Section Three : Metals
Unit Eleven : Basic Chemical Calculations I suggested answer

I. The Avogadro's Number, Mole, Formula Mass, Molecular Mass and Molar Mass

✧ For example:

Formula	Term to describe its mass	Molecular or Formula mass
H_2O	Molecular / Formula	(1) x 2 + (16) x 1 = 18
$Ca(OH)_2$	Formula	74
H_2SO_4	Molecular / Formula	98
$Na_2CO_3.10H_2O$	Formula	286
$Na_2(CO_3)$	Formula	106
$C_6H_{12}O_6$	Molecular / Formula	180

Examples:

1. Mass of carbon dioxide = 7.5 x (12 + 16 x 2)
   = 330 g

2. Number of mole of oxygen = 20 / (16 x 2)
   = 0.625

3. (i) Molar mass of CxH2x = 210 / 2.5
   = 84 g

   (ii) 84 = 12x + 2x
   x = 6
   therefore, the chemical formula = C6H12

Examples:

1. Number of mole of Mg = 2.4 / 24 = 0.1
   Number of Mg atom = 0.1 x 6 x 10^{23}
   = 6 x 10^{22}

2. (a) Molar mass of Be = 9 g
   1 mole Be atom = 6 x 10^{23} Be atom = 9 g
   Mass of 1 Be atom = 9 / 6 x 10^{23} = 1.5 x 10^{-23} g

   (b) Mass of 1 SO_2 molecule = (32 + 2 x 16) / 6 x 10^{23}
   = 1.06 x 10^{-22} g

3. Remark: L is the Avogadro's Number

Substance	Number of mole	Mass (g)	Number of particle
Chlorine molecule (Cl_2)	2	142	Cl_2 molecules: 2L Cl atoms: 4L
Phosphorus (P_4)	0.5	62	P_4 molecules: L/2 P atoms: 2L
Sulphur (S_8)	0.5	128	S_8 molecules: L/2 S atoms: 4L
Sulphur dioxide (SO_2)	2	128	SO_2 molecules: 2L S atoms: 2L O atoms: 4L
Sodium hydroxide (NaOH)	2	80	Total no. of ions: 2.4×10^{24} Na^+ ions: 2L OH^- ions 2L
Sulphuric acid (H_2SO_4)	0.5	49	H atoms: L S atoms: L/2 O atoms: 2L H^+ ions: L SO_4^{2-} ions: L/2
Sucrose ($C_{12}H_{22}O_{11}$)	0.00833	2.85	C atoms: 6×10^{22} H atoms: (0.1/12) x 22L O atoms: (0.1/12) x 11L
Hydrated copper(II) sulphate ($CuSO_4.5H_2O$)	0.5	125	H_2O molecules: 5L/2 Cu^{2+} ions: L/2 SO_4^{2-} ions: L/2
Hydrated sodium carbonate ($Na_2CO_3.10H_2O$)	2	572	H_2O molecules: 20L Na^+ ions: 4L CO_3^{2-} ions: 2L

II. Molar Volume 摩爾體積 for Gases

Examples:

1. Number of mole of carbon dioxide = 2.2 / 44 = 0.05
   Volume of carbon dioxide = 0.05 x 22.4 = 1.12 dm^3

2. Number of mole of hydrogen and oxygen = 2.24 / 22.4 = 0.1

3. Number of mole of ammonia = 2.4 / 24 = 0.1
   Mass of ammonia = 0.1 x (14 + 3 x 1) = 1.7 g

III. Percentage by mass of an element in a compound

Urea	$CO(NH_2)_2$	% N = [28 / (12+16+28+4)] x 100%	= 46.67%
Sodium nitrate	$NaNO_3$	% N = [14 / (23+14+48)] x 100%	= 16.47%
Aqueous ammonia	NH_3	% N = [14 / (14+3)] x 100%	= 82.35%
Ammonium sulphate	$(NH_4)_2SO_4$	% N = [28 / (28+8+32+64)] x 100%	= 21.21%
Ammonium nitrate	NH_4NO_3	% N = [28 / (14+4+14+48)] x 100%	= 35%

IV. Empirical formulae 實驗式, Molecular formulae 份子式, Structural formulae 結構式 and Ionic formulae 離子式

B. Using the mole concept to find the formulae of compounds :

e.g.2

Element	Cu	Cl
Mass of element	47.4	52.6
No. of mole	0.746	1.482
Relative no. of mole (Mole ratio)	1	2

The empirical formula = $CuCl_2$

If the formula mass is 270, then the formula is Cu_2Cl_4.

