 = 10$

Ex. $C_2O_4^{2-}$ (oxalate ion) $\quad ^{12}_{6}C \quad ^{16}_{8}O$

No. of protons $= 12 + 32 = 44$

No. of neutrons $= 12 + 32 = 44$

No. of electrons $= 44 - (-2) = 46$

Atomic No.	Notation of atom	mass no.
1	H	1
2	He	4
3	Li	7
4	Be	9
5	B	11
6	C	12
7	N	14

8	O	16
9	F	19
10	Ne	20
11	Na	23
12	Mg	24
13	Al	27
14	Si	28
15	P	31
16	S	32
17	Cl	35.5
18	Ar	40
19	K	39
20	Ca	40

Mole $\longrightarrow$ It is collection of N_A Particles.

$$N_A = \text{avogadro no.} = 6.023 \times 10^{23}$$
$$\simeq 6 \times 10^{23}$$

1 mole oxygen atoms $=$ N_A oxygen atoms

1 mole H_2O molecules $=$ N_A H_2O molecules

1 mole mangoes $=$ N_A mangoes

Atomic mass $\longrightarrow$ mass of 1 atom of an element

$$\text{Atomic mass} = (\text{mass no.})\ \text{amu}$$

Atomic mass unit (amu) $= \frac{1}{12} \times (\text{mass of 1 atom of C-12})$

Gram atomic mass (Molar mass of atom) $\longrightarrow$

It is the mass of 1 mole atoms of an element

$$* \quad 1\ \text{amu} = \frac{1}{N_A}\ \text{gm}$$

Ex. $^{24}_{12}Mg$

mass no. $= 24$

mass of 1 atom of Mg or atomic mass of Mg $= 24\ \text{amu} = \frac{24}{N_A}\ \text{gm}$

Gram atomic mass of Mg

or

mass of 1 mole Mg atoms $= \frac{24}{\cancel{N_A}} \times \cancel{N_A}\ \text{gm}$

or

mass of N_A Mg atoms $= 24\ \text{gm}$

$$\boxed{\begin{array}{c}\text{Gram atomic mass} \\ \text{or} \\ \text{molar mass of atom}\end{array} = (\text{mass no.})\ \text{gm}}$$

Ex. $^{40}_{20}Ca$

mass no. = 40

atomic mass = 40 amu = $\frac{40}{N_A}$ gm

molar mass = 40 gm

2. If we consider that 1/6, in place of 1/12, mass of carbon atom is taken to be the relative atomic mass unit, the mass of one mole of a substance will (2005)

(A) decrease twice

(B) increase two folds

(C) remain unchanged

(D) be a function of the molecular mass of the substance

Sol^n →

amu = $\frac{1}{12}$ × (mass of 1 atom of C-12)

↓ ↓

2 amu $\frac{1}{6}$

$$1\ \text{amu} = \frac{1}{N_A}\ \text{gm} \Rightarrow \boxed{\text{amu} \times N_A = 1\ \text{gm (const.)}}$$

amu ⟶ Double

N_A ⟶ Half

$^{24}_{12}Mg$

mass of 1 atom of Mg = $\boxed{24 \text{ amu}}$ → 48 amu

mass of 1 mol Mg atoms $= \underbrace{(24 \text{ amu})}_{48 \text{ amu}} \times \underbrace{N_A}_{\frac{N_A}{2}}$ gm

$48 \text{ amu} \times \frac{N_A}{2}$

$= 24 \text{ amu} \times N_A$

$= 24 \text{ gm}$

Molecular mass → mass of 1 molecule

Molecular mass = (Total mass no.) amu

Gram molecular mass (molar mass of molecule) → mass of 1 mole molecules.

Molar mass of molecule = (Total mass no.) gm

Ex. CH_4 Molecular mass = 16 amu

Molar mass = 16 gm

H_2SO_4 Molecular mass = 98 amu

Molar mass = 98 gm

HNO_3 Molecular mass = 63 amu

Molar mass = 63 gm

Average atomic mass (Atomic mass of mix.) →

$$M_{avg} = \frac{n_1 M_1 + n_2 M_2}{n_1 + n_2}$$

$n_1 \longrightarrow$ % abundance of atom A
or
no. of moles of atom A

$M_1 \longrightarrow$ atomic mass of atom A

$n_2 \longrightarrow$ % abundance of atom B
or
no. of moles of atom B

$M_2 \longrightarrow$ atomic mass of atom B

Naturally occuring chlorine is 75% Cl^{35} which has an atomic mass of 35 amu and 25% Cl^{37} which has a mass of 37 amu. Calculate the average atomic mass of chlorine -

