ATOMS AND MOLECULES

Question 1: What is a symbol? What information does it convey?

Answer: A short hand representation of an element is called symbol. It represents the following:

- Name of the element
- One atom of the element
- One mole of atoms. It represents 6.023 x 10^{23} atoms of the element.
- A definite mass of the element

Question 2: What is the difference between symbol of an element and formula of an element?

Answer: Symbol of an element represents the name of the element. It also represents one atom of the element. Example: H represents hydrogen and C represents carbon A formula of an element represents the number of atoms in the molecule of the compound. One molecule of hydrogen element contains two atoms of hydrogen; therefore the formula of hydrogen is H_2. 2H represents two separate atoms of hydrogen, whereas H_2 represents 1 molecule of hydrogen similarly the molecular formula of oxygen element and chlorine element is O_2 and Cl_2.

Question 3: Define atomic mass of an element.

Answer: The atomic mass of an element is the relative mass of its atom as compared to the mass of C - 12 atom taken as 12 units.

Question 4: State the laws of chemical combination.

Answer: Laws of chemical combinations are:

i) Law of Conservation of Mass: The law states that during any physical or chemical change, the total mass of the product remains equal to the total mass of the reactants.

ii) Law of Constant Composition: The law states that a chemical compound always contains same elements combined together in the same proportion by mass.

iii) Law of Multiple Proportions: The law states that when two elements combine with each other to form two or more compounds, the masses of one of the elements, which combine with fixed mass of the other, bear a simple whole number ratio to one another.

Question 5: In an experiment it was found that litharge, red oxide of lead and lead peroxide contained 92.83%, 90.6% and 86.6% of lead respectively. Show that these figures are in agreement with the Law of Multiple Proportions.

Answer: In litharge, the amount of lead = 92.83%

The amount of oxygen = 100 - 92.83 = 7.17% 7.17g of O_2 combines with 92.83g of lead

$$\therefore 1\,g\,of\,O_2\ combines\ with\ \frac{92.83}{7.17} = 12.947\,g\,of\,lead$$

In red oxide of lead, the amount of Pb = 90.6%

The amount of oxygen = 100 - 90.6 = 9.4 %

9.4 g of oxygen combines with 90.6g of lead

$$1\text{g of oxygen combines with } \frac{90.6}{9.4} = 9.638\text{g}$$

In lead peroxide, the amount of lead = 86.6%

The amount of oxygen = 100 - 86.6 = 13.4%

13.4g of oxygen combines with 86.6g of lead

$$1\text{g of oxygen combines with } \frac{86.6}{13.4} = 6.462\text{g}$$

Thus, the different weights of lead combining with fixed weight (1g) of oxygen are in the ratio
12.947: 9.638: 6.462 = 2:1.5: 1 or 4: 3: 2

This is in line with the law of multiple proportions.

Question 6: What do you understand by atomicity of an element? Give an example of a polyatomic molecule.

Answer: The number of atoms that constitute one molecule of an element is called its atomicity. Sulphur is a polyatomic molecule: S_8 - 8 is the atomicity.

Question 7: What do the following stand for? (i) P_4 and 4P (ii) O_2 and 2O

Answer:

- P_4 - 1 molecule of phosphorus 4P - 4 atoms of phosphorus
- O_2 - 1 molecule of oxygen 2O - 2 atoms of oxygen

Question 8: How many gram atoms are present in 69 grams of sodium?

Answer:

$$\text{No. of gram atoms} = \frac{\text{Mass of sodium}}{\text{Atomic mass of sodium}}$$

$$= \frac{69}{\text{atomic mass of sodium}} = \frac{69}{23} = 3$$

The number of gram atoms present in 69 grams of sodium is 3.

Question 9: The mass of a single atom of an element Z is 2.65×10^{-23}g. What is its gram atomic mass?

Answer: 1 atom of element Z has mass = 2.65×10^{-23}g

Hence, 6.023×10^{23} atoms of element Z have mass

$= 2.65 \times 10^{-23} \times 6.023 \times 10^{23} = 15.69$ g

Question 10: What is gram molecular mass?

Answer: The amount of a substance whose mass in grams is numerically equal to its molecular mass is called gram molecular mass.

Question 11: Calculate the molar mass of HNO_3. [N = 14, O = 16, H = 1]

Answer: Molar mass of HNO_3.

H = 1 x 1 = 01

N = 14 x 1 = 14

O = 16 x 3 = 48

Total mass = 63 grams

Molar mass of HNO_3= 63 grams

Question 12: Calculate the formula mass of $CaCl_2$. [Ca = 40, Cl = 35.5]

Answer: 1(Ca) + 2(Cl) 40 + 2x(35.5) = 111 amu

The formula mass of $CaCl_2$ is 111 amu.

