Q25.

Zinc forms many different salts including zinc sulfate, zinc chloride and zinc fluoride.

(a) People who have a zinc deficiency can take hydrated zinc sulfate ($ZnSO_4.xH_2O$) as a dietary supplement.

A student heated 4.38 g of hydrated zinc sulfate and obtained 2.46 g of anhydrous zinc sulfate.

Use these data to calculate the value of the integer x in $ZnSO_4.xH_2O$
Show your working.

(3)

(b) Zinc chloride can be prepared in the laboratory by the reaction between zinc oxide and hydrochloric acid.
The equation for the reaction is

$$ZnO + 2HCl \longrightarrow ZnCl_2 + H_2O$$

A 0.0830 mol sample of pure zinc oxide was added to 100 cm^3 of 1.20 mol dm^{-3} hydrochloric acid.

Calculate the maximum mass of anhydrous zinc chloride that could be obtained from the products of this reaction.

(4)

(c) Zinc chloride can also be prepared in the laboratory by the reaction between zinc and hydrogen chloride gas.

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

An impure sample of zinc powder with a mass of 5.68 g was reacted with hydrogen chloride gas until the reaction was complete. The zinc chloride produced had a mass of 10.7 g.

Calculate the percentage purity of the zinc metal.
Give your answer to 3 significant figures.

(4)

(d) Predict the type of crystal structure in solid zinc fluoride and explain why its melting point is high.

(3)

(Total 14 marks)

Q26.

There is an experimental method for determining the number of water molecules in the formula of hydrated sodium carbonate. This method involves heating a sample to a temperature higher than 300 °C and recording the change in mass of the sample. The equation for the reaction taking place is

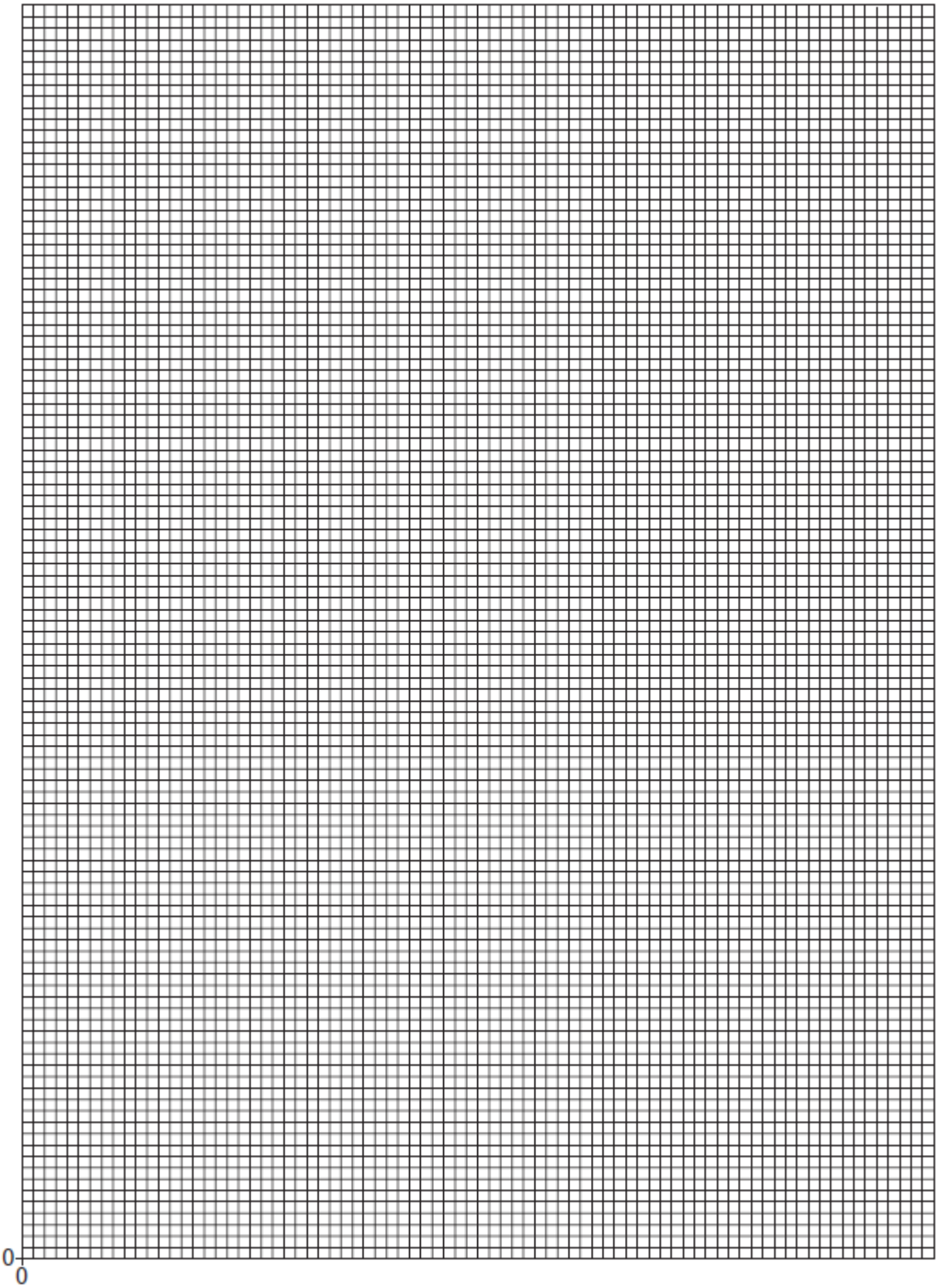
$$Na_2CO_3.10H_2O(s) \longrightarrow Na_2CO_3(s) + 10H_2O(g)$$