(A) 35.5 amu (B) 36.5 amu (C) 71 amu (D) 72 amu

Sol^n →

$$M_{avg} = \frac{(75 \times 35) + (25 \times 37)}{75 + 25}$$

$$= 35.5 \text{ amu}$$

Average molecular mass (Molecular mass of Mix.) →

$$M_{avg} = \frac{n_1 M_1 + n_2 M_2 + ----}{n_1 + n_2 + ----}$$

The molar composition of polluted air is as follows :

Gas	At. wt.	mole percentage composition
Oxygen (O_2)	16	16%
Nitrogen (N_2)	14	80%
Carbon dioxide	-	03%
Sulphurdioxide	-	01%

What is the average molecular weight of the given polluted air ? (Given, atomic weights of C and S are 12 and 32 respectively.

Sol^n →

$$M_{avg} = \frac{(16 \times 32) + (80 \times 28) + (3 \times 44) + (1 \times 64)}{16 + 80 + 3 + 1}$$

$$= 29.48 \text{ amu}$$

Calculation of no. of moles →

(1) $\text{no. of moles} = \dfrac{\text{given mass (gm)}}{\text{Molar mass}}$

(2) $\text{no. of moles} = \dfrac{\text{No. of Particles}}{N_A}$

(3) For ideal gases, $\text{no. of moles } (n) = \dfrac{PV}{RT}$

at NTP/STP → $P = 1 \text{ atm} \simeq 1 \text{ bar}$

$T = 273\ K$

* $0.0821 \times 273 = 22.4$

* $0.0821 \times 298 = 24.46$

* $0.0821 \times 300 = 24.63$

$$\boxed{\text{No. of moles at NTP/STP} = \frac{V_{lit.}}{22.4}}$$

Q. If CH_4 gas occupies 2.446 ml vol. at 2 atm, 25°C. Then find

(i) No. of moles

(ii) No. of molecules

(iii) No. of C-atoms

(iv) No. of H-atoms

(v) Total no. of atoms

(vi) mass in mg

Sol^n →

$$n = \frac{PV}{RT} = \frac{2 \times \frac{2.446}{1000}}{24.46}$$

$$= 2 \times 10^{-4} \text{ moles}$$

$$\text{no. of moles} = \frac{\text{no. of molecules}}{N_A}$$

$$\text{No. of molecules} = 2 \times 10^{-4} N_A$$

$$\text{Total No. of atoms} = 5 \times 2 \times 10^{-4} N_A$$

$$\text{No. of C-atoms} = 1 \times 2 \times 10^{-4} N_A$$

$$\text{No. of H-atoms} = 4 \times 2 \times 10^{-4} N_A$$

$$\underset{(gm)}{\text{mass}} = \text{mole} \times \text{Molar mass}$$

$$= 2 \times 10^{-4} \times 16 \text{ gm}$$

$$= 2 \times 10^{-4} \times 16 \times 10^{3} \text{ mg}$$

$$= 3.2 \text{ mg}$$

Q. Arrange the following in the increasing order of no. of atoms :

(a) 220 gm CO_2

(b) 1960 gm H_2SO_4

(c) 196 amu H_2SO_4

(d) 93 gm P_4

(e) 6.4 kg S_8

Sol^n → (a) $\text{moles} = \frac{220}{44} = 5 \text{ mole}$

$$\text{Molecules} = 5 N_A$$

$$\text{atoms} = 15 N_A$$

(b) $\text{moles} = \dfrac{1960}{98} = 20 \text{ mole}$

$\text{atoms} = 7 \times 20\, N_A = 140\, N_A$

(c) $\text{moles} = \dfrac{\frac{196}{N_A}}{98} = \dfrac{2}{N_A}$

$\text{atoms} = 7 \times \dfrac{2}{N_A} \times N_A = 14$

(d) 93 gm P_4

$\text{mole} = \dfrac{93}{124} = 0.75$

$\text{atoms} = 4 \times 0.75\, N_A = 3\, N_A$

(e) 6.4 kg S_8

$\text{mole} = \dfrac{6.4 \times 10^3}{256} = 25$

$\text{atoms} = 8 \times 25\, N_A = 200\, N_A$

$c < d < a < b < e$

Note →

(1) No. of gram atoms of atom or No. of gram moles of atom = No. of moles

(2) No. of gram molecules of molecule

or

No. of gram moles of molecule = No. of moles

