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# Examiners' Report
# June 2018

## GCE Chemistry 9CH0 01

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# Introduction

This is the second examination in the Pearson Edexcel Level 3 Advanced GCE in Chemistry (9CH0) qualification.

The paper seemed accessible to most candidates and provided them with the opportunity to demonstrate their knowledge and understanding of the key concepts in Topics 1 to 8 and 10 to 15.

There seemed to be some confusion in a few Centres about which equations candidates are expected to know. They should be guided by the specification which determines what is in the examinations and not what is in any textbook or revision guide, which may well go beyond the published specification. The specification makes it clear in Topic 16.12 that the Arrhenius equation will be given if needed and as this is not stated for any other equation, the implication is that all other equations need to be learnt by the candidates. As this is the first time that the equation $\Delta G = -RT\ln K$ has been asked for (all the other equations in the specification were in last year's papers) then we allowed, for this year only, any equation involving these 4 letters for 2 marks out of 3, if calculated correctly using their equation.

Successful candidates:

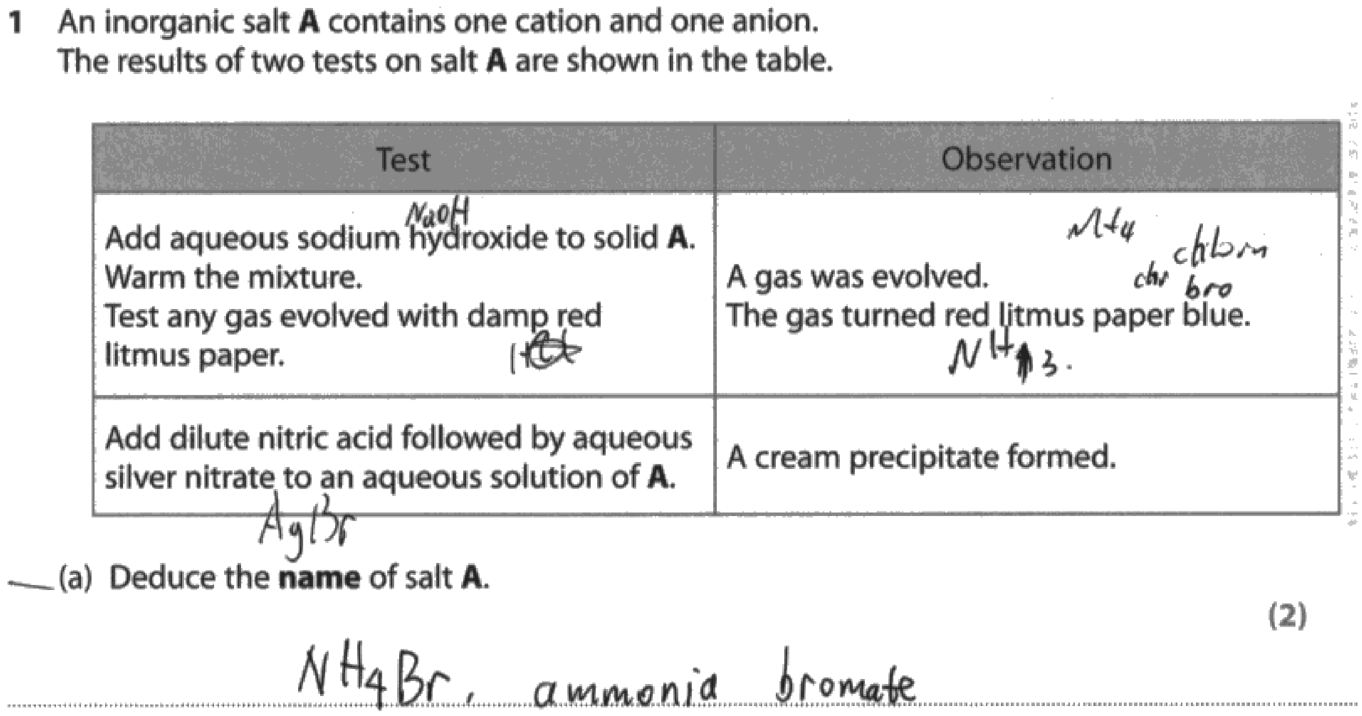
- read the questions carefully and answered the questions as they were set
- understood and used correct scientific terminology
- could carry out unstructured calculations.

Some answers were of a lower standard. Less successful candidates:

- did not read the questions carefully and gave answers that were related to the topic being tested but did not answer the question
- wasted time repeating the question and/or repeating the same points, sometimes several times
- did not use correct scientific terminology
- were not familiar with all the AS topics.

## Question 1 (a)

The majority of candidates could identify at least one ion from ammonium and bromide from the tests and their results, although some did not identify the cation as they did not recognise the test for ammonia gas. Some candidates did not read the question and gave the formula instead of the name, with some giving $NH_3Br$ as an incorrect formula. Candidates are advised to read the questions carefully and take particular note of any words in bold print.



**1** An inorganic salt **A** contains one cation and one anion.
The results of two tests on salt **A** are shown in the table.

| Test | Observation |
|---|---|
| Add aqueous sodium hydroxide to solid **A**. NaOH<br>Warm the mixture.<br>Test any gas evolved with damp red litmus paper. (~~tt~~ | NH4 chlorn chr bro<br>A gas was evolved.<br>The gas turned red litmus paper blue.<br>NH3. |
| Add dilute nitric acid followed by aqueous silver nitrate to an aqueous solution of **A**. AgBr | A cream precipitate formed. |

(a) Deduce the **name** of salt **A**.

**(2)**

NH4Br, ammonia bromate

**ResultsPlus**
**Examiner Comments**

The formula of salt A is correct but both parts of the name are incorrect - it should be ammonium bromide. The incorrect names negate the mark for the formula.

**ResultsPlus**
**Examiner Tip**

Learn the rules for naming inorganic compounds. Ammonia is $NH_3$ but ammonium is $NH_4$. Bromates contain bromine and oxygen e.g. $BrO_3$.

**1** An inorganic salt **A** contains one cation and one anion.
The results of two tests on salt **A** are shown in the table.

| Test | Observation |
|---|---|
| Add aqueous sodium hydroxide to solid **A**.<br>Warm the mixture.<br>Test any gas evolved with damp red litmus paper. | A gas was evolved.<br>The gas turned red litmus paper blue. |
| Add dilute nitric acid followed by aqueous silver nitrate to an aqueous solution of **A**. | A cream precipitate formed. |

(a) Deduce the **name** of salt **A**.

**(2)**

$NH_4Br$

ResultsPlus
**Examiner Comments**

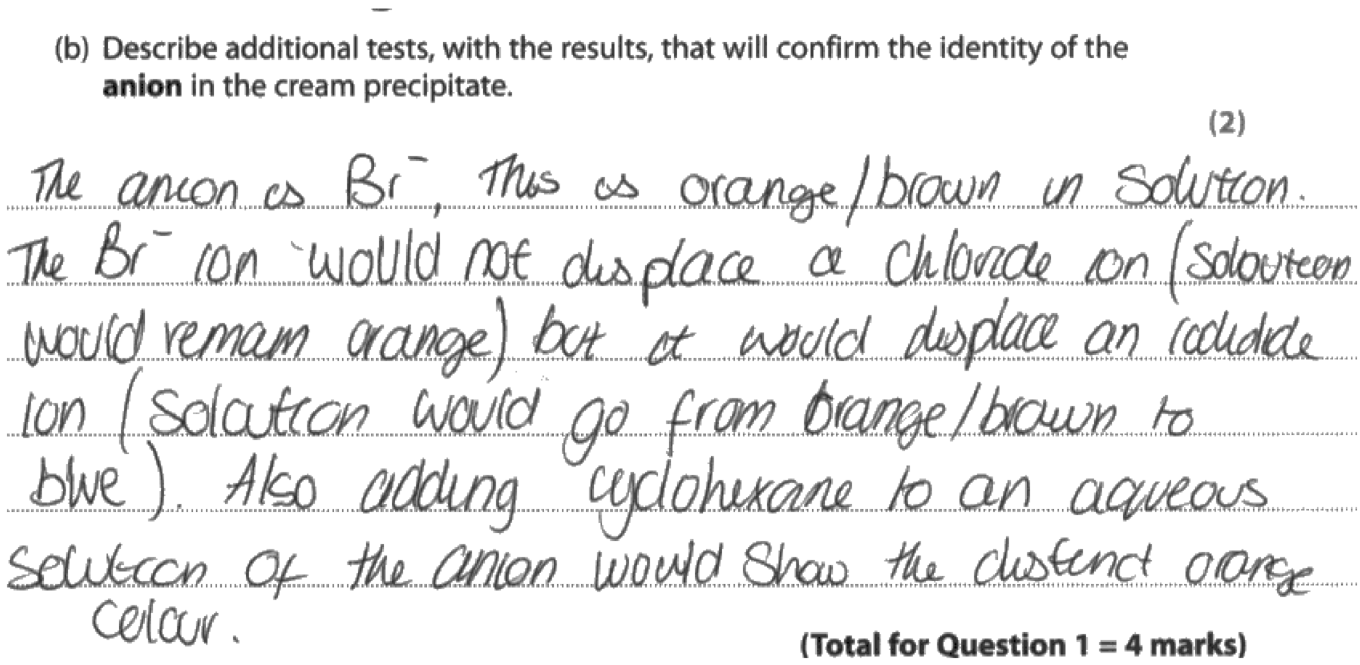
This candidate has given the correct formula for ammonium bromide so has scored 1 mark.

ResultsPlus
**Examiner Tip**

Read the questions carefully. This question asks for the **name** of salt A, not the formula.

## Question 1 (b)

Many candidates were familiar with adding dilute and concentrated ammonia solutions to the cream precipitate to confirm the identity of the anion. Some candidates wrote about adding one type of ammonia but this would not confirm the identity so 1 mark was awarded. Some candidates were confused between bromine and bromide ions and tests for bromine, such as displacement reactions, and therefore did not receive any credit. A few candidates thought that aqueous ammonia was dilute ammonia and excess ammonia was concentrated ammonia.



(b) Describe additional tests, with the results, that will confirm the identity of the **anion** in the cream precipitate.

(2)

The anion is $Br^-$, This is orange/brown in Solution. The $Br^-$ ion would not displace a Chloride ion (Solution would remain orange) but it would displace an iodide ion (Solution would go from orange/brown to blue). Also adding cyclohexane to an aqueous solution of the anion would show the distinct orange colour.

**(Total for Question 1 = 4 marks)**

**ResultsPlus**
**Examiner Comments**

This response scored 0. The candidate has confused a bromide ion with a bromine molecule.

**ResultsPlus**
**Examiner Tip**

Learn the tests for all the species mentioned in the specification.

(b) Describe additional tests, with the results, that will confirm the identity of the **anion** in the cream precipitate.

**(2)**

You can add concerntrated ammonia Solution to the cream precipitate and this will lead to the precipitate disappearing.

ResultsPlus
**Examiner Comments**

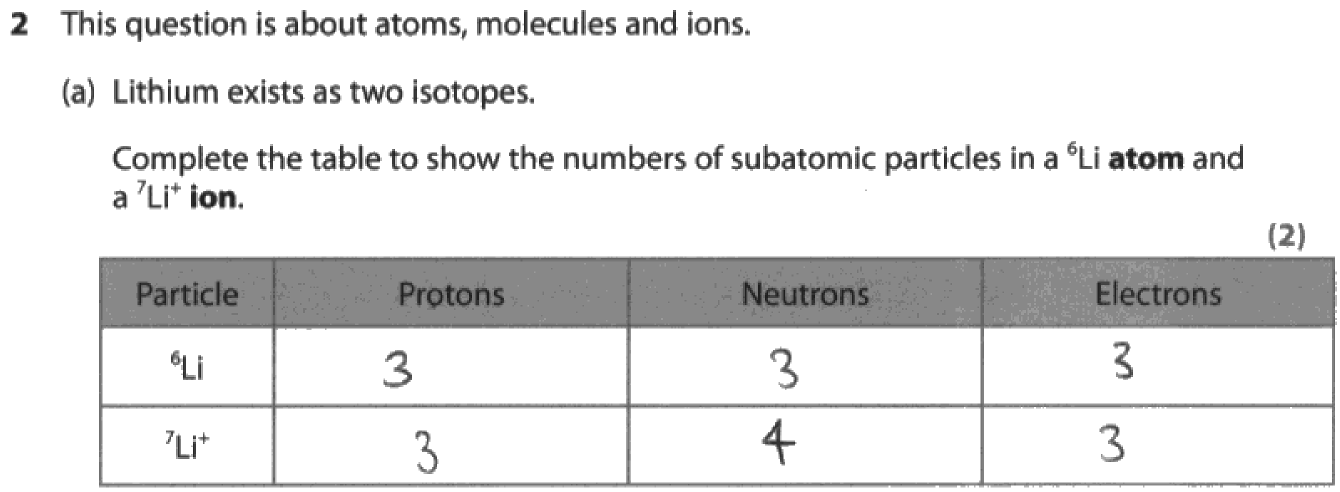
This response scored 1 mark for the correct result when concentrated ammonia is added to the precipitate. The question asked for additional tests to confirm the identity of the precipitate. Silver chloride and silver bromide both dissolve in concentrated ammonia so this one test does not confirm the identity.

ResultsPlus
**Examiner Tip**

Give full details for any tests you describe. The test with dilute ammonia would show that the anion is not a chloride and the test with concentrated ammonia shows that the anion is not an iodide so must be a bromide.

## *Question 2 (a)*

The majority of candidates scored 2 marks for this question. Some candidates did not notice that the second species is a positive ion so wrote an incorrect number of electrons. It was surprising that a small minority of candidates did not know how to work out the correct numbers of subatomic particles from the atomic and mass numbers.



**2** This question is about atoms, molecules and ions.

(a) Lithium exists as two isotopes.

Complete the table to show the numbers of subatomic particles in a $^{6}$Li **atom** and a $^{7}$Li$^{+}$ **ion**.

**(2)**

| Particle | Protons | Neutrons | Electrons |
|---|---|---|---|
| $^{6}$Li | 3 | 3 | 3 |
| $^{7}$Li$^{+}$ | 3 | 4 | 3 |

**ResultsPlus**
**Examiner Comments**

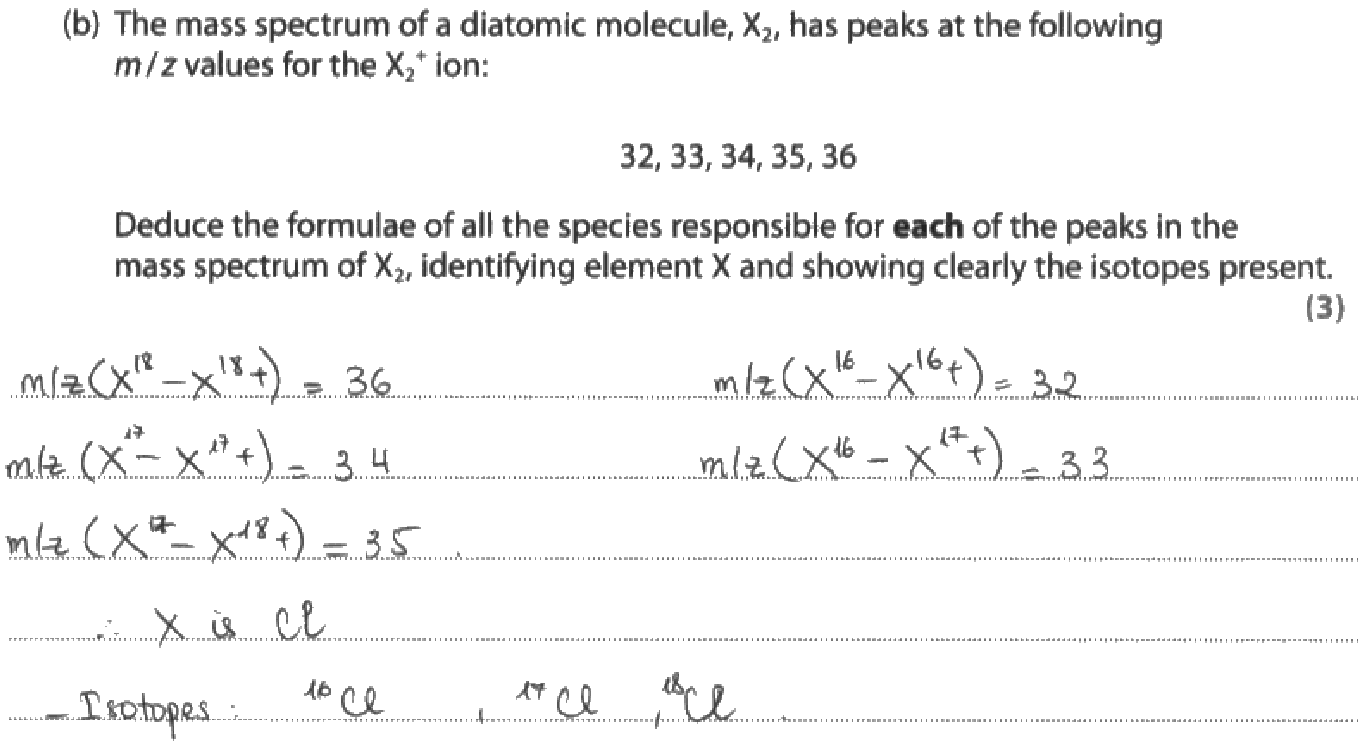
This response scored 1 mark for the numbers of subatomic particles in a lithium atom. The number of electrons is incorrect for the lithium ion.

