



**A-Level Chemistry**  
**Empirical and Molecular**  
**Formula**  
**Mark Scheme**

**Time available: 61 minutes**  
**Marks available: 58 marks**

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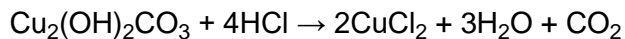
## Mark schemes

1.

- (a) (i)  $\text{H}_2\text{O} + \text{CO}_2$  (as products in any equation)

*Allow  $\text{H}_2\text{O} + \text{H}_2\text{CO}_3$*

1



*Allow multiples*

*Ignore states*

1

- (ii) Bubbles or fizzing or effervescence

Or solid disappears

Or blue(-green) solution

*Do not allow dissolves*

*Ignore  $\text{CO}_2$  gas or gas evolved*

1

- (b) (i) Simplest (whole-number) ratio of atoms of each element in a compound

*Allow atoms of Cu, H & O in this compound*

1

- (ii) Mass of copper = 2.765

Dividing masses by  $A_r$

1

Cu	C	H	O
$\frac{2.765}{63.5} (= 0.0435)$	$\frac{0.348}{12.0} (= 0.029)$	$\frac{0.029}{1.0} (= 0.029)$	$\frac{1.858}{16.0} (= 0.116)$

1

Correct whole number ratio of integers

or

Cu:C:H:O

3:2:2:8

or

Correct empirical formula  $\text{Cu}_3\text{C}_2\text{H}_2\text{O}_8$

*Any order*

*Ignore  $\text{Cu}_3(\text{OH})_2(\text{CO}_3)_2$*

1

[7]

**2.**

- (a) 0.943 g water (M1)

*If Mr of NiSO<sub>4</sub> wrong, can allow M1 and M3 from method 1 i.e. max 2*

$$\begin{array}{cc} \text{NiSO}_4 & \text{H}_2\text{O} \\ \frac{1.344}{154.8} \text{ (M2)} & \frac{0.943}{18} \text{ (M3)} \end{array}$$

$$(8.68 \times 10^{-3} \quad 0.052)$$

$$1 \quad 6 \quad \text{or } x = \underline{6} \text{ (M4)}$$

*Allow Mr = 155*

Allow other methods e.g.

$$M_r(\text{NiSO}_4) = 58.7 + 32.1 + 64.0 = 154.8$$

$$n(\text{NiSO}_4) = \frac{1.344}{154.8} = 0.008682 \text{ mol (M1)}$$

$$M_r(\text{NiSO}_4 \cdot x\text{H}_2\text{O}) = \frac{2.287}{0.008682} = (263.4) \text{ (M2)}$$

$$\text{so } 18x = 263.4 - 154.8 = (108.6) \text{ (M3)}$$

$$\text{so } x = \frac{108.6}{18} = \underline{6} \text{ (M4)}$$

*If using alternative method and Mr of NiSO<sub>4</sub> wrong, allow ecf to score M2 and M3 only i.e. max 2*

4

- (b) re-heat

*Heat to constant mass = 2 marks*

1

check that mass is unchanged

*M2 dependent on M1*

*Allow as alternative:*

*M1: record an IR spectrum*

*M2: peak between 3230 and 3550 (cm<sup>-1</sup>)*

1

**[6]****3.**

- (a)
- M1**
- Amount CO
- <sub>2</sub>
- =
- <sup>1.89</sup>
- /
- <sub>44</sub>
- = 0.043 = mol C

1

$$\textbf{M2} \quad \text{Amount H}_2\text{O} = \frac{0.643}{18} = 0.0357 \text{ mol}$$

1

$$\textbf{M3} \quad \text{Amount H} = 0.036 \times 2 = 0.0714 \text{ mol}$$

1

**M4** Amount O =  $0.913/16 = 0.057$  mol

1

	C	H	O
	0.043	0.0714	0.057
<b>M5</b>	1	1.66	1.33
	3	5	4

1

*Alternate method*

**M1** mass C =  $1.89 - (1.89 \times \frac{32}{44}) = 0.515$  g

**M2** mass H =  $1.5 - (0.515 + 0.913)$

**M3** = 0.0715 g

OR mass **M2** H =  $0.643 - (0.643 \times \frac{16}{18})$

**M3** = 0.0714 g C H O

	C	H	O
<b>M4</b>	$\frac{0.515}{12} = 0.043$	$\frac{0.0715}{1} = 0.0715$	$\frac{0.913}{16} = 0.057$
<b>M5</b>	1	1.66	1.33
	3	5	4