If the formula mass is 540, then the formula is Cu_4Cl_8.

e.g. 3

Element	Mg	C	O
Mass of element	28.6	14.3	57.1
No. of mole	1.2	1.2	3.6
Relative no. of mole	1	1	3

The empirical formula = $MgCO_3$

e.g. 4

Element	Pb	O
Mass of element	1.374 – 0.126 = 1.248	0.126
No. of mole	0.006	0.0079
Relative no. of mole	3	4

The empirical formula = Pb_3O_4

e.g. 5

Element	C	H	O
Mass of element	40	6.66	53.33
No. of mole	3.33	6.66	3.33
Relative no. of mole	1	2	1

The empirical formula = CH_2O

Let the molecular formula be $(CH_2O)_n$

Therefore, n (12+2+16) = 60 $\Rightarrow$ n = 2

The molecular formula = $C_2H_4O_2$

e.g. 6

(a) (i) mass of H = 9 x (2/18) = 1g

(ii) mass of C = 5.8 – 1 = 4.8g

(iii)

Element	C	H
Mass of element	**4.8**	**1**
No. of mole	**0.4**	**1**
Relative no. of mole	**2**	**5**

The empirical formula = C_2H_5

(b) (i) 1.2/M = 0.5/24 $\Rightarrow$ M = 57.6 (molecular mass)

(ii) Let the molecular formula = $(C_2H_5)_n$

n (24+5) = 57.6 $\Rightarrow$ n ~ 2

Molecular formula = C_4H_{10}

VI. Calculations Using Equations

A. Calculations from Equations —Reacting Masses and Volumes

Examples:

1. Number of mole of sodium hydrogencarbonate = 3.36 / 84 = 0.04

   Number of mole of carbon dioxide = 0.04 / 2 = 0.02

   Maximum volume of carbon dioxide = 0.02 x 22.4 = **0.448 dm^3**

2. $Zn + 2HCl \longrightarrow ZnCl_2 + H_2$

   Number of mole of HCl = 2 x 0.025 = 0.05

   Number of mole of H_2 = 0.05 / 2 = 0.025

   Volume of hydrogen = 0.025 x 24 = **0.6 dm^3**

3. $2Mg + O_2 \longrightarrow 2MgO$

   (a) Number of mole of magnesium = 2.43 / 24.3 = 0.1

   Number of mole of magnesium oxide = 0.1

   Mass of magnesium oxide = 0.1 x (24.3 + 16) = **4.03 g**

   (b) Number of mole of oxygen = 1.28 / 32 = 0.04

   Number of mole of magnesium = 0.1

   Magnesium is in excess!!!

   Number of mole of magnesium oxide = 0.04 x 2 = 0.08

   Mass of magnesium oxide = 0.08 x (24.3 + 16) = **3.224 g**

4. Number of mole of sodium carbonate = 5.3 / 106 = 0.05
   Number of mole of HCl = 2 x 0.04 = 0.08
   Sodium carbonate is in excess!!!
   Number of mole of carbon dioxide = 0.08 / 2 = 0.04
   Volume of carbon dioxide = 0.04 x 24 = **0.96 dm^3**

5. Number of mole of copper(II) oxide = 15.9 / 79.5 = 0.2
   Number of mole of hydrogen = 0.2
   Mass of copper = 0.2 x 63.5 = **12.7 g**

6. Number of mole of sulphuric acid = 3 x 0.025 = 0.075
   Number of mole of hydrated copper(II) sulphate = 0.075
   Molar mass of hydrated copper(II) sulphate = 249.5 g
   Mass of hydrated copper(II) sulphate = 0.075 x 249.5 = **18.1725 g**

7. $NH_4Cl + NaOH \longrightarrow NH_3 + NaCl + H_2O$
   $2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$
   Number of mole of ammonium sulphate = 2.64 / 132 = 0.02
   Number of mole of ammonia = 0.02 x 2 = 0.04
   Number of mole of ammonium chloride = 0.04
   Mass of ammonium chloride = 0.04 x 53.5 = **2.14 g**

B. Calculations from Equations — Reacting gaseous volumes
Examples:

1. $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$
   (a) Volume of methane = 40 cm^3
   Volume of oxygen = 40 x 2 = **80 cm^3**
   (b) Volume of gaseous products at r.t.p. (CO_2) = **40 cm^3**

2. $2H_2 + O_2 \longrightarrow 2H_2O$
   Volume of H_2 = 150 cm^3 Volume of O_2 = 100 cm^3
   Oxygen is in excess!!!
   Volume of O_2 used = 150 / 2 = 75 cm^3
   Volume of O_2 remained = 100 – 75 = **25 cm^3**

3. Volume of CO_2 = 50 – 20 = 30 cm^3
   Volume of O_2 remained = 20 cm^3
   Volume of O_2 reacted = 70 – 20 = 50 cm^3
   $C_xH_y + (x+y/4)O_2 \longrightarrow xCO_2 + (y/2)H_2O$
   From the volume, get $x = 3$ $x + y/4 = 5 \Rightarrow y = 8$
   Therefore, the molecular formula = **C_3H_8**