**ResultsPlus**
**Examiner Tip**

Read the question carefully, particularly the words in bold. The lithium ion has a positive charge so the number of electrons is one less than the number of protons.

## *Question 2 (b)*

Many candidates identified element X as oxygen, although a significant minority confused mass numbers with atomic numbers and thought it was chlorine. Other elements, such as fluorine, nitorgen and sulfur were not uncommon. Many candidates scored 2 marks as they identified X and at least 3 of the species giving the peaks. Some candidates read the question carefully and realised that there are two different combinations of isotopes that would give 34, so they scored 3 marks.



(b) The mass spectrum of a diatomic molecule, $X_2$, has peaks at the following $m/z$ values for the $X_2^+$ ion:

32, 33, 34, 35, 36

Deduce the formulae of all the species responsible for **each** of the peaks in the mass spectrum of $X_2$, identifying element X and showing clearly the isotopes present.

(3)

$m/z(X^{18}-X^{18}+) = 36$ $m/z(X^{16}-X^{16}+) = 32$

$m/z\,(X^{17}-X^{17}+) = 34$ $m/z(X^{16}-X^{17}+) = 33$

$m/z\,(X^{17}-X^{18}+) = 35$

$\therefore$ X is Cl

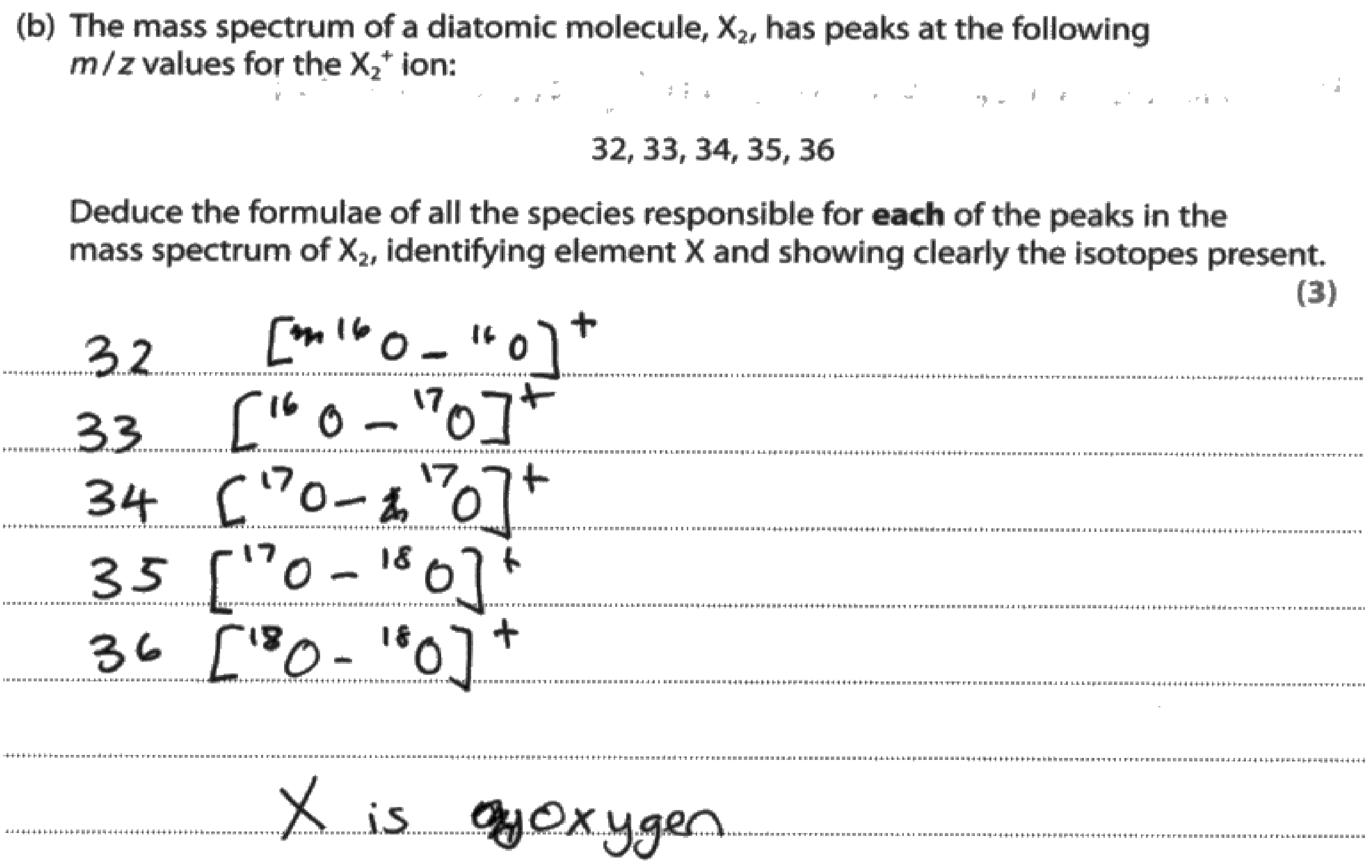
Isotopes : $^{16}Cl$ , $^{17}Cl$ , $^{18}Cl$

**ResultsPlus**
**Examiner Comments**

This candidate has confused mass and atomic numbers so identified X as chlorine instead of oxygen. However, they still score 1 mark for identification of the isotopes responsible for the peaks at 32, 33, 35 and 36. They have only given one combination of isotopes for the peak at 34.

**ResultsPlus**
**Examiner Tip**

Make sure that you understand the difference between atomic number and mass number.



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32, 33, 34, 35, 36

Deduce the formulae of all the species responsible for **each** of the peaks in the mass spectrum of $X_2$, identifying element X and showing clearly the isotopes present.

**(3)**

32 $[\cancel{m}\,^{16}O-{}^{16}O]^+$

33 $[^{16}O-{}^{17}O]^+$

34 $[^{17}O-\cancel{1}\,^{17}O]^+$

35 $[^{17}O-{}^{18}O]^+$

36 $[^{18}O-{}^{18}O]^+$

X is ~~oy~~ oxygen

**ResultsPlus**
**Examiner Comments**

This is an example of a common answer that scored 2 marks. The question asked for all the species responsible for each of the peaks and the isotopes of 16 and 18 would also give a peak at 34.

**ResultsPlus**
**Examiner Tip**

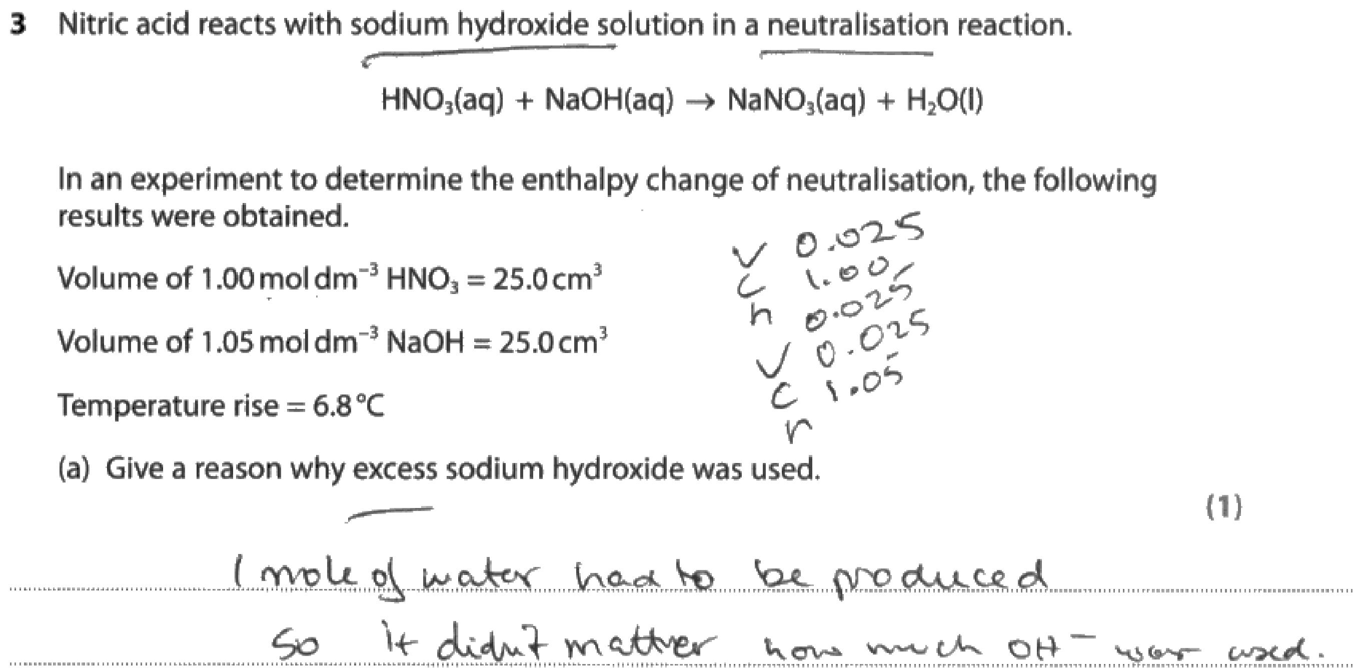
Try to give all the combinations of isotopes in this style of question.

## *Question 2 (c)*

The majority of candidates knew the maximum numbers of electrons in the 1s orbital and the 2p subshell. The maximum number of electrons in the third quantum shell proved to be more of a challenge as many candidates forgot about the 3d subshell.

## *Question 3 (a)*

The majority of candidates realised that excess sodium hydroxide was needed to ensure that all of the nitric acid reacted. There were a few general answers seen that did not score a mark, for example, 'to ensure the reaction is complete'.



**3** Nitric acid reacts with sodium hydroxide solution in a neutralisation reaction.

$$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$$

In an experiment to determine the enthalpy change of neutralisation, the following results were obtained.

Volume of 1.00 mol dm$^{-3}$ $HNO_3$ = 25.0 cm$^3$

Volume of 1.05 mol dm$^{-3}$ NaOH = 25.0 cm$^3$

Temperature rise = 6.8 °C

V 0.025
c 1.00
n 0.025
V 0.025
c 1.05
n

(a) Give a reason why excess sodium hydroxide was used.

(1)

1 mole of water had to be produced so it didn't matter how much $OH^-$ was used.

**ResultsPlus**
**Examiner Comments**

This response scored 0. The candidate knows that the definition of enthalpy change of neutralisation is for the formation of 1 mol of water but in this experiment only 0.025 mol of water is produced.

**ResultsPlus**
**Examiner Tip**

Apply your knowledge of definitions to the particular question that is asked.

$HNO_3$ NaOH

**3** Nitric acid reacts with sodium hydroxide solution in a neutralisation reaction.

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Volume of 1.05 mol dm$^{-3}$ NaOH = 25.0 cm$^3$

Temperature rise = 6.8 °C

(a) Give a reason why excess sodium hydroxide was used.

(1)

To ensure all the nitric acid had been neutralised and so NaOH was not a limiting reagent, ensuring the reaction was complete.

**ResultsPlus**
**Examiner Comments**

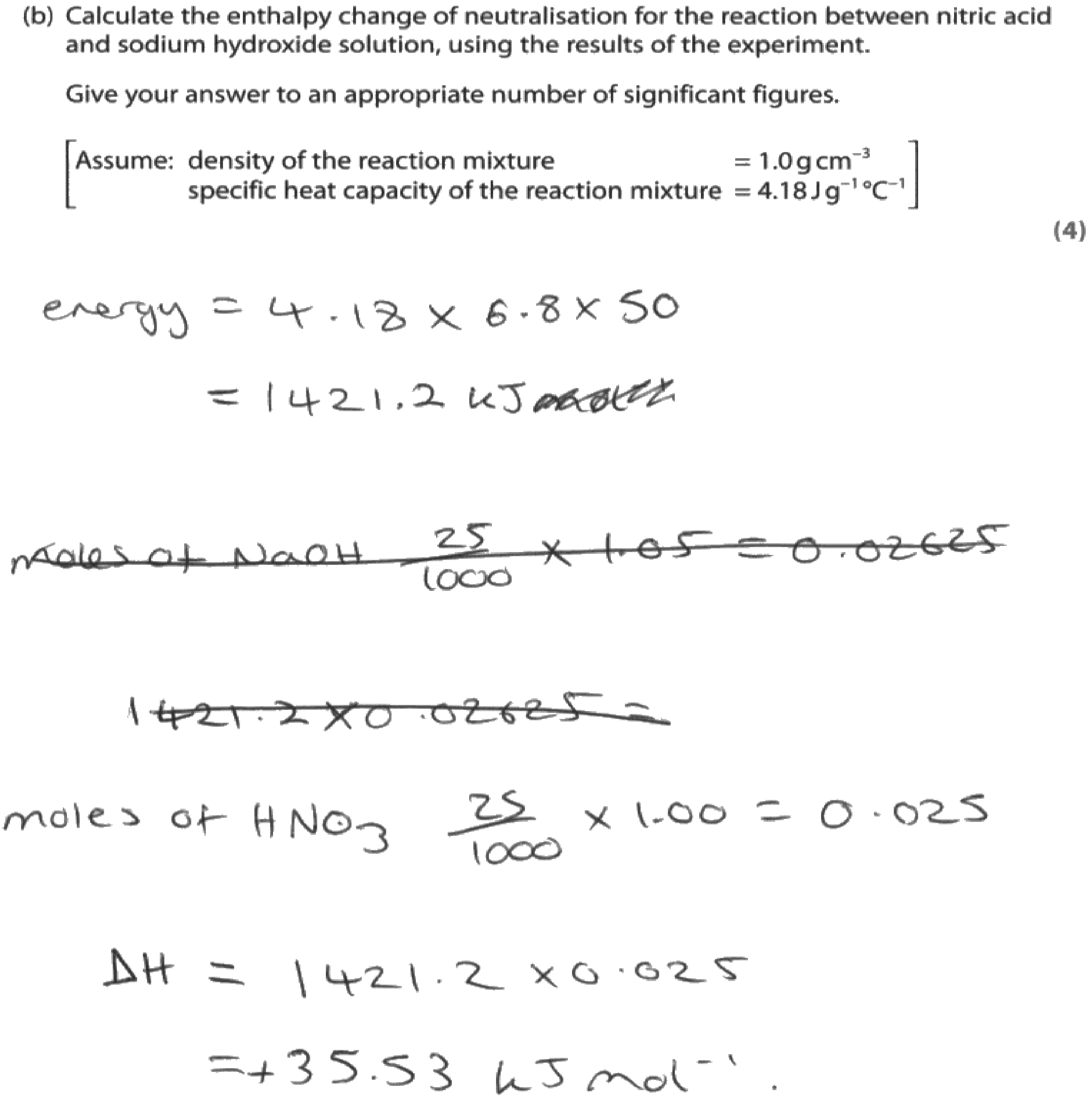
This is an excellent answer that scored 1 mark.