(b) **M1** Amount H<sub>2</sub>O =  $0.26/18 = 0.014$  mol

1

**M2** Amount H<sub>3</sub>Y.xH<sub>2</sub>O =  $3/210 = 0.014$  mol  
or

Amount of H<sub>3</sub>Y =  $2.74/192 = 0.014$  mol  
(hence ratio 1:1)

1

*Common alternate method*

**M1** Amount H<sub>3</sub>Y .xH<sub>2</sub>O =  $3/210 = 0.0143$  mol

**M2**  $M_r \times H_3Y = \frac{2.74}{0.0143} = 192$

$M_r H_2O = 210 - 192 = 18$

(hence x= 1)

(c) 2(-) Hydroxy

1

(d) Number of peaks = 4

*Allow Four*

1

[9]

4.

(a) Percentage of oxygen by mass =  $100 - 40.9 - 4.5 = 54.6$

1

	C	H	O
%	<u>40.9</u>	<u>4.5</u>	<u>54.6</u>
Divide by $A_r$	<u>12</u>	<u>1</u>	<u>16</u>
	= 3.41	= 4.5	= 3.41

1

Divide by smallest =  $\frac{3.41}{3.41} = 1$        $\frac{4.5}{3.41} = 1.32$        $\frac{3.41}{3.41} = 1$

Nearest whole number ratio =  $1 \times 3$        $1.32 \times 3$        $1 \times 3$   
 = 3 : 3.96 : 3

Nearest integer ratio = 3 : 4 : 3

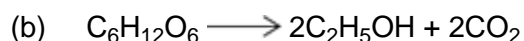
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Empirical formula  $C_3H_4O_3$

Empirical formula mass = 88 = molecular formula mass

Therefore, molecular formula is same as the empirical formula -  $C_3H_4O_3$

1



1

(c) Advantage – ethanol is produced at a faster rate

1

Disadvantage – more energy is used / required in the reaction

1

(d) Air gets in / oxidation occurs

1

(e) Alcohol OH absorption in different place ( $3230\text{--}3550\text{ cm}^{-1}$ ) from acid OH absorption ( $2500\text{--}3000\text{ cm}^{-1}$ )

1

The C=O in acids has an absorption at  $1680\text{--}1750\text{ cm}^{-1}$

1

[10]

5.

(a) (i)  $M_1 - M_r$  calcium phosphate = 310(.3)  
 If  $M_r$  wrong, lose M1 and M5.

1

M2 - Moles calcium phosphate =  $\frac{7.26}{M1}$  (= 0.0234)

0.0234 moles can score M1 and M2.

If  $M_r$  incorrect, can score M2 for  $\frac{7.26}{M1}$ .

Allow M2 and / or M3 to 2 significant figures here but will lose M5 if answer not 1.23.

1

M3 - Moles phosphoric acid =  $2 \times 0.0234 = 0.0468$

Allow student's  $M2 \times 2$ . If not multiplied by 2 then lose M3 and M5.

1

M4 - Vol phosphoric acid =  $0.038(0) \text{ dm}^3$

If not  $0.038(0) \text{ dm}^3$  then lose M4 and M5.

1

Conc phosphoric acid =  $\frac{0.0468}{0.038(0)}$

M5 =  $1.23 \text{ (mol dm}^{-3}\text{)}$

This answer only – unless arithmetic or transcription error that has been penalised by 1 mark.

Allow no units but incorrect units loses M5.

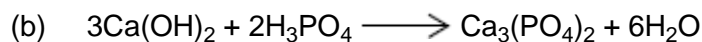
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(ii)  $\frac{492.3}{688.3} \times 100$  OR  $\frac{492}{688} \times 100$

1 mark for both  $M_r$  correctly placed.

= 71.5%

2



Allow multiples.