Question 13: A certain non-metal X forms two oxides I and II. The mass percentage of oxygen in oxide I (X_4O_6) is 43.7, which is same as that of X in oxide II. Find the formula of the second oxide.

Answer:

Solution	Oxygen	X
I Oxide :	43.7 parts	56.3 parts
II Oxide :	56.3 parts	43.7 parts

Now 43.7 parts of oxygen in I corresponds to = 6 oxygen atoms

$$\therefore \text{ 56.3 parts of oxygen in II corresponds to } \frac{6 \times 56.3}{43.7} = 7.730 \text{ atoms}$$

Also 56.3 parts of X in I correspond to = 4 X atom

$$\therefore \text{ 43.7 parts of X in II will correspond to } = \frac{4 \times 43.7}{56.3} \times 3.1 \text{ X atoms}$$

Now the atomic ratio X : O in the second

$$\text{Oxide} = \frac{3.1}{3.1} : \frac{7.73}{3.1} \quad \text{or } 1:25 \text{ or } 2:5$$

The formula of the second oxide is X_2O_5.

Question 14: *(i) Calculate the mass of 0.2 moles of water (O=16, H=1).*

(ii) What is the volume of 7.1 g of chlorine (Cl=35.5) at S.T.P.

Answer: (i) Gram Molecular Weight of H_2O = 2 x 1 + 16 = 18 g

1 mole of water weighs 18 g

$$\therefore 0.2 \text{ moles of water weighs } \frac{18}{1} \times 0.2 = 3.6 \text{ g}$$

(ii) Gram Molecular Weight of Cl_2 (one mole)= 35.5 x 2 = 71 g.

71 g of Cl_2 at S.T.P occupies 22.4 litres

$$\therefore 7.1 \text{ g of } Cl_2 \text{ at S.T.P occupies } \frac{22.4}{71} \times 7.1 = 2.24 \text{ litres}$$

Question 15: *The reaction between aluminium carbide and water takes place according to the following equation:*

$$Al_4C_3 + 12\,H_2O \longrightarrow 3CH_4 + 4Al(OH)_3$$

Calculate the volume of CH_4 released from 14.4 g of Al_4C_3 by excess water at S.T.P. (C = 12, Al = 27)

Answer: Molecular weight of Al_4C_3 is (27 x 4) + (12 x 3) = 144

144 g of Al_4C_3 produces 3 x 22.4 litres of CH_4 at S.T.P

$$\therefore 14.4 \text{ g } Al_4C_3 \text{ produces } \frac{3 \times 22.4}{144} \times 14.4$$

$$= \frac{967.7}{144} = 6.72 \text{ litres}$$

Question 16: **A compound of sodium, sulphur and oxygen has the following percentage composition. Na=29.11%, S=40.51%, O=30.38%.**

Find its empirical formula (O=16, Na=23, S=32).

Answer:

Element	Percentage	Atomic weight	Relative number of atom	Simplest ratio
Na	29.11	23	29.11/23=1.26	1.26/1.26 = 1
S	40.51	32	40.51/32=1.26	1.26/1.26 = 1
O	30.38	16	30.38/16=1.89	1.89/1.26 = 1.5

Empirical formula is $NaSO_{1.5}$ or to its nearest whole number i.e., the formula is $Na_2S_2O_3$.

Question 17: Solid ammonium dichromate with relative molecular mass of 252 g decomposes according to the equation.

$$(NH_4)_2Cr_2O_7 \longrightarrow N_2 + Cr_2O_3 + 4H_2O$$

(i) What volume of nitrogen at S.T.P will be evolved when 63 g of $(NH_4)_2Cr_2O_7$ is decomposed?

(ii) If 63 g of $(NH_4)_2Cr_2O_7$ is heated above 100^0C, what will be the loss of mass? (H=1, N=14, O=16, Cr=52).

Answer: 252 g of $(NH_4)_2Cr_2O_7$ gives one mole or 22.4 litres of N_2 at S.T.P as per the given equation.

$$\therefore 63\text{ g of } (NH_4)_2Cr_2O_7 = \frac{22.4}{252} \times 63 = \frac{1411.2}{252} = 5.6 \text{ litres of } N_2 \text{ at S.T.P}$$

(ii) At temperatures above 100^0C water is in the form of steam.

Products as vapours are N_2 and H_2O.

The transformation of solids and liquids into gaseous substances results in loss of mass.