**ResultsPlus**
**Examiner Tip**

It was not essential to include the phrase about sodium hydroxide not being the limiting reagent, but this is a useful concept to understand.

## Question 3 (b)

Many candidates scored 3 marks for carrying out the calculation correctly to give -56.8 kJ $mol^{-1}$, however they did not read, or did not understand the instruction to give their answer to an appropriate number of significant figures. The temperature rise and density are given to 2 significant figures so the final answer should not have more than this. Candidates should be encouraged to think carefully about the number of significant figures to give in their final answer rather than give all answers to 3 significant figures. Other common errors included: only using 25g as the mass instead of 50g, adding together the moles of nitric acid and sodium hydroxide and omitting the negative sign for the final answer. Some candidates just calculated the heat produced in the experiment and thought that was the enthalpy change of neutralisation and a few candidates added 273 to the temperature change to try to convert it to kelvin.



(b) Calculate the enthalpy change of neutralisation for the reaction between nitric acid and sodium hydroxide solution, using the results of the experiment.

Give your answer to an appropriate number of significant figures.

[Assume: density of the reaction mixture = 1.0 g $cm^{-3}$
specific heat capacity of the reaction mixture = 4.18 J $g^{-1}$ °$C^{-1}$]

**(4)**

energy = 4.18 × 6.8 × 50

= 1421.2 kJ

~~moles of NaOH $\frac{25}{1000}$ × 1.05 = 0.02625~~

~~1421.2 × 0.02625 =~~

moles of $HNO_3$ $\frac{25}{1000}$ × 1.00 = 0.025

$\Delta H$ = 1421.2 × 0.025

= +35.53 kJ $mol^{-1}$.

**ResultsPlus**
**Examiner Comments**

This response scored 2 marks for calculating the heat produced in the reaction and the number of moles of nitric acid. The candidate has multiplied the heat produced by the number of moles, instead of dividing, and has given a positive sign for the final answer.

**ResultsPlus**
**Examiner Tip**

Remember that enthalpy changes are measured in kilojoules per mole and 'per' means divide.

The temperature increased during the experiment showing that it is an exothermic reaction so the final answer should have a negative sign.

(b) Calculate the enthalpy change of neutralisation for the reaction between nitric acid and sodium hydroxide solution, using the results of the experiment.

Give your answer to an appropriate number of significant figures.

[Assume: density of the reaction mixture = 1.0 g cm$^{-3}$
specific heat capacity of the reaction mixture = 4.18 J g$^{-1}$ °C$^{-1}$]

**(4)**

$q = mc\Delta t$

$q = 50 \times 4.18 \times 6.8 = 1421.2$ J

moles $HNO_3 = \frac{25}{1000} \times 1 = 0.025$ moles

Temperature rise ∴ $-1421.2$ J $= -1.4212$ kJ

$\Delta H_{neut} = \frac{-1.4212}{0.025} = -56.848$ kJ mol$^{-1}$

$= -56.8$ kJ mol$^{-1}$ (3 sf)

**ResultsPlus**
**Examiner Comments**

This is an example of a common answer that scored 3 marks. The final answer is given to too many significant figures as the temperature rise and density are only given to 2 significant figures.

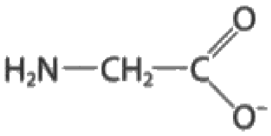
**ResultsPlus**
**Examiner Tip**

Always check the accuracy of the data you are given in calculations. Your final answer should not be given to more significant figures than the least accurate data.

## *Question 4 (e)*

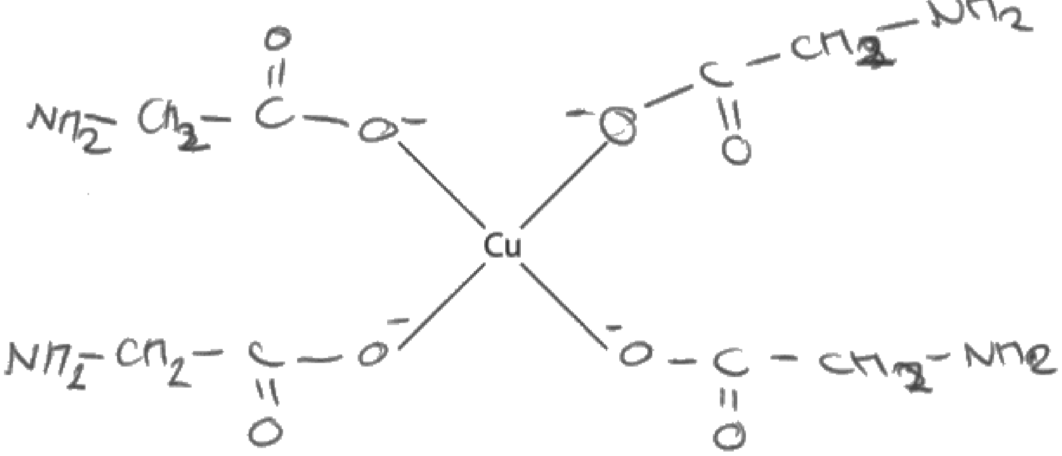
Many candidates could show the structure of the complex correctly. However, common errors included showing four monodentate ligands instead of two bidentate ligands, showing the hydrogens of the $NH_2$ groups linked to copper instead of the nitrogen atoms, showing the oxygens of the C=O groups joined to the copper instead of the single-bonded oxygens and splitting the two bidentate ligands into four monodentate ligands.

(e) Glycinate ions are bidentate ligands and can be represented by the structure



Complete the diagram below to show the structure of the $[Cu(NH_2CH_2COO)_2]$ complex, which is square planar.

**(2)**



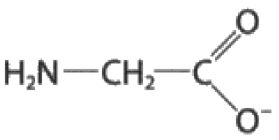
**ResultsPlus**
**Examiner Comments**

This response scored 0. The candidate has missed the point about glycinate ions being bidentate ligands and the formula given shows two ligands attached to the copper ion.

**ResultsPlus**
**Examiner Tip**

Make sure that you understand the meaning of the term 'bidentate ligand'.

(e) Glycinate ions are bidentate ligands and can be represented by the structure



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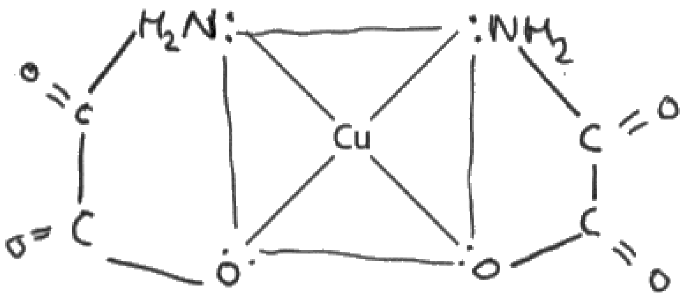
(2)



**ResultsPlus**
**Examiner Comments**

This response scored 1 mark for the two nitrogens attached to the copper. The two single-bonded oxygens bonded to copper are also correct but the mark cannot be awarded as the candidate has copied the structure of the glycinate ions incorrectly and shown two C=O groups instead of C=O and $CH_2$.

**ResultsPlus**
**Examiner Tip**

Check the structures given in the question carefully and make sure you copy them accurately.

## Question 4 (f)

Many candidates could explain the sequence of changes in rate of reaction and there were some very good descriptions of autocatalysis. Some candidates omitted to explain why the reaction starts slowly or stated there would be little catalyst present, instead of no catalyst. Some candidates seemed unfamiliar with this reaction and the concept of autocatalysis and they just wrote generally about rate of reaction. A few candidates thought that the reaction slows down at the end as the $Mn^{2+}$ ions are used up, showing they had little understanding of catalysis.

(f) Manganate(VII) ions, $MnO_4^-$, react with ethanedioate ions in acid solution.

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

The reaction starts slowly, the rate of reaction then increases, before it decreases again. Explain this sequence.

(3)

Initially reaction starts slowly, but increases in speed as $mn^{2+}$ is produced. This acts as a catalyst speeding up tho rate of the reaction, as it provides an alternative pathway for the reaction with a lower activation energy. The reaction slows down as $mn^{2+}$ is up.

**ResultsPlus**
**Examiner Comments**

This response scored 1 mark for why the rate of reaction speeds up. There is no reason given for why the reaction starts slowly. The reaction does not slow down as the $Mn^{2+}$ is used up as this is a product of the reaction.

**ResultsPlus**
**Examiner Tip**

Remember that reactions slow down when the reactants are used up.

(f) Manganate(VII) ions, $MnO_4^-$, react with ethanedioate ions in acid solution.

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

The reaction starts slowly, the rate of reaction then increases, before it decreases again. Explain this sequence.

(3)

autocatalysis where $2Mn^{2+}$ ions catalyses the reaction, increasing the rate until the reactants, $2MnO_4^-$ and $5C_2O_4^{2-}$ ions run out and the rate decreases again as there is less product, $Mn^{2+}$ to catalyse rate of reaction

**ResultsPlus**
**Examiner Comments**

This response scored 2 marks. The candidate has correctly described the increases in rate of reaction and why the rate decreases again. However, they have not commented on why the reaction starts slowly.

**ResultsPlus**
**Examiner Tip**

Read the question carefully and check to make sure that you have written about all parts of it.

# *Question 5 (a)*

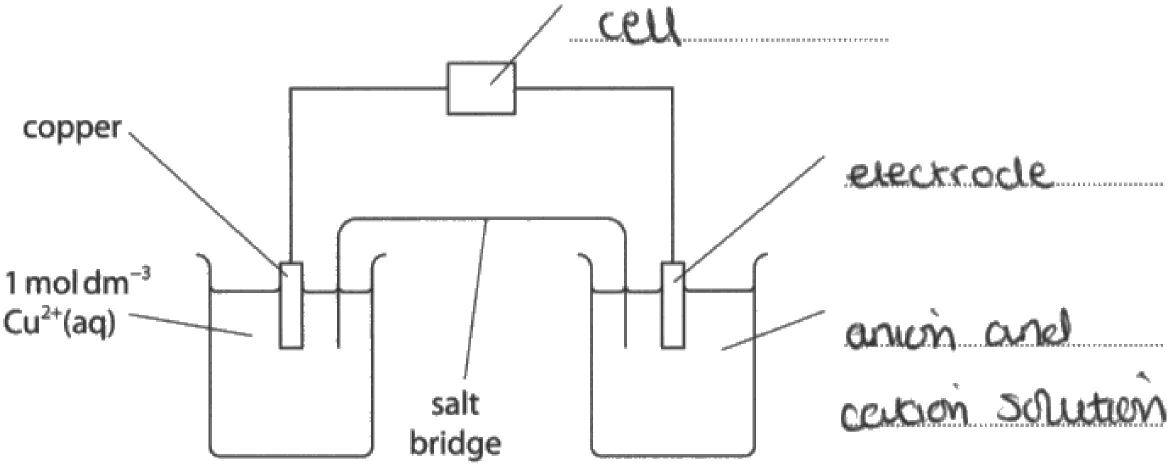
Many candidates were familiar with electrochemical cells and labelled the diagram correctly to score 3 marks. A few candidates used a cell or ammeter instead of a voltmeter, showing a lack of understanding. Some candidates used a manganese electrode instead of platinum and some did not include both ions in the solution. Candidates should practise drawing and labelling the different types of electrochemical cell.

**5** An electrochemical cell is made from the electrode systems represented by these half-equations.

$$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$$

$$Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$$

The $E^{\ominus}_{cell}$ value is measured using the apparatus shown.



**ResultsPlus**
**Examiner Comments**

This response scored 0. The labels are too vague and there must not be a cell in an electrochemical cell.

**ResultsPlus**
**Examiner Tip**

Learn how to draw and label different types of electrochemical cells.

**5** An electrochemical cell is made from the electrode systems represented by these half-equations.

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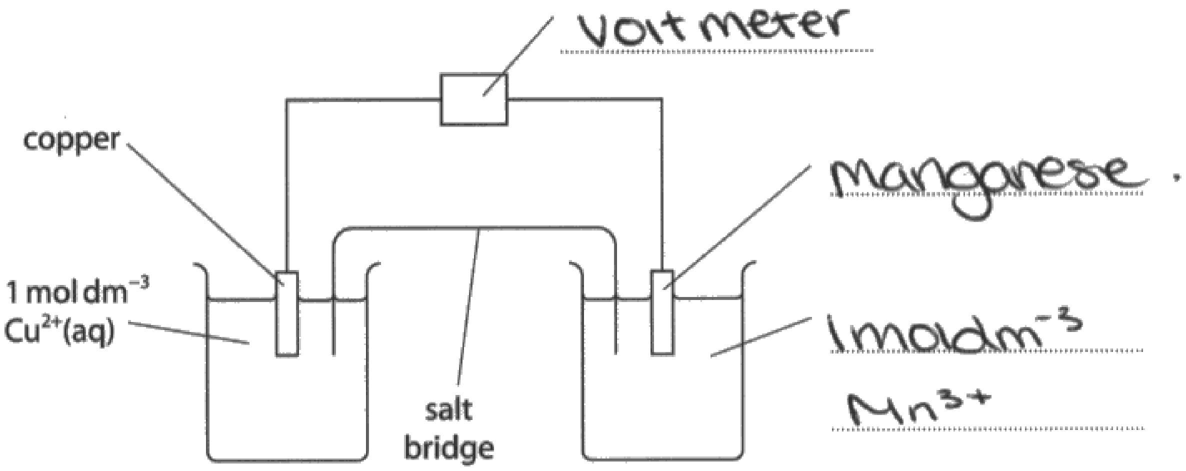


**ResultsPlus**
**Examiner Comments**

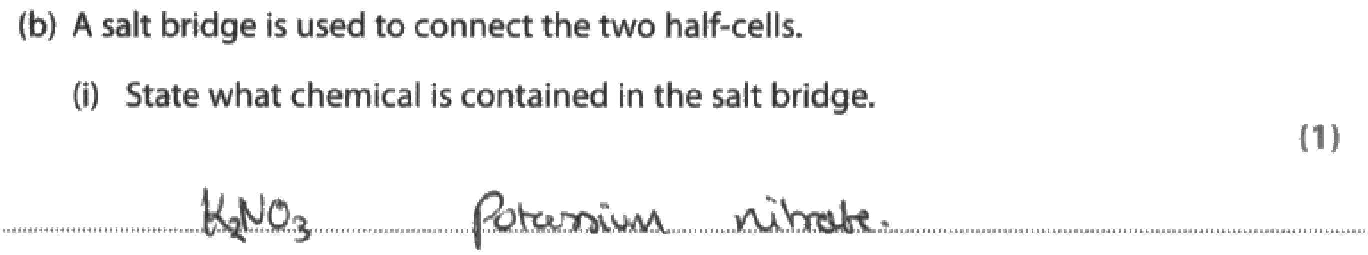
This is an example of a common answer that scored 1 mark. The half-equation involving manganese ions does not include solid manganese so this must not be the electrode.

**ResultsPlus**
**Examiner Tip**

When there is no solid metal in a half-equation, the electrode must be platinum. The solution in the beaker must include both of the ions in the half-equation.