A group of six students carried out this experiment. They each weighed out a sample of hydrated sodium carbonate. They then heated their sample to a temperature higher than 300 °C in a crucible for ten minutes and recorded the final mass after the crucible had cooled. Their results are summarised in the table.

Student	1	2	3	4	5	6
Initial mass / g	2.43	1.65	3.58	1.09	2.82	1.95
Final mass / g	0.90	0.61	1.53	0.40	1.15	0.72

(a) Plot the values of **Initial mass** (*y*-axis) against **Final mass** on the grid below.

A graph of these results should include an additional point.
Draw a circle on the grid around the additional point that you should include.



(4)

(b) Draw a best-fit straight line for these results that includes your additional point.

(1)

(c) Identify each student whose experiment gave an anomalous result.

_____

_____

(1)

(d) All the students carried out the experiment exactly according to this method.
Explain why a student that you identified in part (c) obtained an anomalous result.

_____

_____

_____

_____

(2)

(Total 8 marks)

Q27.

The pigment 'Cobalt Yellow' contains an octahedral complex of cobalt(III) and nitrate(III) ions (NO_2^-). Analysis shows that Cobalt Yellow contains 13.0% of cobalt, 18.6% of nitrogen and 25.9% of potassium by mass. The remainder is oxygen.

(a) Use these data to calculate the empirical formula of Cobalt Yellow. Show your working.

_____

_____

_____

_____

_____

_____

_____

(3)

(b) Deduce the structural formula of the cobalt-containing ion in Cobalt Yellow.

_____

(1)

(Total 4 marks)

Q28.

The following table shows the electronegativity values of the elements from lithium to fluorine.

	Li	Be	B	C	N	O	F
Electronegativity	1.0	1.5	2.0	2.5	3.0	3.5	4.0

(a) (i) State the meaning of the term *electronegativity*.

_____

_____

_____

(2)

(ii) Suggest why the electronegativity of the elements increases from lithium to fluorine.

_____

_____

_____

(2)

(b) State the type of bonding in lithium fluoride.
Explain why a lot of energy is needed to melt a sample of solid lithium fluoride.

Bonding _____

Explanation _____

_____

_____

(3)

(c) Deduce why the bonding in nitrogen oxide is covalent rather than ionic.

_____

_____

(1)

(d) Oxygen forms several different compounds with fluorine.

(i) Suggest the type of crystal shown by OF_2

_____

(1)

(ii) Write an equation to show how OF_2 reacts with steam to form oxygen and hydrogen fluoride.

_____

(1)

(iii) One of these compounds of oxygen and fluorine has a relative molecular mass of 70.0 and contains 54.3% by mass of fluorine.

Calculate the empirical formula and the molecular formula of this compound. Show your working.

Empirical formula _____

_____

_____

_____

_____

_____

Molecular formula _____

_____

(4)

(Total 14 marks)

Q29.

(a) Boron trichloride (BCl_3) can be prepared as shown by the following equation.

$$B_2O_3(s) + 3C(s) + 3Cl_2(g) \longrightarrow 2BCl_3(g) + 3CO(g)$$

A sample of boron oxide (B_2O_3) was reacted completely with carbon and chlorine.
The two gases produced occupied a total volume of 5000 cm^3 at a pressure of 100 kPa and a temperature of 298 K.

Calculate the mass of boron oxide that reacted.
Give your answer to 3 significant figures.

(The gas constant R = 8.31 J K^{-1} mol^{-1})

(5)

(b) Boron trichloride can also be prepared from its elements.

Write an equation for this reaction.
Explain why boron trichloride has a trigonal planar shape with equal bond angles.