Ex. 2 gm molecules of H_2 = 2 moles of H_2 molecules

2 gm of H_2 molecules = 1 mole of H_2 molecules

Ex. 5 gm atoms of N
5 gm moles of N } = 5 moles of N-atoms

5 gm of N atoms = $\frac{5}{14}$ moles of N-atoms

Q. Calculate No. of gram atoms of C and H in 5 gm molecules of C_2H_6 ?

Sol^n→ No. of moles of C_2H_6 = 5

$$C_2H_6 \longrightarrow 2C + 6H$$

1 mole	2 mole	6 mole
5 mole	10 mole	30 mole

No. of gram atoms of C = 10

No. of gram atoms of H = 30

Solution → It is a homogeneous mix. of two or more components dispersed on a molecular scale.

Major component → solvent

Minor component → solute

Methods to express concentration of a solution →

(1) mass Percentage $\left(\% \frac{w}{w}\right)$ →

Temp. independent

$$\text{sol}^n \to A, B$$

mass → w_A w_B

$$\left(\% \frac{w}{w}\right)_A = \frac{w_A}{w_A + w_B} \times 100 = \frac{w_A}{w_{sol^n}} \times 100$$

$$\left(\% \frac{w}{w}\right)_B = \frac{w_B}{w_A + w_B} \times 100$$

(2) volume Percentage $\left(\% \frac{V}{V}\right)$ →

Temp. dependent

$$\text{sol}^n \to A, B$$

Vol. → V_A V_B

$$\left(\% \frac{V}{V}\right)_A = \frac{V_A}{V_A + V_B} \times 100 = \frac{V_A}{V_{sol^n}} \times 100$$

$$\left(\% \frac{V}{V}\right)_B = \frac{V_B}{V_A + V_B} \times 100 = \frac{V_B}{V_{sol^n}} \times 100$$

(3) mass by vol. Percentage $\left(\% \frac{w}{v}\right)$ →

Temp. dependent

$$\left(\% \frac{w}{v}\right)_A = \frac{w_A}{V_A + V_B} \times 100$$

gm

ml

$$\left(\% \frac{w}{v}\right)_B = \frac{w_B}{V_A + V_B} \times 100$$

(4) mole fraction (x) →

chi

Temp. independent

sol^n → A, B

mole → n_A n_B

$$x_A = \frac{n_A}{n_A + n_B}$$

$$x_B = \frac{n_B}{n_A + n_B}$$

$$= 1 - x_A$$

(5) Molarity (M) →

$$\frac{\text{No. of moles of solute}}{\text{vol. of sol}^n \text{ in lit}}$$

* Temp. dependent
* Unit → mol/litre

(6) Molality (m) $\longrightarrow$ $\dfrac{\text{no. of moles of solute}}{\text{mass of solvent in Kg}}$

* Unit $\rightarrow$ mol/kg
* Temp. independent

(7) Strength of sol^n (S) $\longrightarrow$ $\dfrac{\text{mass of solute in gm}}{\text{vol. of } sol^n \text{ in lit.}}$

$$S = M \times M_o$$

Unit = $\dfrac{gm}{lit.}$

M_o $\downarrow$ molar mass of solute

* Temp. dependent

(8) Parts Per million (ppm) $\longrightarrow$ $\dfrac{\text{mass of solute}}{\text{mass of } sol^n} \times 10^6$

(9) Parts Per billion (ppb) $\longrightarrow$ $\dfrac{\text{mass of solute}}{\text{mass of } sol^n} \times 10^9$

32. What would be the molality of 20% (mass/mass) aqueous solution of KI? **(2019)**

(molar mass of KI = 166 g mol^{-1})

(A) 1.48 ✓**(B)** 1.51 **(C)** 1.08 **(D)** 1.35

$Sol^n \rightarrow$

$20\% \frac{w}{w}$ KI

If 100 gm sol^n $\longrightarrow$ 20 gm KI

80 gm H_2O

$$m = \frac{\left(20/166\right)}{\left(80/1000\right)} = 1.506 \simeq 1.51$$

Homework

Workbook- DTS 1 to 11

Q. 1-15, 17,18,24,26,27,29,30,31,43-47,53,58,68,69,86, 98,99,108,110,116,118,130,135