## Question 5 (b) (i)

The majority of candidates gave a correct chemical that could be used in the salt bridge. Potassium nitrate will always be suitable for all electrochemical cells as all potassium salts and all nitrates are soluble so there is no risk of a precipitate forming in one of the beakers. A general term such as 'salt' did not score a mark.



(b) A salt bridge is used to connect the two half-cells.

(i) State what chemical is contained in the salt bridge.

**(1)**

$K_2NO_3$ Potassium nitrate.

**ResultsPlus**

**Examiner Comments**

This candidate has written the correct name of the chemical used in the salt bridge but this response scored 0 as the formula of potassium nitrate is incorrect and negates the mark.

**ResultsPlus**

**Examiner Tip**

If you give the name and formula of a substance, both must be correct.

## Question 5 (b) (ii)

Many general answers were seen about wires conducting electricity that were confusing and contradictory. Some candidates thought that an unreactive metal would not allow the flow of electrons and in some answers it was not clear whether the candidate was referring to the metal wire or the salt bridge. Candidates should make sure that they understand why a salt bridge is necessary when setting up an electrochemical cell.

(ii) Give a possible reason why the salt bridge cannot be replaced by an unreactive metal wire.

(1)

The Ions need to move across the salt bridge in order to balance the charge between the two half cells. An unreactive wire cannot carry these ions.

**ResultsPlus**
**Examiner Comments**

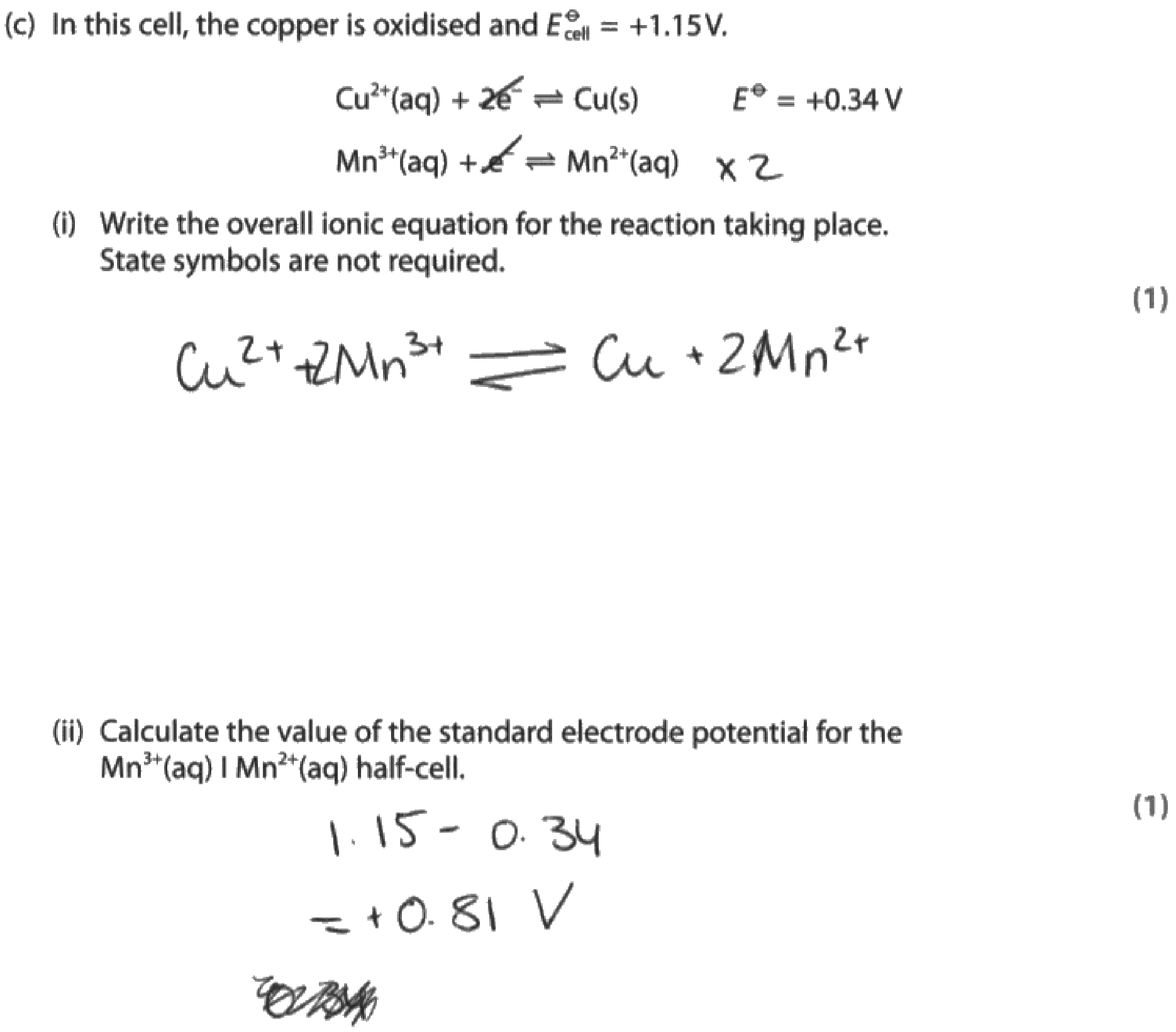
This is an example of a good answer that scored 1 mark.

**ResultsPlus**
**Examiner Tip**

Make sure that you understand why a salt bridge is used in an electrochemical cell.

## Question 5 (c)

Many candidates scored the marks for (i) and (ii). Some candidates did not cancel the electrons from their overall ionic equation and others forgot to reverse the direction of the copper half-equation, even though they were told that copper is oxidised.



(c) In this cell, the copper is oxidised and $E^\ominus_{cell} = +1.15\,V$.

$Cu^{2+}(aq) + \cancel{2e^-} \rightleftharpoons Cu(s)$ $E^\ominus = +0.34\,V$

$Mn^{3+}(aq) + \cancel{e^-} \rightleftharpoons Mn^{2+}(aq)$ x 2

(i) Write the overall ionic equation for the reaction taking place.
State symbols are not required.

(1)

$Cu^{2+} + 2Mn^{3+} \rightleftharpoons Cu + 2Mn^{2+}$

(ii) Calculate the value of the standard electrode potential for the $Mn^{3+}(aq) \mid Mn^{2+}(aq)$ half-cell.

(1)

$1.15 - 0.34$

$= +0.81\,V$

**ResultsPlus**
**Examiner Comments**

Both parts of this answer scored 0.

(i) The candidate has multiplied the manganese half-equation by 2 but has not reversed the direction of the copper half-equation to show that the copper is oxidised.

(ii) The electrode potential is incorrect as the candidate has subtracted the value for the copper half-cell from the total, instead of adding them.

**ResultsPlus**
**Examiner Tip**

When you add two half-equations together, make sure that the electrons are on opposite sides of the equations so that they cancel.

(c) In this cell, the copper is oxidised and $E^{\ominus}_{cell} = +1.15\,V$.

$$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s) \qquad E^{\ominus} = +0.34\,V$$

$$Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$$

(i) Write the overall ionic equation for the reaction taking place.
State symbols are not required.

**(1)**

oxidised
form in
middle.

Pt ~~|~~ Cu(s)

~~Pt~~ Cu(s) | $Cu^{2+}$(aq) || $Mn^{3+}$(aq) }, $Mn^{2+}$(aq) | Pt

(ii) Calculate the value of the standard electrode potential for the $Mn^{3+}$(aq) I $Mn^{2+}$(aq) half-cell.

**(1)**

Cu + Mn = 1.15.

Mn − 0.34 = 1.15

Mn = 1.15 + 0.34

= 1.49 $E^{\ominus}$ cell value.

**ResultsPlus**
**Examiner Comments**

(i) This candidate has written a 'cell diagram' instead of the overall ionic equation so scores 0.

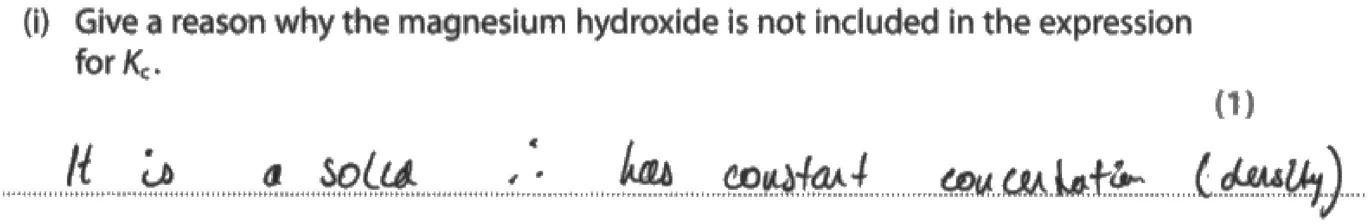
(ii) This is correct and scores 1 mark.

**ResultsPlus**
**Examiner Tip**

Read the questions carefully and check your answers.

## Question 6 (b) (i)

Only a minority of candidates scored a mark for giving a reason why solids are not included in the expression for the equilibrium constant. Many candidates stated that magnesium hydroxide is a solid but did not follow this through with the idea that its concentration does not change. Some candidates thought that solids do not have a concentration or that it cannot be measured.



(i) Give a reason why the magnesium hydroxide is not included in the expression for $K_c$.

(1)

It is a solid ∴ has constant concentration (density)

**ResultsPlus**
**Examiner Comments**

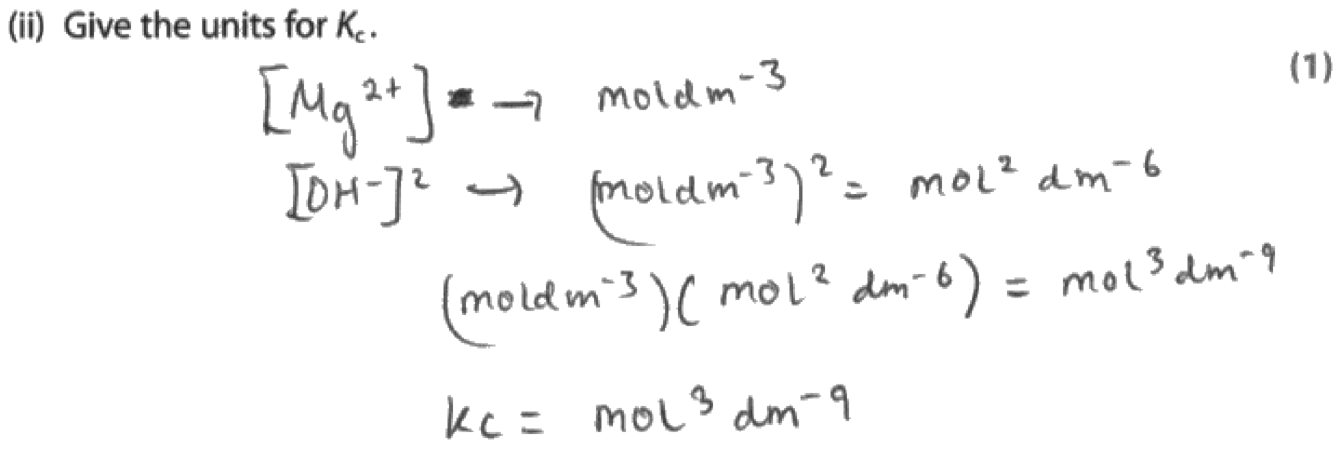
This is a good answer that scored 1 mark.

**ResultsPlus**
**Examiner Tip**

The concentration of a solid is the equivalent of its density and this does not change during the reaction.

## Question 6 (b) (ii)

Many candidates could work out the correct units for $K_c$, but there were many careless errors. Some candidates did not look at the expression carefully and forgot to square the units for the concentration of hydroxide ions. Candidates are advised to write down their working when deducing the units as they will be less likely to make careless errors.



(ii) Give the units for $K_c$.

(1)

$[Mg^{2+}] \rightarrow moldm^{-3}$

$[OH^-]^2 \rightarrow (moldm^{-3})^2 = mol^2 dm^{-6}$

$(moldm^{-3})(mol^2 dm^{-6}) = mol^3 dm^{-9}$

$Kc = mol^3 dm^{-9}$

**ResultsPlus**
**Examiner Comments**

This is a good answer that scored 1 mark.

**ResultsPlus**
**Examiner Tip**

It is a good idea to write out the working for the units from the equation then you are less likely to make a careless error.

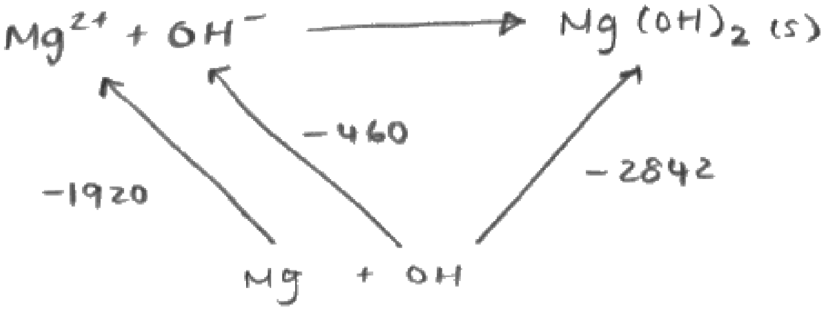
## *Question 6 (b) (iii)*

Many candidates calculated the correct enthalpy change of solution. The calculation can be carried out without using a Hess cycle but many candidates who tried this got an incorrect final answer. The most common errors were, not multiplying the enthalpy change of hydration of hydroxide ions by 2 and using the Hess cycle the wrong way around.

(iii) Calculate the enthalpy change of solution of magnesium hydroxide, using the following data.

| Energy or enthalpy change | Value / kJ mol$^{-1}$ |
|---|---|
| Lattice energy of $Mg(OH)_2(s)$ | −2842 |
| $\Delta_{hyd}H$ ($Mg^{2+}(aq)$) | −1920 |
| $\Delta_{hyd}H$ ($OH^-(aq)$) | −460 |

(2)



1920 + 460 − 2842 = $\boxed{-462 \text{ kJ mol}^{-1}}$

**ResultsPlus**
**Examiner Comments**

This answer scored 0 as the candidate has omitted to multiply the enthalpy change of hydration of hydroxide ions by 2 and the equation is the wrong way around.

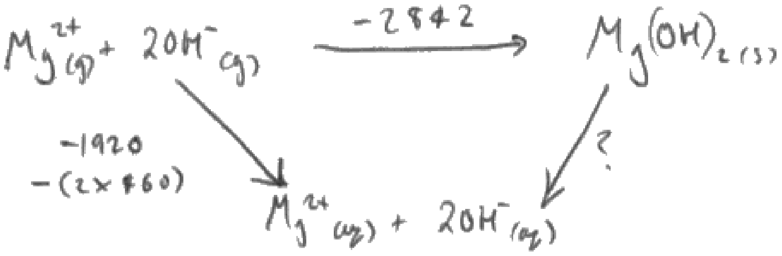
**ResultsPlus**
**Examiner Tip**

Practise drawing energy cycles and calculating enthalpy changes.