(3)

(c) (i) Boron trichloride is easily hydrolysed to form two different acids as shown in the following equation.

$$BCl_3(g) + 3H_2O(l) \longrightarrow H_3BO_3(aq) + 3HCl(aq)$$

Calculate the concentration, in mol dm^{-3}, of hydrochloric acid produced when 43.2 g of boron trichloride are added to water to form 500 cm^3 of solution.
Give your answer to 3 significant figures.

(4)

(ii) Boric acid (H_3BO_3) can react with sodium hydroxide to form sodium borate and water.
Write an equation for this reaction.

(1)

(d) Boron trichloride can be reduced by using hydrogen to form pure boron.

$$BCl_3(g) + 1\tfrac{1}{2}\,H_2(g) \longrightarrow B(s) + 3HCl(g)$$

Calculate the percentage atom economy for the formation of boron in this reaction.

Apart from changing the reaction conditions, suggest **one** way a company producing pure boron could increase its profits from this reaction.

(3)

(e) A different compound of boron and chlorine has a relative molecular mass of 163.6 and contains 13.2% of boron by mass.

Calculate the molecular formula of this compound.
Show your working.

(4)

(Total 20 marks)

Q30.

Potassium carbonate can also occur as a hydrated compound, $K_2CO_3.xH_2O$.
Analysis of this hydrated compound showed that it contained 11.5% by mass of water.
Determine the value of x. Show your working.

(Total 2 marks)

Q31.

The element nitrogen forms compounds with metals and non-metals.

(a) Nitrogen forms a nitride ion with the electron configuration $1s^2\ 2s^2\ 2p^6$
Write the formula of the nitride ion.

(1)

(b) An element forms an ion **Q** with a single negative charge that has the same electron configuration as the nitride ion.
Identify the ion **Q**.

_____

(1)

(c) Use the Periodic Table and your knowledge of electron arrangement to write the formula of lithium nitride.

_____

(1)

(d) Calcium nitride contains 81.1% by mass of the metal.
Calculate the empirical formula of calcium nitride.
Show your working.

_____

_____

_____

_____

_____

_____

(3)

(e) Write an equation for the reaction between silicon and nitrogen to form silicon nitride, Si_3N_4

_____

(1)

(Total 7 marks)

Mark Scheme

Q25.

(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 (= 0.0784)
136.4

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

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]

Q26.

(a) 'Initial mass' must be the *y*-axis

If axis unlabelled, use data to decide that 'Initial mass' is on the y-axis.

1

Sensible scale

*Do not award this mark if **plotted points** do not cover at least half of the grid.*

Do not award this mark if any plotted point is outside the grid.

1

All points plotted correctly

Allow ± one small square.

1

Point at (0,0) is ringed

1

(b) Best-fit straight line that goes through the origin ± ½ small square

Mark consequentially to plotted points but the line must still go

through the origin ± ½ small square.

Lose this mark if the line is doubled or kinked.

If the points are plotted correctly, lose this mark if the line deviates towards the anomalies.

1

(c) Students 3 and 5

Allow masses of 1.15 and 1.53 or 2.82 and 3.58

Mark consequentially to plot.

1

(d) Samples 3 or 5 have not lost all their water

Allow reaction / decomposition incomplete.

1

Sample not heated for enough time / larger masses will take a longer time to dehydrate / decompose

1

[8]

Q27.

(a) Percentage of oxygen is 42.5% **(M1)**

Allow if shown clearly in the calculation.

1

Co 13.0 / 58.9 = 0.221, N 18.6 / 14 = 1.329,

K 25.9 / 39.1 = 0.662, O 42.5 / 16 = 2.656 **(M2)**

Allow alternative method if chemically correct.

*If A_r has been divided by the percentage, chemical error, lose **M2** and **M3**.*

1

$CoN_6K_3O_{12}$ **(M3)**

Allow in any order.

Correct answer without working scores this mark only.

1

(b) $Co(NO_2)_6^{3-}$

Allow a correct diagram bonding through N or O

Do not allow $CoN_6O_{12}^{3-}$

Must have correct overall charge.

Allow consequential answer from part(a) if the charge on the anion is correct.

1

[4]

Q28.

