A-Level Chemistry

Empirical and Molecular Formula

Mark Scheme

Time available: 61 minutes
Marks available: 58 marks

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1.

(a) (i) $H_2O + CO_2$ (as products in any equation)

Allow $H_2O + H_2CO_3$

1

$Cu_2(OH)_2CO_3 + 4HCl \rightarrow 2CuCl_2 + 3H_2O + CO_2$

Allow multiples

Ignore states

1

(ii) Bubbles or fizzing or effervescence
Or solid disappears
Or blue(-green) solution

Do not allow dissolves

Ignore 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 $Cu_3C_2H_2O_8$

Any order

Ignore $Cu_3(OH)_2(CO_3)_2$

1

[7]

2. (a) 0.943 g water (M1)

If Mr of $NiSO_4$ wrong, can allow M1 and M3 from method 1 i.e. max 2

$NiSO_4$	H_2O
$\frac{1.344}{154.8}$ (M2)	$\frac{0.943}{18}$ (M3)
(8.68×10^{-3}	0.052)
1	6 or $x = \underline{6}$ (M4)

Allow Mr = 155

Allow other methods e.g.

M_r ($NiSO_4$) = 58.7 + 32.1 + 64.0 = 154.8

n($NiSO_4$) = $\frac{1.344}{154.8}$ = 0.008682 mol (M1)

M_r ($NiSO_4.xH_2O$) = $\frac{2.287}{0.008682}$ = (263.4) (M2)

so $18x$ = 263.4 − 154.8 = (108.6) (M3)

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

If using alternative method and Mr of $NiSO_4$ 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^{-1})

1

[6]

3. (a) **M1** Amount CO_2 = $^{1.89}/_{44}$ = 0.043 = mol C

1

M2 Amount H_2O = $^{0.643}/_{18}$ = 0.0357 mol

1

M3 Amount H = 0.036 x 2 = 0.0714 mol

1

M4 Amount O = $^{0.913}/_{16}$ = 0.057 mol

1

	C	H	O
	0.043	0.0714	0.057
M5	1	1.66	1.33
	3	5	4

1

Alternate method

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

M2 *mass H = 1.5 – (0.515 + 0.913)*

M3 *= 0.0715 g*

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

M3 *= 0.0714 g C H O*

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

(b) **M1** Amount H_2O = $^{0.26}/_{18}$ = 0.014 mol

1

M2 Amount $H_3Y.xH_2O$ = $^{3}/_{210}$ = 0.014 mol
or
Amount of H_3Y = 2.74/192 = 0.014 mol
(hence ratio 1:1)

1

Common alternate method

M1 *Amount* $H_3Y\ .xH_2O$ = $^{3}/_{210}$ *= 0.0143 mol*

M2 $M_r\ xH_3Y$ = $\frac{2.74}{0.0143}$ = 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
%			
Divide by A_r	$\frac{40.9}{12}$	$\frac{4.5}{1}$	$\frac{54.6}{16}$
	= 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 × 3	1.32 × 3	1 × 3

= 3 : 3.96 : 3

Nearest integer ratio = 3 : 4 : 3

1

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

(b) $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$

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 (3230–3550 cm^{-1}) from acid OH absorption (2500–3000 cm^{-1})

1

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

1

[10]

5. (a) (i) M1 - 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 × 0.0234 = 0.0468

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

1

M4 - Vol phosphoric acid = 0.038(0) dm^3

If not 0.038(0) dm^3 then lose M4 and M5.

1

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

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

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

Allow no units but incorrect units loses M5.

1

(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

(b) $3Ca(OH)_2 + 2H_3PO_4 \longrightarrow Ca_3(PO_4)_2 + 6H_2O$

Allow multiples.

1

(c)

Ca	H	P	O
$\frac{1.67}{40.1}$	$\frac{0.17}{1}$	$\frac{2.59}{31}$	$\frac{5.33}{16}$
= 0.042	0.17	0.084	0.333
1	4	2	8

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

$CaH_4P_2O_8$ **OR** $Ca(H_2PO_4)_2$ **OR** x = 2

Value of x or correct formula (M4).

1

Alternative

Ca H_2PO_4

Ca = 1.67 g (M1).

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

Mark for dividing by correct A_r / M_r in Ca and H_2PO_4 (M2).
If M1 incorrect can only score M2.

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

Correct ratio (M3).

$CaH_4P_2O_8$ **OR** $Ca(H_2PO_4)_2$ **OR** x = 2

Value of x or correct formula (M4).

[12]

6. (a)

Method 1	Method 2
Mass of H_2O = 4.38−2.46 (= 1.92 g)	Percentage of H_2O = 44%

If there is an AE in M1 then can score M2 and M3
If M_r incorrect can only score M1

1

$ZnSO_4$	H_2O	ZnSO4	H2O
2.46	1.92	56	44
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 $ZnCl_2$ = 0.06(0) ***OR*** 0.12 / 2

1

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

mass $ZnCl_2$ = 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 $ZnCl_2 = \frac{10.7}{136.4}$ (= 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 × 100 / 5.68 provided M2 is < 5.68

1

= 90.2% ***OR*** 90.3%

Allow alternative methods.

M1 = Moles $ZnCl_2$ = 10.7 / 136.4 (= 0.0784)

M2 = Theoretical moles Zn = 5.68 / 65.4 (= 0.0869)

M3 = M1 × 100 / M2 = (0.0784 × 100 / 0.0869)

*M4 = 90.2% **OR** 90.3%*

1

(d) Ionic

If not ionic CE = 0/3

1

Strong (electrostatic) attraction (between ions)

1

between oppositely charged ions / + and − ions / F^- and Zn^{2+} ions

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

1

[14]