(iii) Calculate the enthalpy change of solution of magnesium hydroxide, using the following data.

| Energy or enthalpy change | Value / kJ $mol^{-1}$ |
|---|---|
| Lattice energy of $Mg(OH)_2(s)$ | −2842 |
| $\Delta_{hyd}H$ ($Mg^{2+}(aq)$) | −1920 |
| $\Delta_{hyd}H$ ($OH^-(aq)$) | −460 |

**(2)**



$\Delta H_{sol} = -(-2842) - 2840 = \underline{\underline{+2}}\ kJ\ mol^{-1}$

**ResultsPlus**
**Examiner Comments**

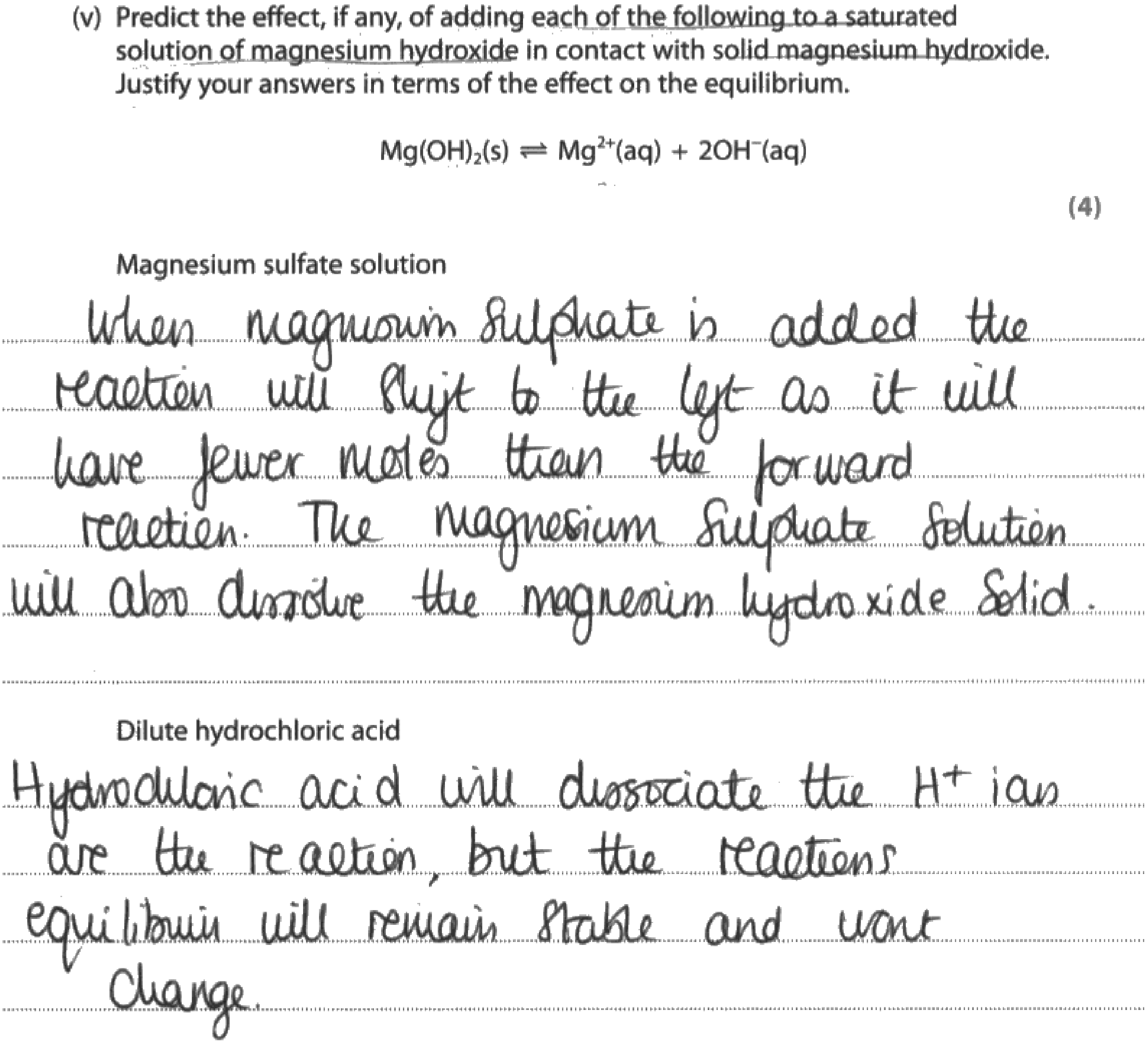
This response scored 2 marks.

**ResultsPlus**
**Examiner Tip**

Try to set out calculations clearly and use a Hess cycle, where appropriate. This will help you to avoid losing marks due to careless errors.

## Question 6 (b) (v)

Many candidates scored full marks for this question. Some candidates were confused between left and right and sometimes contradicted themselves by using both in the same sentence. It is acceptable to use forward and reverse directions instead. Some candidates did not realise that adding magnesium sulfate will increase the concentration of $Mg^{2+}$ ions and that $H^+$ ions from the hydrochloric acid react with the $OH^-$ ions. Very few candidates were penalised for writing that the equilibrium constant changes.



(v) Predict the effect, if any, of adding each of the following to a saturated solution of magnesium hydroxide in contact with solid magnesium hydroxide. Justify your answers in terms of the effect on the equilibrium.

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$$

**(4)**

Magnesium sulfate solution

When magnesium Sulphate is added the reaction will shift to the left as it will have fewer moles than the forward reaction. The magnesium Sulphate Solution will also dissolve the magnesium hydroxide Solid.

Dilute hydrochloric acid

Hydrochloric acid will dissociate the $H^+$ ions are the reaction, but the reactions equilibrium will remain stable and wont change.

**ResultsPlus**
**Examiner Comments**

This is an example of a response where there is a contradiction. The candidate starts by stating that the reaction will shift to the left when the magnesium sulfate is added but then states that the magnesium sulfate solution will dissolve the magnesium hydroxide. When magnesium hydroxide dissolves, the equilibrium position shifts to the right. There is nothing worthy of credit for adding hydrochloric acid so this response scored 0.

**ResultsPlus**
**Examiner Tip**

Check your answers carefully to make sure that you have not made a contradiction. Some candidates were confused between left and right in the same part of the answer. They are advised to use the terms forward and reverse directions instead.

(v) Predict the effect, if any, of adding each of the following to a saturated solution of magnesium hydroxide in contact with solid magnesium hydroxide. Justify your answers in terms of the effect on the equilibrium.

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$$

**(4)**

$MgSO_4$

Magnesium sulfate solution

Equilibrium will shift to the left hand side (Backward reaction) to keep Kc constant.

Dilute hydrochloric acid HCl

Adding HCl would shift equilibrium towards the right hand side (forward reaction) So more $OH^-$ cons produced can keep Kc constant

**ResultsPlus**
**Examiner Comments**

This response scored 2 marks for the correct shifts in the equilibrium positions. There is no justification for either of these shifts.

**ResultsPlus**
**Examiner Tip**

Try to give reasons for your answers when you are asked to justify them.

## *Question 7 (a)*

Many candidates could write the balanced equation for the reaction between borax and hydrochloric acid. Some candidates did not balance the equation or balanced it incorrectly. Many candidates were unable to work out that the other products were sodium chloride and water.

**7** Boric acid, $H_3BO_3$, is a weak acid with antiseptic properties.

(a) Boric acid can be prepared by reacting borax, $Na_2B_4O_7.10H_2O$, with hydrochloric acid.

Write the equation for this reaction. State symbols are not required.

**(1)**

$Na_2B_4O_7.10H_2O + HCl \longrightarrow H_3BO_3 + NaCl + H_2O$

**ResultsPlus**
**Examiner Comments**

This equation scored 0. All of the reactants and products are correct but the equation is not balanced.

**ResultsPlus**
**Examiner Tip**

All equations must be balanced.

## Question 7 (b) (i)

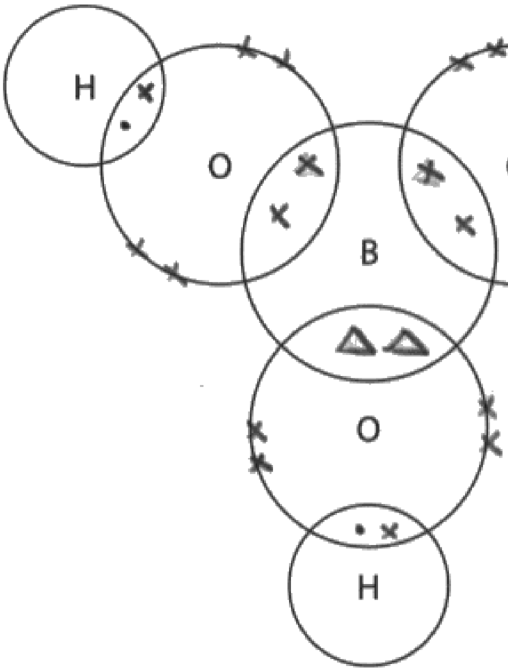
Many correct answers scoring 2 marks were seen for this question. Some candidates included a double bond between boron and one of the oxygen atoms and some put a lone pair on the boron atom. Candidates should realise that boron and aluminium have 3 electrons in their outer shells so can form covalent compounds where they have an empty orbital. A small minority of candidates did not use the correct symbols for the electrons and lost an easy mark.

(b) The formula of boric acid can also be written as $B(OH)_3$. + $5H_2O$

(i) Complete the dot-and-cross diagram of a molecule of boric acid. Show the outer shell electrons only.

Use dots (•) for the hydrogen electrons, crosses (×) for the oxygen electrons and triangles (△) for the boron electrons.

**(2)**



**ResultsPlus**
**Examiner Comments**

This response scored 1 mark. All of the electrons are in the correct positions but the candidate has ignored the instruction about which symbol to use for the electrons from each of the elements.

**ResultsPlus**
**Examiner Tip**

Read the question carefully and don't make up your own symbols for electrons when you have been given specific ones to use.

# *Question 7 (d) (i)*

Many candidates were able to calculate the pH of boric acid from the first dissociation. Some candidates did not realise that they needed to convert p$K_a$ into $K_a$ and some tried to use the formula for calculating the pH of a buffer solution. Some candidates calculated very low pH values and others were above 7. These did not receive a transferred error mark for the pH value as it was unrealistic for a weak acid. Candidates should be encouraged to consider the final answer for any calculation and if it is unrealistic, they should check their working to find out where they have gone wrong.

(d) In aqueous solution, boric acid dissociates into ions in three stages.
The equation for the first dissociation is

$$H_3BO_3(aq) \rightleftharpoons H^+(aq) + H_2BO_3^-(aq)$$

p$K_a$ for this dissociation is 9.24

(i) Calculate the pH of a 0.0500 mol dm$^{-3}$ solution of boric acid from the p$K_a$ value for the first dissociation.

**(3)**

$pH = -\log_{10}[H^+]$

$9.24 = \frac{(H^+)(H_2BO_3^-]}{(H_3BO_3)}$ $9.24 = \frac{(H^+)^2}{(H_3BO_3)}$

$(H^+)^2 = 9.24(H_3BO_3)$ $Mr = 61.8.$

$H^+ = \sqrt{9.24\ (H_3BO_3)}.$

$H^+ = \sqrt{9.24 \times 0.05}$

~~$H^+ = 0.680$ 3sf)~~ $H^+ = 0.6797.$

$pH = 0.168\ (3sf)$

**ResultsPlus**
**Examiner Comments**

This candidate has not converted the p$K_a$ value into $K_a$. They have calculated the concentration of hydrogen ions correctly from this so scored 1 mark as a transferred error. Although they have then calculated the pH correctly, they were not awarded a mark as the value is too low for a weak acid.

**ResultsPlus**
**Examiner Tip**

Always check to see if your final answer is realistic and if it isn't, check your working to see where you have gone wrong. In this question, the examiners did not allow the pH of a weak acid to be less than 2 or greater than 7.

(d) In aqueous solution, boric acid dissociates into ions in three stages. The equation for the first dissociation is

$$H_3BO_3(aq) \rightleftharpoons H^+(aq) + H_2BO_3^-(aq)$$

p$K_a$ for this dissociation is 9.24

(i) Calculate the pH of a 0.0500 mol dm$^{-3}$ solution of boric acid from the p$K_a$ value for the first dissociation.

**(3)**

$$Ka = \frac{[H^+_{(aq)}][H_2BO^-_{3(aq)}]}{[H_3BO_{3(aq)}]}$$

$$Ka = 10^{-9.24} = 5.754399373 \times 10^{-9}$$

$$5.75... \times 10^{-9} = \frac{[H^+]^2}{0.0500}$$

$$[H^+]^2 = 5.75 \times 10^{-9} \times 0.0500 = 2.877... \times 10^{-10}$$

$$[H^+] = \sqrt{2.877 \times 10^{-10}} = 1.69... \times 10^{-5}$$

$$pH = -\log[H^+] = 4.77$$

$$pH = 4.77$$

**ResultsPlus**
**Examiner Comments**

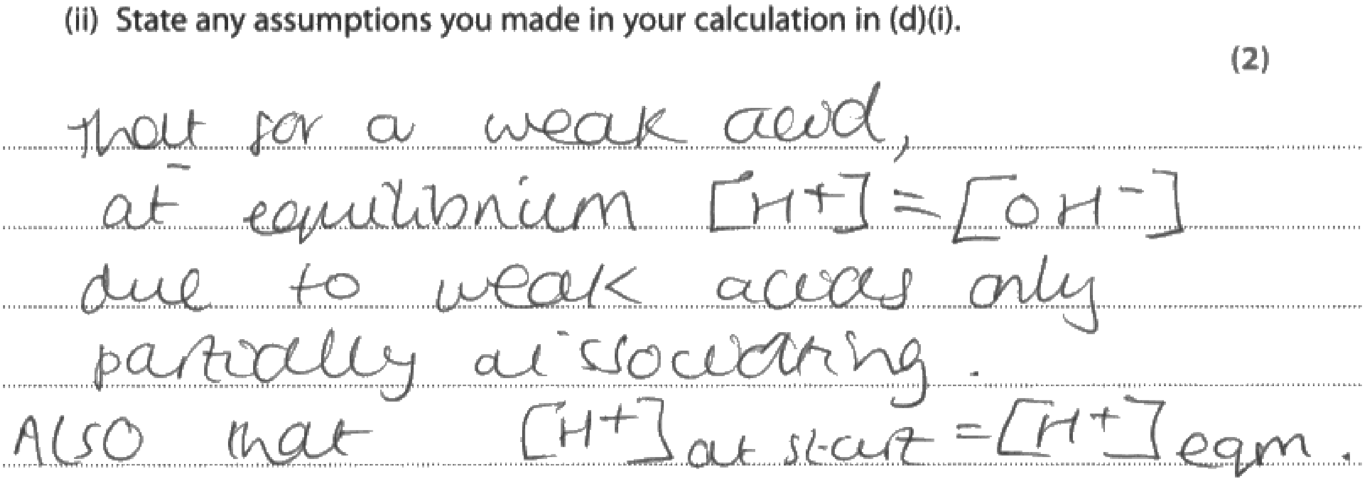
The working to calculate $K_a$ is correct but the final value is incorrect as it should be to the power of minus 10. The candidate has then used this value correctly in the next two steps so scored 2 marks.

**ResultsPlus**
**Examiner Tip**

Show all your working clearly, as in this example, then if you make a slip you will still be awarded some marks.

## Question 7 (d) (ii)

The assumptions made in calculating the pH of a weak acid were generally well-known and many candidates scored 2 marks. Some candidates only wrote 1 assumption and others generally referred to 'standard conditions'. Some candidates were confused about which species had equal concentrations and $[H^+] = [H_3BO_3]$ was not uncommon.



(ii) State any assumptions you made in your calculation in (d)(i).

(2)

that for a weak acid,
at equilibrium $[H^+]=[OH^-]$
due to weak acids only
partially dissociating.
Also that $[H^+]_{at\ start}=[H^+]_{eqm}$.

**ResultsPlus**
**Examiner Comments**

This response scored 0. The candidate seems confused about weak acids and has remembered a little but has the species incorrect. Only a neutral solution has $[H^+] = [OH^-]$ and it is the concentration of boric acid that is the same at equilibrium as at the start.

**ResultsPlus**
**Examiner Tip**

Make sure that you understand the theory of weak acids and the assumptions made when calculating their pH.

(ii) State any assumptions you made in your calculation in (d)(i).

