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PHYSICS & CHEMISTRY

Chemistry

Preliminary Course

Module 2
Introduction to Quantitative Chemistry

————— **Foundation** —————

1. Define the term “molecular formula”.

The molecular formula of a compound shows exactly how many atoms of each element are present in the compound.

2. Define the term “empirical formula”.

The empirical formula of a compound gives the simplest ratio in which the elements are present in the compound.

3. Fill in the following table by identifying the molecular and empirical formula of each substance.

Substance	Molecular Formula	Empirical Formula
Octane	C_8H_{18}	C_4H_9
Glucose	$C_6H_{12}O_6$	CH_2O
Hydrogen peroxide	H_2O_2	HO
Carbon dioxide	CO_2	CO_2
Dinitrogen tetroxide	N_2O_4	NO_2
Water	H_2O	H_2O

4. Which substance(s) has a chemical formula that must always be an empirical formula?

- (a) Covalent molecular substances
- (b) Covalent network lattices
- (c) Ionic compounds
- (d) **Two of the above**

Development

1. Gravimetric analysis was carried out on samples of different compounds to determine their elemental composition.

Determine the empirical formula of each compound if the samples were found to contain:

- (a) 11.5 g of sodium and 8.00 g of sulfur.

2

$$\begin{aligned}n(\text{Na}) : n(\text{S}) &= \frac{11.5 \text{ g}}{22.99 \text{ g mol}^{-1}} : \frac{8.00 \text{ g}}{32.07 \text{ g mol}^{-1}} \\ &= 0.500 \text{ mol} : 0.249 \text{ mol} \\ &\approx 2 : 1\end{aligned}$$

∴ The EF is Na₂S.

2 marks – Calculates the correct moles of Na and S, and determines the correct EF (1 mark each)

- (b) 0.700 g of hydrogen, 11.4 g of sulfur and 22.9 g of oxygen.

2

$$\begin{aligned}n(\text{H}) : n(\text{S}) : n(\text{O}) &= \frac{0.700 \text{ g}}{1.008 \text{ g mol}^{-1}} : \frac{11.4 \text{ g}}{32.07 \text{ g mol}^{-1}} : \frac{22.9 \text{ g}}{16.00 \text{ g mol}^{-1}} \\ &= 0.694 \text{ mol} : 0.355 \text{ mol} : 1.43 \text{ mol} \\ &\approx 2 : 1 : 4\end{aligned}$$

∴ The EF is H₂SO₄.

2 marks – Calculates the correct moles of H, S and O, and determines the correct EF (1 mark each)

- (c) 3.60 g of carbon, 21.3 g of chlorine and 11.4 g of fluorine.

2

$$\begin{aligned}n(\text{C}) : n(\text{Cl}) : n(\text{F}) &= \frac{3.60 \text{ g}}{12.01 \text{ g mol}^{-1}} : \frac{21.3 \text{ g}}{35.45 \text{ g mol}^{-1}} : \frac{11.4 \text{ g}}{19.00 \text{ g mol}^{-1}} \\ &= 0.300 \text{ mol} : 0.601 \text{ mol} : 0.600 \text{ mol} \\ &\approx 1 : 2 : 2\end{aligned}$$

∴ The EF is CCl₂F₂.

2 marks – Calculates the correct moles of C, Cl and F, and determines the correct EF (1 mark each)

2. A compound with a molar mass of 80.07 g mol^{-1} was analysed gravimetrically and found to contain 40.0% sulfur and 60.0% oxygen.

(a) Determine the empirical formula of this compound.

2

In 100 g of the compound,

$$\begin{aligned}n(\text{S}) : n(\text{O}) &= \frac{40.0 \text{ g}}{32.07 \text{ g mol}^{-1}} : \frac{60.0 \text{ g}}{16.00 \text{ g mol}^{-1}} \\ &= 1.25 \text{ mol} : 3.75 \text{ mol} \\ &\approx 1 : 3\end{aligned}$$

\therefore The EF is SO_3 .

2 marks – Calculates the correct moles of S and O, and determines the correct EF (1 mark each)

(b) Determine the molecular formula of this compound.

1

Let the MF be $(\text{SO}_3)_n$.

$$\begin{aligned}n(32.07 + 3(16.00)) \text{ g mol}^{-1} &= 80.07 \text{ g mol}^{-1} \\ n &= 1\end{aligned}$$

\therefore The MF is SO_3 .

1 mark – Determines the correct MF with appropriate working

3. Ethylene glycol is an organic compound with a molar mass of 62.07 g mol^{-1} . A small sample of ethylene glycol was analysed for its elemental composition and it was found to contain 3.96 g of carbon, 1.01 g of hydrogen and 5.28 g of oxygen.

(a) Determine the empirical formula of ethylene glycol.

2

$$\begin{aligned}n(\text{C}) : n(\text{H}) : n(\text{O}) &= \frac{3.96 \text{ g}}{12.01 \text{ g mol}^{-1}} : \frac{1.01 \text{ g}}{1.008 \text{ g mol}^{-1}} : \frac{5.28 \text{ g}}{16.00 \text{ g mol}^{-1}} \\ &= 0.330 \text{ mol} : 1.00 \text{ mol} : 0.330 \text{ mol} \\ &\approx 1 : 3 : 1\end{aligned}$$

\therefore The EF is CH_3O .

2 marks – Calculates the correct moles of C, H and O, and determines the correct EF (1 mark each)

(b) Determine the molecular formula of ethylene glycol.

1

Let the MF be $(\text{CH}_3\text{O})_n$.

$$\begin{aligned}n(12.01 + 3(1.008) + 16.00) \text{ g mol}^{-1} &= 62.07 \text{ g mol}^{-1} \\ n &= 2\end{aligned}$$

\therefore The MF is $\text{C}_2\text{H}_6\text{O}_2$.

1 mark – Determines the correct MF with appropriate working