1

(c)

$$= 0.042 \frac{\begin{array}{c} \text{Ca} \\ 1.67 \\ 40.1 \end{array}}{1} \left( \frac{\begin{array}{c} \text{H} \\ 0.17 \\ 1 \end{array}}{4} \right) \left( \frac{\begin{array}{c} \text{P} \\ 2.59 \\ 31 \end{array}}{2} \right) \left( \frac{\begin{array}{c} \text{O} \\ 5.33 \\ 16 \end{array}}{8} \right)$$

If  $x = 2$  with no working, allow M4 only.

Ca = 1.67 g (M1).

1

Mark for dividing by correct  $A_r$  in Ca and P (M2).  
If M1 incorrect can only score M2.

1

Correct ratio (M3).

1

$\text{CaH}_4\text{P}_2\text{O}_8$  OR  $\text{Ca}(\text{H}_2\text{PO}_4)_2$  OR  $x = 2$   
Value of x or correct formula (M4).

1

### Alternative

Ca                       $\text{H}_2\text{PO}_4$   
 $\text{Ca} = 1.67 \text{ g}$  (M1).

$\frac{1.67}{40.1}$                        $\frac{8.09}{97.0}$

Mark for dividing by correct  $A_r / M_r$  in Ca and  $\text{H}_2\text{PO}_4$  (M2).  
If M1 incorrect can only score M2.

$= \frac{0.042}{1}$                        $\frac{0.083}{2}$

Correct ratio (M3).

$\text{CaH}_4\text{P}_2\text{O}_8$  OR  $\text{Ca}(\text{H}_2\text{PO}_4)_2$  OR  $x = 2$   
Value of x or correct formula (M4).

[12]

**6.**

(a)

Method 1

Mass of H<sub>2</sub>O = 4.38–2.46  
(= 1.92 g)

Method 2

Percentage of H<sub>2</sub>O = 44%

*If there is an AE in M1 then can score M2 and M3*

*If M<sub>r</sub> incorrect can only score M1*

1

ZnSO<sub>4</sub>H<sub>2</sub>OZnSO<sub>4</sub>H<sub>2</sub>O2.461.925644

161.5

18

161.5

18

1

(0.0152

0.107)

(0.347

2.444)

( 1 : 7 )

( 1 : 7 )

x = 7

x = 7

*If x = 7 with working then award 3 marks.*

*Allow alternative methods.*

*If M1 incorrect due to AE, M3 must be an integer.*

1

(b) Moles HCl = 0.12(0)

1

mol ZnCl<sub>2</sub> = 0.06(0) **OR** 0.12 / 2

1

*If M2 incorrect then CE and cannot score M2, M3 and M4.*

mass ZnCl<sub>2</sub> = 0.06 × 136.4

*Allow 65.4 + (2 × 35.5) for 136.4*

1

= 8.18(4) (g) **OR** 8.2 (g)

*Must be to 2 significant figures or more.*

*Ignore units.*

1

(c) Moles ZnCl<sub>2</sub> =  $\frac{10.7}{136.4}$  (= 0.0784)

1

**OR** moles Zn = 0.0784

Mass Zn reacting = 0.0784 × 65.4 = (5.13 g)

*M2 is for their M1 × 65.4*

1



$$\% \text{ purity of Zn} = \frac{5.13}{5.68} \times 100$$

M3 is  $M2 \times 100 / 5.68$  provided M2 is  $< 5.68$

1

= 90.2% **OR** 90.3%

*Allow alternative methods.*

$$M1 = \text{Moles ZnCl}_2 = \frac{10.7}{136.4} (= 0.0784)$$

$$M2 = \text{Theoretical moles Zn} = \frac{5.68}{65.4} (= 0.0869)$$

$$M3 = M1 \times 100 / M2 = (0.0784 \times 100 / 0.0869)$$

$$M4 = \underline{90.2\%} \text{ **OR** } \underline{90.3\%}$$

1

(d) Ionic

*If not ionic CE = 0/3*

1

Strong (electrostatic) attraction (between ions)

1

between oppositely charged ions / + and – ions /  $\text{F}^-$  and  $\text{Zn}^{2+}$  ions

*If IMF, molecules, metallic bonding implied CE = 0/3*

1

[14]