**(2)**

~~The concentration of~~ $[H^+] = [A^-]$ ∴ $= [H]^2$

The concentration is constant throughout and ~~it is~~ are in its standard state

$1\ mol\ dm^{-3}$ each solution, 1 atm pressure, 298K } the solutions

**ResultsPlus**
**Examiner Comments**

This response scored 1 mark for the first point. 'The concentration is constant' was not awarded a mark as it did not state what the concentration refers to.

**ResultsPlus**
**Examiner Tip**

Check to make sure that your answer is complete and makes sense to an examiner reading it.

(ii) State any assumptions you made in your calculation in (d)(i).

(2)

- $[H^+] = [H_2BO_3^-]$
- $[H_3BO_3]_{initial} = [H_3BO_3]_{equilibrium}$
- The ionisation of water is negligible

**ResultsPlus**
**Examiner Comments**

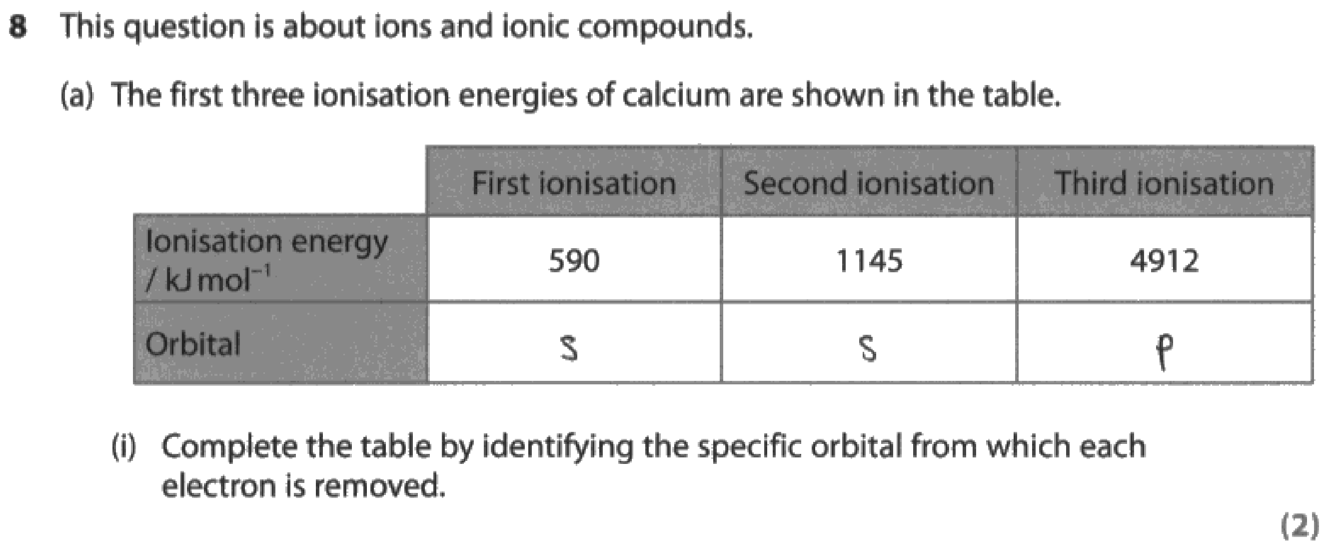
This is an excellent answer that scored 2 marks.

**ResultsPlus**
**Examiner Tip**

Only 2 points were needed here so the last point was not needed. It is acceptable to write answers using bullet points and equations, as in this example.

## Question 8 (a) (i)

Many candidates scored full marks for this question. Some candidates just gave the type of orbital without the number of the quantum shell and others gave incorrect quantum shells. Candidates would find it helpful to write the full electronic configuration of calcium as rough working then work backwards by seeing which orbital the outermost electron is removed from.



**8** This question is about ions and ionic compounds.

(a) The first three ionisation energies of calcium are shown in the table.

|  | First ionisation | Second ionisation | Third ionisation |
|---|---|---|---|
| Ionisation energy / kJ mol$^{-1}$ | 590 | 1145 | 4912 |
| Orbital | s | s | p |

(i) Complete the table by identifying the specific orbital from which each electron is removed.

**(2)**

**ResultsPlus**
**Examiner Comments**

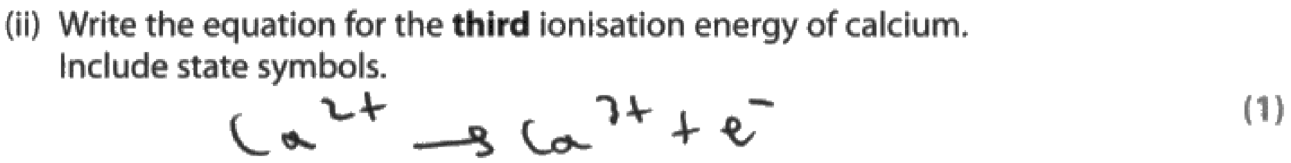
This response scored 1 mark. The candidate has identified the correct type of orbital but not given the numbers in front of the orbitals to show the quantum shell.

**ResultsPlus**
**Examiner Tip**

When you are asked for a specific orbital you must show the quantum shell as well as the type of orbital.

## *Question 8 (a) (ii)*

The majority of candidates scored 1 mark for this question. Some candidates omitted state symbols and others put (aq) instead of (g). A small minority of candidates removed 3 electrons from a calcium atom and a very small number added an electron to a calcium ion.



(ii) Write the equation for the **third** ionisation energy of calcium.
Include state symbols.

(1)

$Ca^{2+} \rightarrow Ca^{3+} + e^-$

**ResultsPlus**
**Examiner Comments**

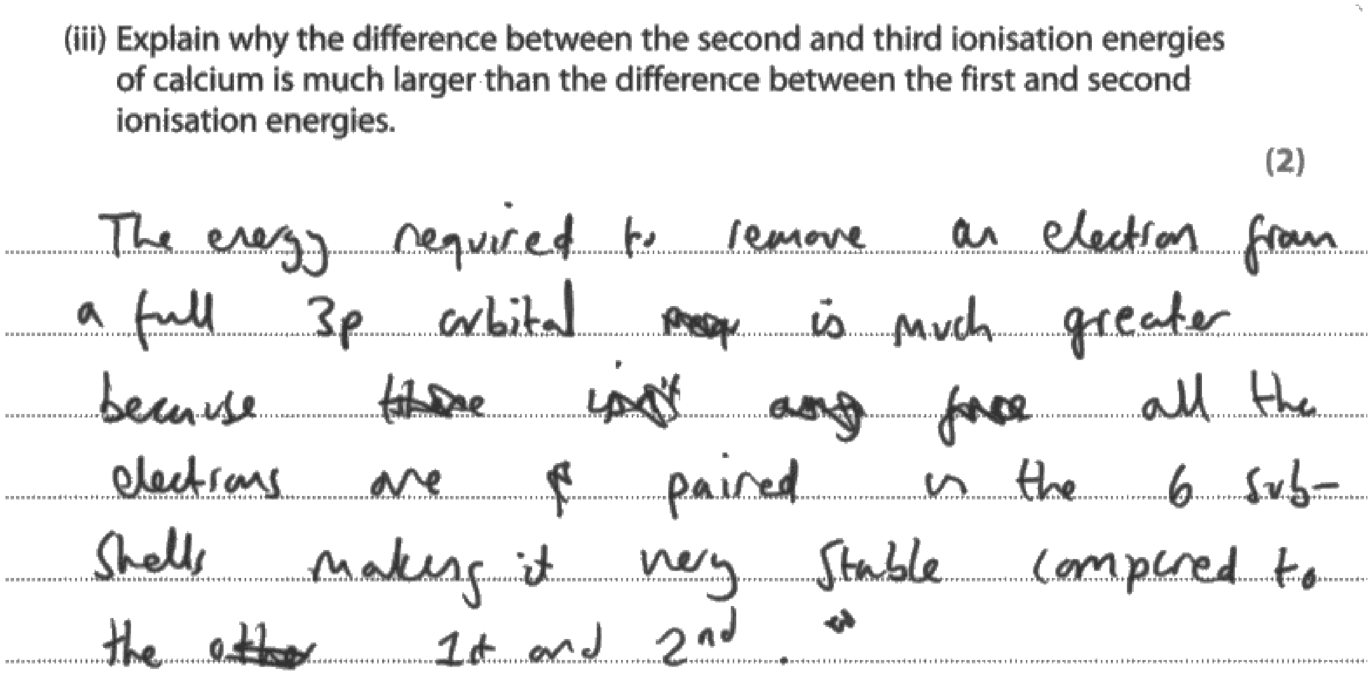
This response scored 0 as the candidate has omitted the state symbols.

**ResultsPlus**
**Examiner Tip**

Read the question carefully. If you are asked for state symbols, you will not receive the mark unless you include them.

## Question 8 (a) (iii)

Some excellent answers were seen to this question where the candidates explained why there was a small difference between the first and second ionisation energies but a much larger difference between the second and third. Some candidates wrote about the large difference. Some candidates wrote generally about the stability of a full sub-shell of electrons and did not receive any credit as they missed the point about the third electron being removed from a new quantum shell that is closer to the nucleus. A few candidates thought that the third quantum shell was of higher energy than the fourth.



(iii) Explain why the difference between the second and third ionisation energies of calcium is much larger than the difference between the first and second ionisation energies.

(2)

The energy required to remove an electron from a full 3p orbital ~~[illegible]~~ is much greater because ~~there~~ ~~isn't~~ ~~any~~ ~~force~~ all the electrons are ~~p~~ paired in the 6 sub-shells making it very stable compared to the ~~other~~ 1st and 2nd.

**ResultsPlus**
**Examiner Comments**

This answer scored 0 as the candidate has just written about the stability of paired electrons and there is no mention about the new quantum shell which is much closer to the nucleus.

**ResultsPlus**
**Examiner Tip**

When considering the relative values of ionisation energies, remember that the large jumps occur when the next electron to be removed is in a new quantum shell that is much closer to the nucleus.

(iii) Explain why the difference between the second and third ionisation energies of calcium is much larger than the difference between the first and second ionisation energies.

(2)

It is much larger due to the fact we are now removing ~~the~~ an electron from ~~a shell bellow~~ lower energy shell. This shell is closer to the nucleus so the electrons feel a greater ~~Et~~ electrostatic attraction and also shielding due to lower electrons is reduced. This is in contrast between 1 and 2 where we are still in the same energy shell so have the same shielding.

**ResultsPlus**
**Examiner Comments**

This is an example of an excellent answer that scored 2 marks.

**ResultsPlus**
**Examiner Tip**

Try to write detailed explanations, such as this one.

## *Question 8 (c)*

It was pleasing to see many excellent answers scoring 6 marks but the full range of marks was seen in other answers. Some candidates gave lengthy descriptions of theoretical and experimental lattice energies but did not always relate these to the two compounds given in the question. Some candidates referred to electronegativity differences, which were not required in this question. The most common indicative points omitted from answers stated that lithium chloride is almost 100% ionic and also there was a tendency to compare the sizes of the chloride and iodide ions. Some candidates showed a lack of understanding by writing that the bond between magnesium and iodine is polarised, or that there is a bond between the two iodide ions, or they completely missed the point and wrote about experimental error. Candidates would benefit from more practice in answering this style of question as some candidates wrote very little and others wrote far too much, often repeating the same points several times. They also need to consider the use of correct scientific terminology. It was not uncommon to see a discussion about ions, then (in the same sentence) 'molecules' being included.

*(c) The table shows the theoretical and experimental lattice energy values of two compounds.

| Compound | Theoretical lattice energy / kJ mol$^{-1}$ | Experimental lattice energy / kJ mol$^{-1}$ |
|---|---|---|
| lithium chloride, LiCl | −845 | −848 |
| magnesium iodide, $MgI_2$ | −1944 | −2327 |

Comment on the theoretical and experimental lattice energy values, giving the reasons for any differences and similarities.

**(6)**

Lithium Chloride has a very similar theoretical lattice energy and experimental lattice energy. However, Magnesium iodide has a big difference between the experimental and theoretical lattice energies.
Theoretical lattice energies are calculated from an equation - which means that the values will not necessarily be correct. However the experimental lattice energy is calculated by carrying out an experiment. There are many things to take into consideration when carrying out an experiment, such as temperature, and whether any heat etc is escaping from the reaction mixture. This may be why there is such a big difference for $MgI_2$.
The person carrying out the experiment may have carried it out incorrectly.
Theoretical ~~values used~~ equations use fixed values and do not give way for

anything else that could be going on. Neither of these is 100% correct. However, if the experiment was carried out properly then the experimental lattice energies will be more accurate than the theoretical lattice energy.

**ResultsPlus**
**Examiner Comments**

This response scored 0 as the candidate has not revised the meaning of the term 'experimental lattice energy'. They seem to think that this is related to an experiment that a student can carry out whereas it is the value calculated using experimental values in the Born-Haber cycle.

**ResultsPlus**
**Examiner Tip**

Make sure you understand the meaning of the terms 'theoretical lattice energy' and 'experimental lattice energy'.

*(c) The table shows the theoretical and experimental lattice energy values of two compounds.

| Compound | Theoretical lattice energy / kJ mol$^{-1}$ | Experimental lattice energy / kJ mol$^{-1}$ |
|---|---|---|
| lithium chloride, LiCl | −845 | −848 |
| magnesium iodide, $MgI_2$ | −1944 | −2327 |

Comment on the theoretical and experimental lattice energy values, giving the reasons for any differences and similarities.

**(6)**

Lithium chloride has a much smaller difference between the theoretical and experimental lattice energies compared to magnesium iodide. The reason that magnesium iodide has a much more negative lattice energy value is because of its covalent character which is not accounted for in the theoretical value. The iodide ion has a large atomic radius that is significantly larger than the chloride ion. Magnesium is a small atom with a small atomic radius and therefore a high nuclear charge. This means that the magnesium ion is able to distort the iodide ions due to its polarising power. This increases the covalent character of magnesium iodide, so that [illegible]

[illegible]

the experimental lattice energy is more exothermic than the theoretical energy. Lithium and chlorine have a relatively small ionic radius as both atoms have a small atomic radius.

**ResultsPlus**

**Examiner Comments**

This is quite a good answer that scored 4 marks. There are 4 correct indicative points: covalent character in magnesium iodide, the large radius of the iodide ion, magnesium ions are polarising and iodide ions are polarised. The candidate has not mentioned that lithium chloride is almost completely ionic and the charges on the magnesium and lithium ions.

*(c) The table shows the theoretical and experimental lattice energy values of two compounds.

| Compound | Theoretical lattice energy / kJ mol$^{-1}$ | Experimental lattice energy / kJ mol$^{-1}$ |
|---|---|---|
| lithium chloride, LiCl | −845 | −848 |
| magnesium iodide, $MgI_2$ | −1944 | −2327 |

Comment on the theoretical and experimental lattice energy values, giving the reasons for any differences and similarities.

**(6)**

For LiCl, the theoretical lattice energy is very close to the experimental lattice energy, which suggests that the compound consists of mainly ionic bonding, with very little covalent character.

For $MgI_2$, the experimental lattice energy is more exothermic than the theoretical value by 383 kJ mol$^{-1}$, suggesting that there is a lot of covalent character, more than LiCl. The reason for the increased covalent character in $MgI_2$, is because magnesium ion has a greater charge than a lithium ion (+2 to +1), and therefore has a greater charge density. This means the $Mg^{2+}$ is able to polarise and distort the anion more. Also, the $Cl^-$ ion is smaller ~~than~~, in terms of ionic radius, than the $I^-$ ion. This means that the $I^-$ ion is more easily polarised and distorted by the cation ($Mg^{2+}$), giving it more covalent character.

The theoretical model is pure 100% ionic bonding

**ResultsPlus**
**Examiner Comments**

This is an example of a clear and concise answer that scored 6 marks.