Total weight of gaseous products = {(2 x 14) + 4 (2 x 1) + 16}

= 28 + 72 = 100 g

Heating 252 g of $(NH_4)_2Cr_2O_7$ causes 100 g loss of mass.

$$\therefore \text{Heating 63 g of } (NH_4)_2Cr_2O_7 \text{ causes } \frac{100}{252} \times 63 = 25 \text{ g loss of mass.}$$

The loss of mass is 25 g

Question 18: How many litres of ammonia are present in 3.4 kg of it? (N = 14, H = 1)

Answer: Gram molecular weight of NH_3 = 14 + (1 x 3) = 17 g.

17 g of NH_3 = 22.4 litres

$$\therefore 3.4\times10^3 \text{ g of } NH_3 = \frac{22.4}{17} \times 3.4 \times 10^3$$

$$= \frac{76160}{17}$$

= 4480 litres.

Question 19: About 640 mL of carbon monoxide is mixed with 800 mL of oxygen and ignited in an enclosed vessel. Calculate the total volume of gases after the burning is completed. All volumes are measured at S.T.P.

Answer: The chemical reaction actually taking place is:

$$\underset{\substack{2\\640\text{ mL}}}{2CO} + \underset{\substack{1\\320\text{ mL}}}{O_2} \longrightarrow \underset{\substack{2\\640\text{ mL}}}{2CO_2}$$

Volume of O_2 used = 320 mL.

Volume of O_2 left = 800 - 320 = 480 mL.

Volume of CO_2 formed = 640 mL.

Therefore the total volume of gases after burning is 480 + 640 = 1120 mL.

Question 20: Calculate the number of moles of ammonium sulphate present in 15.84 kg of it.

(H=1, N=14, O=16, S=32)

Answer: Molecular weight of $(NH_4)_2SO_4$

= (2 x 14) + (2 x 4) + 32 + (16 x 4)

= 132 a.m.u.

132 g of $(NH_4)_2SO_4$ = 1 mole

$$15.84 \times 10^3 \text{ g of } (NH_4)_2SO_4 = \frac{1}{132} \times 15.84 \times 10^3 = 120 \text{ moles}$$

The number of moles of ammonium sulphate present in 15.84 kg is 120 moles.

Question 21: What is the mass of 0.2 mole of lead nitrate? (N=14, O=16, Pb=207).

Answer:

Gram molecular weight of $Pb(NO_3)_2$ = 207 + (2 x 14) + 2(16 x 3)

= 207 + 28 + 96

= 331

1 mole of $Pb(NO_3)_2$ is 331 g

Therefore 0.2 mole of $Pb(NO_3)_2$ is 331 x 0.2 = 66.2 g

Question 22: Find the total percentage of oxygen in magnesium nitrate crystals i.e., $Mg(NO_3)_2.6H_2O$ (Atomic weight: H=1, N=14, O=16, Mg=24).

Answer: Molecular weight of $Mg(NO_3)_2.6H_2O$

= 24 + 2(14 + 16 x 3) + 6(2 x 1 + 16)

= 24 + 124 + 108

= 256 a.m.u

Atomic mass of oxygen in $Mg(NO_3)_2.6H_2O$ is,

= 2 (16 x 3) + 6 (16) = 96 + 96 = 192

$$\therefore \text{Percentage of oxygen} = \frac{192}{256} \times 100 = 75\%$$

Question 23: A compound has the following percentage composition H=2.04%, S=32.65%, O=65.31%. Relative molecular mass of the compound = 98. Calculate its molecular formula (H = 1, S = 32, O = 16).

Answer:

Element	Percentage weight	Atomic weight	Relative number of atoms	Simplest ratio of atoms
H	2.04	1	2.04/1 = 2.04	2.04/1.02 = 2
S	32.65	32	32.65/32 = 1.02	1.02 / 1.02 = 1
O	65.31	16	65.31/16 = 4.08	4.08/1.02 = 4

Empirical formula is H_2SO_4

Empirical formula mass = (2 x 1) + 32 + (16 x 4)

= 98.

Relative molecular mass = 98

$$n = \frac{\text{Relative molecular mass}}{\text{Empirical formula mass}} = \frac{98}{98} = 1$$

$\therefore$ Molecular formula = H_2SO_4

Question 24: Calculate the amount of nitrogen supplied to soil by 1 quintal (100 kg) of ammonium nitrate (N=14, H=1, O=16).

Answer: Molecular weight of NH_4NO_3 = 14 + (4 x 1) + 14 + (16 x 3)

= 80 g

Molecular weight of N in the above formula = 14 x 2 = 28

80 units of NH_4NO_3 yield 28 units of Nitrogen.

$\therefore$ 100 kg of NH_4NO_3 yield $\frac{28}{80} \times 100 = 35$ kg of nitrogen

Question 25: Identify diatomic molecules from the following:

(i) *HCl*
(ii) P_4
(iii) *He*
(iv) O_3
(iv) H_2S
(vi) *CO*

Answer: HCl, CO are diatomic.