(a) (i) The power of an atom or nucleus to withdraw or attract electrons ***OR*** *electron density* ***OR*** *a pair of electrons (towards itself)*

Ignore retain

1

In a covalent bond

1

(ii) More protons / bigger nuclear charge

1

Same or similar shielding / electrons in the same shell or principal energy level / atoms get smaller

Not same sub–shell
Ignore more electrons

1

(b) Ionic

If not ionic then CE = 0 / 3
If blank lose M1 and mark on

1

Strong or many or lots of (electrostatic) attractions (between ions)

If molecules / IMF / metallic / atoms lose M2 + M3, penalise incorrect ions by 1 mark

1

Between + and − ions / between Li^+ and F^- ions / oppositely charged ions

Allow strong (ionic) bonds for max 1 out of M2 and M3

1

(c) Small electronegativity difference / difference = 0.5

Must be comparative
Allow 2 non-metals

1

(d) (i) (simple) molecular

Ignore simple covalent

1

(ii) $OF_2 + H_2O \longrightarrow O_2 + 2HF$

Ignore state symbols
Allow multiples
Allow OF_2written as F_2O

1

(iii) 45.7% O

1

(O F)
(45.7 54.3)
(16 19)

If students get M2 upside down lose M2 + M3
Check that students who get correct answer divide by 16 and 19 (not 8 and 9). If dividing by 8 and 9 lose M2 and M3 but could allocate M4 ie max 2

1

(2.85 2.85)

(1 1)

EF = <u>OF or FO</u>

Calculation of OF by other correct method = 3 marks
Penalise Fl by 1 mark

1

MF (= 70.0 / 35) = O_2F_2 or F_2O_2

1

[14]

Q29.

(a) P = 100 000 (Pa) and V = 5.00 x 10^{-3} (m^3)

M1 is for correctly converting P and V in any expression or list
Allow 100 (kPa) and 5 (dm^3) for M1.

1

$$n = \frac{PV}{RT} = \frac{100\ 000 \times 5.00 \times 10^{-3}}{8.31 \times 298}$$

M2 is correct rearrangement of PV = nRT

1

= 0.202 moles (of gas produced)

This would score M1 and M2.

Therefore $\frac{0.202}{5}$ = 0.0404 moles B_2O_3

M3 is for their answer divided by 5

1

Mass of B_2O_3 = 0.0404 x 69.6

M4 is for their answer to M3 x 69.6

1

= <u>2.81</u> (g)

M5 is for their answer to 3 sig figures.
2.81 (g) gets 5 marks.

1

(b) B + 1.5 Cl_2 → BCl_3

Accept multiples.

1

<u>3</u> bonds

1

Pairs repel <u>equally</u>/ by the <u>same amount</u>

Do not allow any lone pairs if a diagram is shown.

1

(c) (i) 43.2/117.3 (= 0.368 moles BCl_3)

1

0.368 x 3 (= 1.105 moles HCl)

Allow their BCl_3 moles x 3

1

Conc HCl = $\frac{1.105 \times 1000}{500}$

Allow moles of HCl × 1000 / 500

1

= 2.20 to 2.22 mol dm^{-3}

Allow 2.2

Allow 2 significant figures or more

1

(ii) $H_3BO_3 + 3NaOH \rightarrow Na_3BO_3 + 3H_2O$

Allow alternative balanced equations to form acid salts.

Allow $H_3BO_3 + NaOH \rightarrow NaBO_2 + 2H_2O$

1

(d) $\frac{10.8}{120.3}(\times 100)$

Mark is for both M_r values correctly as numerator and denominator.

1

8.98(%)

Allow 9(%).

1

Sell the HCl

1

(e) Alternative method

Cl = 86.8%

Cl = 142 g

1

B	Cl
$\frac{13.2}{10.8}$	$\frac{86.8}{35.5}$

B	*Cl*
$\frac{21.6}{10.8}$	$\frac{142}{35.5}$

1

1.22 *2.45 or ratio 1:2 or BCl_2*

2:4 ratio

1

BCl_2 has M_r of 81.8 so
81.8 x 2 = 163.6
Formula = B_2Cl_4

B_2Cl_4

Allow 4 marks for correct answer with working shown.

Do not allow $(BCl_2)_2$

1

[20]

Q30.

Ratios 88.5 / 138.2 and 11.5 / 18

Correct answer without working scores one mark only.

1

$x = 1$

Allow $K_2CO_3.H_2O$ / 1:1 ratio / one molecule of water of crystallisation.

M2 can be awarded for a correct method using incorrect ratios.

Allow correct answer if integer or decimal number.

1

[2]

Q31.

(a) N^{3-} / N^{-3}

1

(b) F^-/ fluoride

Ignore fluorine/F

Penalise Fl

1

(c) Li_3N / NLi_3

1

(d) $\frac{81.1}{40.1}$ $\frac{18.9}{14}$

M1 for correct fractions

1

(=2.02 = 1.35)

1.5 1 or 3 : 2

M2 for correct ratio

1

Ca_3N_2

If Ca_3N_2 shown and with no working award 3 marks

If Ca_3N_2 obtained by using atomic numbers then lose M1

1

(e) $3\ Si + 2\ N_2 \rightarrow Si_3N_4$

Accept multiples

1

[7]