**ResultsPlus**
**Examiner Tip**

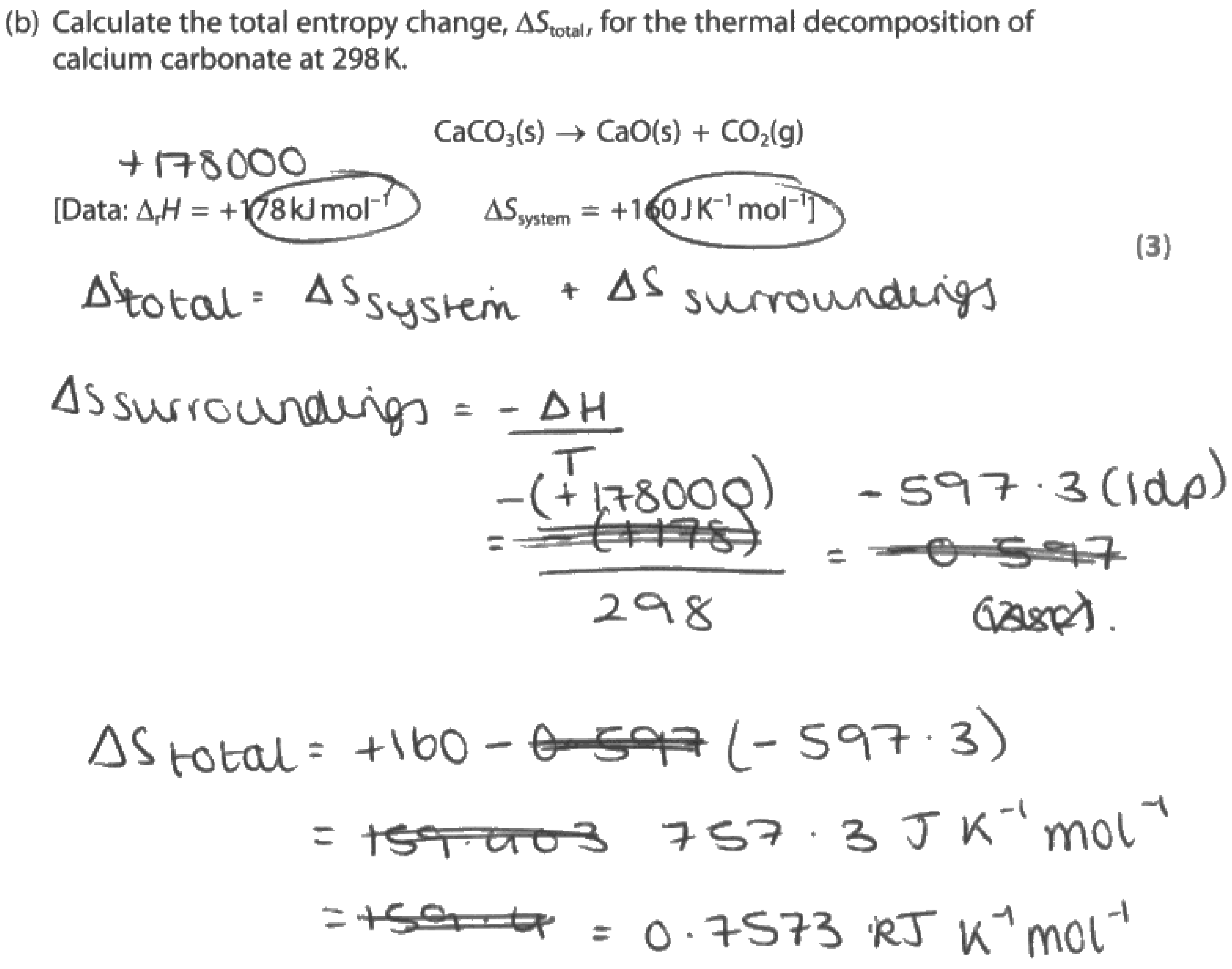
Although a lot of space is given for answers to the extended writing 6 mark questions, it is not necessary to fill up all the lines. Just include the important, relevant points to answer the question.

## Question 9 (a)

The majority of candidates were familiar with the signs of $\Delta S_{system}$ and could apply their knowledge to the changes given in the question. A small number of candidates showed all the signs incorrectly so thought, for example, that there is decrease in entropy when solid carbon dioxide changes to a gas.

## Question 9 (b)

The majority of candidates scored 3 marks for this question. Marks were lost when candidates omitted the minus sign when using -$\Delta H/T$ and not converting the value for either $\Delta S_{system}$ or $\Delta S_{surroundings}$ so that they were in the same unit before adding them together. A few candidates gave incorrect units and lost the last mark.



(b) Calculate the total entropy change, $\Delta S_{total}$, for the thermal decomposition of calcium carbonate at 298 K.

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

+178000

[Data: $\Delta_r H = +178\ kJ\ mol^{-1}$ $\Delta S_{system} = +160\ J\ K^{-1}\ mol^{-1}$]

(3)

$\Delta S_{total} = \Delta S_{system} + \Delta S_{surroundings}$

$\Delta S_{surroundings} = \frac{-\Delta H}{T}$

$= \frac{-(+178000)\ \cancel{-(+178)}}{298} = \cancel{-0.597}\ -597.3\ (1dp)$ (3sf).

$\Delta S_{total} = +160 - \cancel{0.597}\ (-597.3)$

$= \cancel{159.403}\ 757.3\ J\ K^{-1}\ mol^{-1}$

$= \cancel{+159.4} = 0.7573\ kJ\ K^{-1}\ mol^{-1}$

**ResultsPlus**
**Examiner Comments**

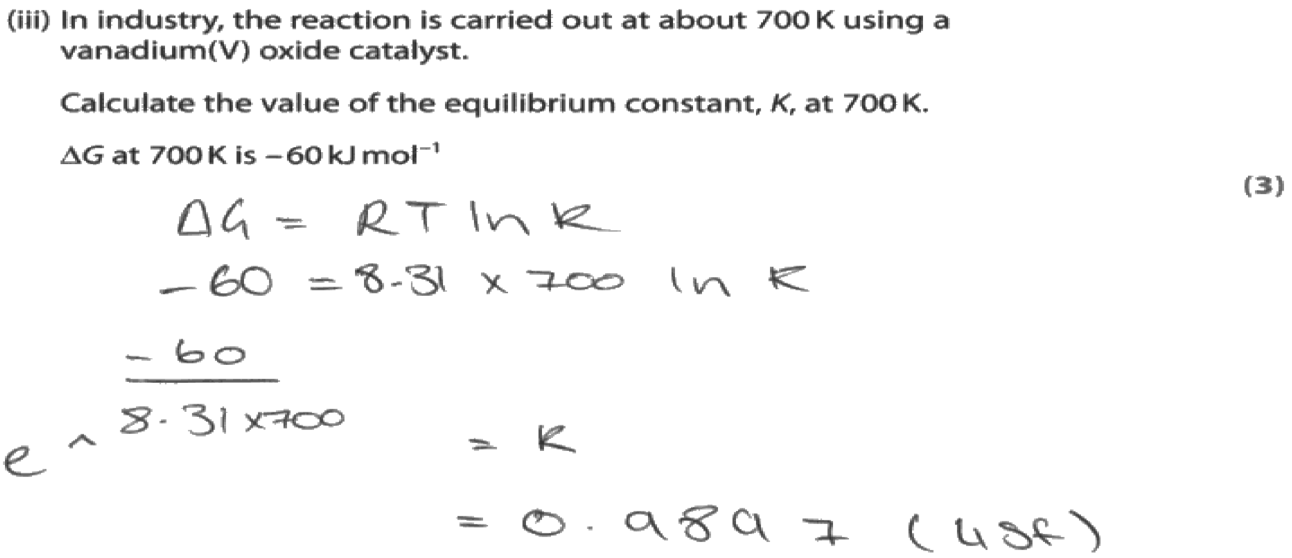
This response scored 2 marks for calculating the value of $\Delta S_{\text{surroundings}}$. The value of $\Delta S_{\text{total}}$ is incorrect as the candidate has added a value in joules to one in kilojoules.

**ResultsPlus**
**Examiner Tip**

In calculations involving enthalpy changes, entropy and free energy, always check whether you are using values in joules or kilojoules and do not mix them up in the same equation.

## *Question 9 (c) (iii)*

This is the first time that a question involving calculating an equilibrium constant from a free energy change has been set on this specification and many candidates carried it out well, scoring full marks. The common errors included omitting the minus sign from the equation and not converting Δ*G* into J mol$^{-1}$. Some candidates did not know the equation so they were unable to score any marks unless they used an equation involving Δ*G*, *K*, *R* and *T*. Candidates do need to learn all of the equations involving enthalpy, entropy and free energy changes. Some candidates used an incorrect value for *R*, even though this is given in the Data Booklet.



**(iii)** **In industry, the reaction is carried out at about 700 K using a vanadium(V) oxide catalyst.**

**Calculate the value of the equilibrium constant, *K*, at 700 K.**

**Δ*G* at 700 K is −60 kJ mol$^{-1}$**

**(3)**

$\Delta G = RT \ln K$

$-60 = 8.31 \times 700 \ln K$

$e \wedge \frac{-60}{8.31 \times 700} = K$

$= 0.9897$ (4sf)

**ResultsPlus**
**Examiner Comments**

This response scored 1 mark. The candidate has omitted the minus sign from the equation and they have not converted the free energy change into J mol$^{-1}$.

**ResultsPlus**
**Examiner Tip**

Learn all the equations involving enthalpy, entropy and free energy changes.

Check that you are working in the correct units. When you use this equation, Δ*G* must be in J mol$^{-1}$ as R is in J mol$^{-1}$ K$^{-1}$.

## *Question 9 (c) (i) - (ii)*

Many candidates scored full marks for the calculation in (c)(i). Common errors included not using the multiples of 2, as shown in the equation for the reaction, and writing the cycle the wrong way around.

Not as many candidates scored full marks for (c)(ii). Quite a number of candidates did not convert one of the values so they were both in kilojoules or both in joules. Some candidates did not include units for the free energy change and some gave the units of an entropy change, which is incorrect as it includes $K^{-1}$. A few candidates quoted an incorrect equation. Most candidates could relate the sign of the free energy change to the feasibility of the reaction but some thought that a negative value meant the reaction was not feasible.

(c) Sulfur dioxide reacts with oxygen to form sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta_r H = -288.4\,kJ\,mol^{-1}$$

The standard molar entropy values at 298 K are given in the table.

| | $SO_2(g)$ | $O_2(g)$ | $SO_3(g)$ |
|---|---|---|---|
| $S^{\ominus}$ / $J\,K^{-1}\,mol^{-1}$ | +248.1 | +205.0 | +95.6 |

(i) Calculate the entropy change of the system, $\Delta S_{system}$, for the forward reaction. Include a sign and units in your answer.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

**(2)**

prod - reactants.

$2(95.6) \quad - (248.1 \times 2 + 205.0)$

$191.6 \quad -(496.2 + 205.0)$

$191.6 \quad - \quad 701.2$

$= \quad - 509.6 J\,K^{-1} mol^{-1}$.

(ii) Calculate the free energy change, ΔG, at 298 K and hence deduce whether the reaction is feasible.

**(3)**

$\Delta G = \Delta H - T\Delta S system$

$-288.4 - (298)(-509.6)$

$= +151572.4$

ΔG is positive, so the reaction is feasible.

**ResultsPlus**
**Examiner Comments**

(i) This is almost the correct answer. The candidate has the correct working so scores 1 mark. There is an arithmetical error as 2 x 95.6 = 191.2 and not 191.6 so the second mark cannot be awarded.

(ii) The equation is correct. The candidate has used an enthalpy change in kilojoules and an entropy change in joules in the same equation so the final answer is incorrect. The units are also missing. The final statement is incorrect so only 1 mark was awarded.

**ResultsPlus**
**Examiner Tip**

Always check your numerical answers.

Check that you are not using amounts in kilojoules and joules in the same equation - always convert one of them so they are in the same unit.

(c) Sulfur dioxide reacts with oxygen to form sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta_r H = -288.4\,kJ\,mol^{-1}$$

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| $S^\ominus / J\,K^{-1}\,mol^{-1}$ | +248.1 | +205.0 | +95.6 |

(i) Calculate the entropy change of the system, $\Delta S_{system}$, for the forward reaction. Include a sign and units in your answer.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

**(2)**

$\Delta S$ system = products − reactants.

$= (2 \times 95.6) - (2 \times 248.1) - 205.0$

$= 191.2 - 701.2$

$= -510\ JK^{-1}mol^{-1}$

(ii) Calculate the free energy change, $\Delta G$, at 298 K and hence deduce whether the reaction is feasible.

**(3)**

$\Delta G = \Delta H - T\Delta S_{system}$

$= -288.4 - \frac{298 \times -510}{1000}$

$= 151619$

$= 151.6919$

~~The~~ $\Delta G$ is positive therefore the reaction is not feasible.

**ResultsPlus**
**Examiner Comments**

(i) This is the correct value with sign and units so scored 2 marks.

(ii) The equation is correct and the candidate has written the correct numbers down, remembering to divide the 510 by 1000 to convert it into kilojoules. However, the answer to the calculation is incorrect as the candidate has not actually divided 510 by 1000. They have also omitted the units. The final statement is correct so 2 marks were awarded.

**ResultsPlus**
**Examiner Tip**

Always check your numerical answers.

Include a sign and units for all calculations involving enthalpy changes, entropy and free energy.

(c) Sulfur dioxide reacts with oxygen to form sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta_r H = -288.4\,kJ\,mol^{-1}$$

The standard molar entropy values at 298 K are given in the table.

| | $SO_2(g)$ | $O_2(g)$ | $SO_3(g)$ |
|---|---|---|---|
| $S^\ominus$ / $J\,K^{-1}\,mol^{-1}$ | +248.1 | +205.0 | +95.6 |

(i) Calculate the entropy change of the system, $\Delta S_{system}$, for the forward reaction. Include a sign and units in your answer.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

**(2)**

$\Delta S$ system = product − reactants

$= (2 \times 95.6) - [(248.1 \times 2) + (205)]$

$= (191.2) - (701.2)$

$= -510\ JK^{-1}mol^{-1}$

(ii) Calculate the free energy change, $\Delta G$, at 298 K and hence deduce whether the reaction is feasible.

**(3)**

$\Delta G = \Delta H - T\Delta S$

$\Delta G = (-288.4 \times 1000) - 298\,(-510)$

$\Delta G = -136420\ JK^{-1}mol^{-1}$

↳ negative

$\Delta G$ is negative therefore is feasible.

**ResultsPlus**
**Examiner Comments**

(i) Correct for 2 marks.

(ii) The units are incorrect so only 2 marks awarded.

**ResultsPlus**
**Examiner Tip**

$\Delta G$ is the free energy change so has the units of kJ mol$^{-1}$ or J mol$^{-1}$.

## Question 9 (c) (iv)

Many candidates scored 2 marks for this question as they considered the effect of changing the temperature on the yield of product and the rate of reaction. Some candidates only considered the rate of reaction and some wrote generally about 'favouring the reverse reaction' without linking it to the yield.

(iv) The equilibrium constant has a larger value at 298 K than at 700 K. Explain why the reaction is carried out at 700 K and not at 298 K.

**(2)**

A higher temperature increases the rate of a reaction by increasing the number of particles collide with energy higher than the activation energy, thus more successful collisions take place per minute and the equilibrium of the reaction will be reached sooner at 700K. Reactions at 298K maybe too slow.

**ResultsPlus**
**Examiner Comments**

This candidate has written a good explanation about why the rate of reaction is higher at 700 K than 298 K so scored 1 mark. There is no mention of the yield, which is related to the equilibrium constant.

**ResultsPlus**
**Examiner Tip**

Remember that in industrial processes, the yield and rate of reaction are important and the temperature chosen is a compromise between these.

(iv) The equilibrium constant has a larger value at 298 K than at 700 K.
Explain why the reaction is carried out at 700 K and not at 298 K.

(2)

The equilibrium yield is lower at higher temperature because K is smaller. But if the value of T were to be decreased, the rate of reaction will be too low to be economically feasible for the industries. So, although the compromise T gives a low eqm. yield, it reaches eqm. at fast enough rate to ensure profit.

**ResultsPlus**
**Examiner Comments**

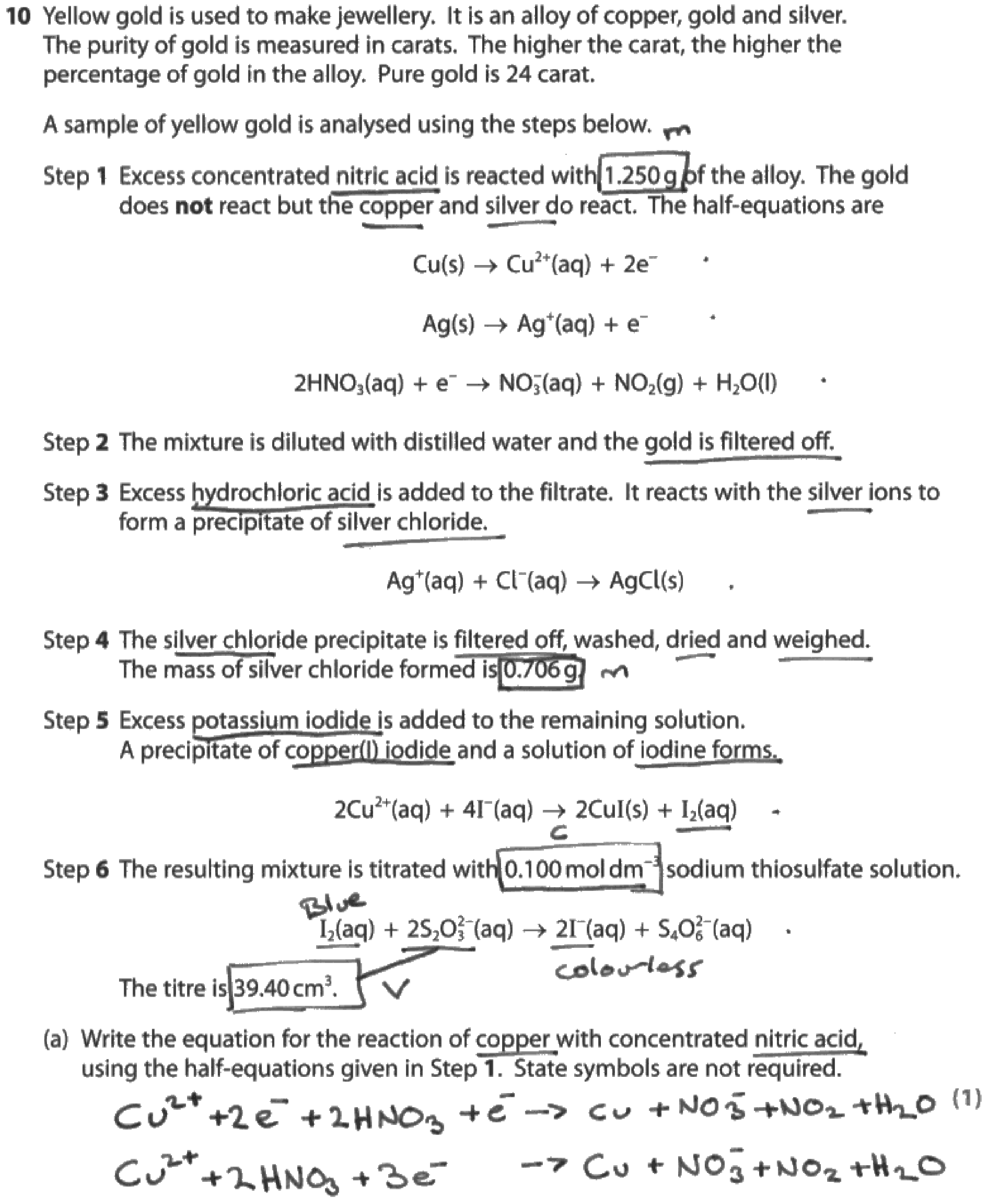
This is an example of a good response that scored 2 marks.

**ResultsPlus**
**Examiner Tip**

Consider the yield and rate of reaction in industrial processes.

## Question 10 (a)

Many candidates were able to add together the two half-equations to give the correct balanced equation. Some candidates included silver and some left uncancelled electrons in their equation. Some candidates did not use the half-equations given and were unsuccessful as they tried to make up their own equation. A few candidates left out the sign on the nitrate ion and some wrote copper atoms and copper ions on the wrong sides of the equation. Candidates should always check that ionic equations are balanced in terms of atoms and charges.



**10** Yellow gold is used to make jewellery. It is an alloy of copper, gold and silver. The purity of gold is measured in carats. The higher the carat, the higher the percentage of gold in the alloy. Pure gold is 24 carat.

A sample of yellow gold is analysed using the steps below. m

**Step 1** Excess concentrated nitric acid is reacted with 1.250 g of the alloy. The gold does **not** react but the copper and silver do react. The half-equations are

$$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$$

$$Ag(s) \rightarrow Ag^+(aq) + e^-$$

$$2HNO_3(aq) + e^- \rightarrow NO_3^-(aq) + NO_2(g) + H_2O(l)$$

**Step 2** The mixture is diluted with distilled water and the gold is filtered off.

**Step 3** Excess hydrochloric acid is added to the filtrate. It reacts with the silver ions to form a precipitate of silver chloride.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

**Step 4** The silver chloride precipitate is filtered off, washed, dried and weighed. The mass of silver chloride formed is 0.706 g. m

**Step 5** Excess potassium iodide is added to the remaining solution. A precipitate of copper(I) iodide and a solution of iodine forms.

$$2Cu^{2+}(aq) + 4I^-(aq) \xrightarrow[c]{} 2CuI(s) + I_2(aq)$$

**Step 6** The resulting mixture is titrated with 0.100 mol dm$^{-3}$ sodium thiosulfate solution.

Blue

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

colourless

The titre is 39.40 cm$^3$. V

(a) Write the equation for the reaction of copper with concentrated nitric acid, using the half-equations given in Step **1**. State symbols are not required.

$$Cu^{2+} + 2e^- + 2HNO_3 + e^- \rightarrow Cu + NO_3^- + NO_2 + H_2O$$

**(1)**

$$Cu^{2+} + 2HNO_3 + 3e^- \rightarrow Cu + NO_3^- + NO_2 + H_2O$$

**ResultsPlus**
**Examiner Comments**

This response scored 0. The candidate has reversed the direction of the copper half-equation so there are electrons on the left side of both half-equations. The equation is also not balanced.

**ResultsPlus**
**Examiner Tip**

Practise working out overall equations from half-equations. Remember the electrons must always cancel.

## Question 10 (b)

Many candidates were familiar with iodine/thiosulfate titrations and scored 2 marks for starch and the colour change of blue-black to colourless. It was surprising that a significant minority of candidates suggested an acid-base indicator for this titration. Some candidates thought that either iodine or sodium thiosulfate was the indicator and some did not know the colour change.

(b) State the indicator used and its colour change at the end-point in the titration in Step **6**.

**(2)**

Methyl Red

Red to Yellow

ResultsPlus
**Examiner Comments**

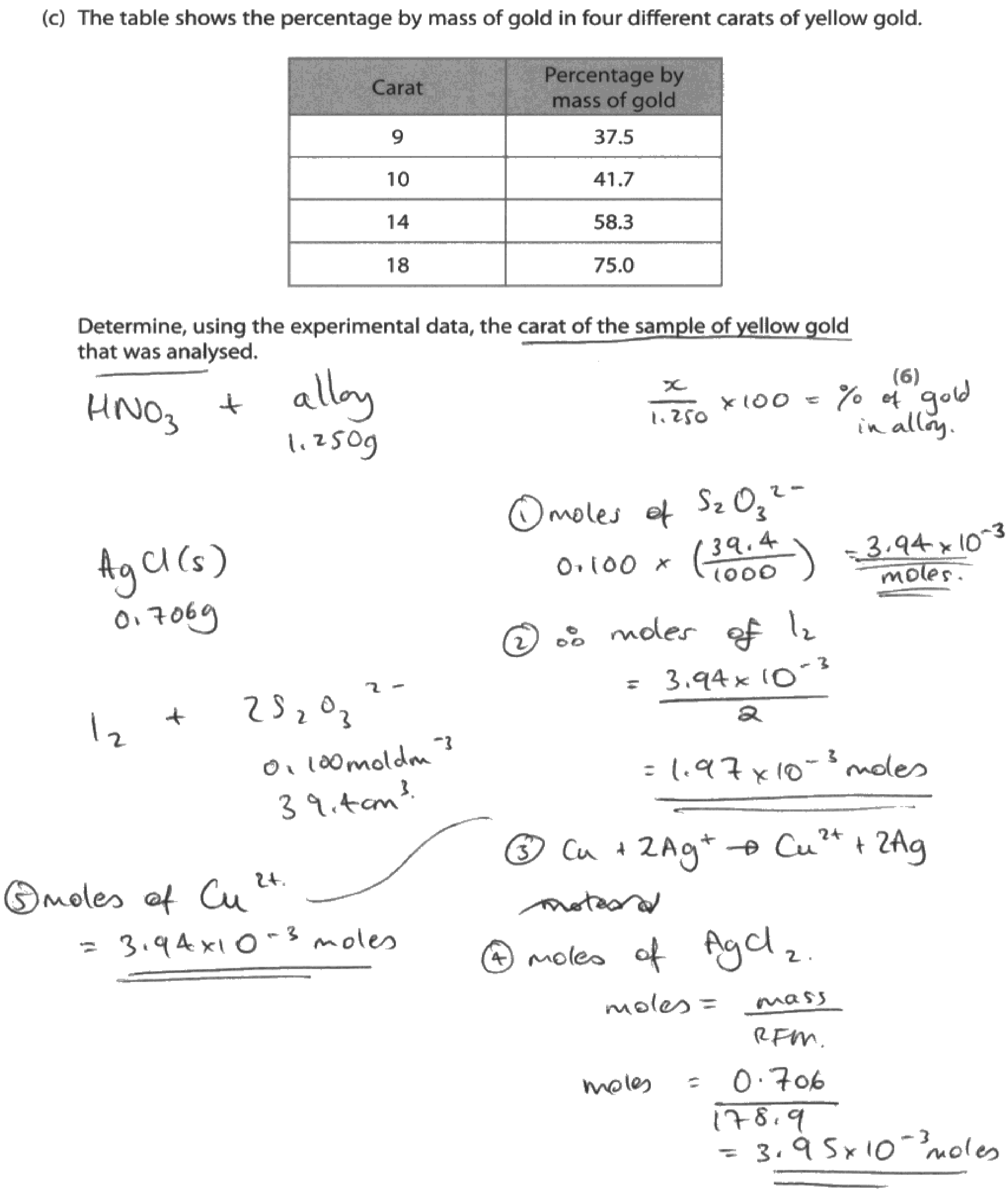
This is a common response that scored 0.

ResultsPlus
**Examiner Tip**

Learn the indicator and its colour change at the end-point for iodine/thiosulfate titrations.

## Question 10 (c)

It was pleasing to see a large number of completely correct answers scoring 6 marks. However, there are some candidates who would benefit from more practice at redox titration calculations as they struggled to get further than working out the numbers of moles of silver chloride and sodium thiosulfate, although some thought that 0.706g was the mass of silver. Some candidates were unable to use the equations given to work out the mole ratio of copper ions to thiosulfate ions as 1:1.



(c) The table shows the percentage by mass of gold in four different carats of yellow gold.

| Carat | Percentage by mass of gold |
|---|---|
| 9 | 37.5 |
| 10 | 41.7 |
| 14 | 58.3 |
| 18 | 75.0 |

Determine, using the experimental data, the carat of the sample of yellow gold that was analysed.

(6)

$HNO_3$ + alloy
1.250g

$\frac{x}{1.250} \times 100$ = % of gold in alloy.

$AgCl(s)$
0.706g

$I_2 + 2S_2O_3^{2-}$
0.100moldm$^{-3}$
39.4cm$^3$.

① moles of $S_2O_3^{2-}$
$0.100 \times \left(\frac{39.4}{1000}\right) = 3.94 \times 10^{-3}$ moles.

② ∴ moles of $I_2$
$= \frac{3.94 \times 10^{-3}}{2}$
$= 1.97 \times 10^{-3}$ moles

③ $Cu + 2Ag^+ \rightarrow Cu^{2+} + 2Ag$
~~moles of~~

④ moles of $AgCl_2$.
moles = $\frac{\text{mass}}{\text{RFM}}$.
moles = $\frac{0.706}{178.9}$
$= 3.95 \times 10^{-3}$ moles

⑤ moles of $Cu^{2+}$.
$= 3.94 \times 10^{-3}$ moles

**ResultsPlus**
**Examiner Comments**

This response scored 1 mark for calculating the number of moles of $Cu^{2+}$ ions.

The candidate has attempted to calculate the number of moles of silver chloride but has used an incorrect formula - $AgCl_2$ instead of AgCl.

**ResultsPlus**
**Examiner Tip**

Always check that you are using the correct formula. The formula of silver chloride was given in an equation earlier in the question.

(c) The table shows the percentage by mass of gold in four different carats of yellow gold.

| Carat | Percentage by mass of gold |
|---|---|
| 9 | 37.5 |
| 10 | 41.7 |
| 14 | 58.3 |
| 18 | 75.0 |

Determine, using the experimental data, the carat of the sample of yellow gold that was analysed.

**(6)**

① mols $AgCl = \frac{mass}{M_r}$

$= \frac{0.706}{143.4}$

$= 4.92 \times 10^{-3}$ mols

② ⇒ mols $Ag^+ = 4.92 \times 10^{-3}$ mols

③ ⇒ mols $Ag(s) = 4.92 \times 10^{-3}$ mols

④ ⇒ mass $Ag$ = mols × $M_r$

$= 4.92 \times 10^{-3} \times 107.9$

$= 0.531223$ g

⑤ mols thiosulfate $= \frac{c \times v}{1000}$

$= \frac{0.1 \times 39.4}{1000}$

$= 3.94 \times 10^{-3}$ mols

⑥ ⇒ mols $I_2 = \frac{3.94 \times 10^{-3}}{2}$

$= 1.97 \times 10^{-3}$ mols

⑦ ⇒ mols $Cu^{2+} = 1.97 \times 10^{-3} \times 2$

$= 3.94 \times 10^{-3}$ mols

⑧ ⇒ mols $Cu = 3.94 \times 10^{-3}$ mols

⑨ ⇒ mass $Cu = 3.94 \times 10^{-3} \times 63.5$

$= 0.25019$ g

⑩ ⇒ mass gold $= 1.250 - 0.531 - 0.250$

$= 0.469$

⑪ ∴ % mass gold $= \frac{0.469}{1.250} \times 100$

$= 37.49$

$\approx 37.5\%$

⇒ 9 carat gold

**ResultsPlus**
**Examiner Comments**

This is an example of an excellent answer that scored 6 marks.

**ResultsPlus**
**Examiner Tip**

Try to set out your calculations clearly and explain all of your working, as in this example.

# Paper Summary

On the basis of their performance on this paper, candidates are offered the following advice:

- read all the information in the question carefully and use it to help you to answer the question
- learn the meanings of as many of the key scientific words in each topic as possible
- practise answering the extended writing questions so you understand how to improve your performance by giving more relevant details, or in some cases, by writing more concisely and not repeating points
- learn all of the equations needed for carrying out enthalpy change, entropy change and free energy change calculations and remember to give your answer to an appropriate number of significant figures and include a sign and units, where appropriate
- explain each stage in your working for multi-stage calculations.

# Grade Boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

http://www.edexcel.com/iwantto/Pages/grade-boundaries.aspx

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