Examiners' Report
June 2017

GCE Chemistry 9CH0 01

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Introduction

This is the first examination in the Pearson Edexcel Level 3 Advanced GCE in Chemistry (9CH0) qualification. Papers 1 and 2 are marked out of 90 and paper 3 is out of 120.
The marks for papers 9CH0/01, 9CH0/02 and 9CH0/03 are added together to give the total mark out of 300 on which the overall grade is awarded.

Paper 1 was 1 hour 45 minutes. The paper consisted of a mixture of multiple-choice, short open, open-response, calculations and extended writing questions.

- The main differences between this paper and those A2 papers from the previous specification are:
- 10 multiple-choice questions spread throughout the paper instead of a Section A with 20 multiple-choice questions
- more calculations at level 2 or above
- a 6 mark extended writing question
- 40 to 50% of the marks on AS content.

The overall impression of the examiners was that many candidates coped very well with this first examination and gave excellent answers. However, there was a significant number of candidates who did not seem well-prepared.

Successful candidates:

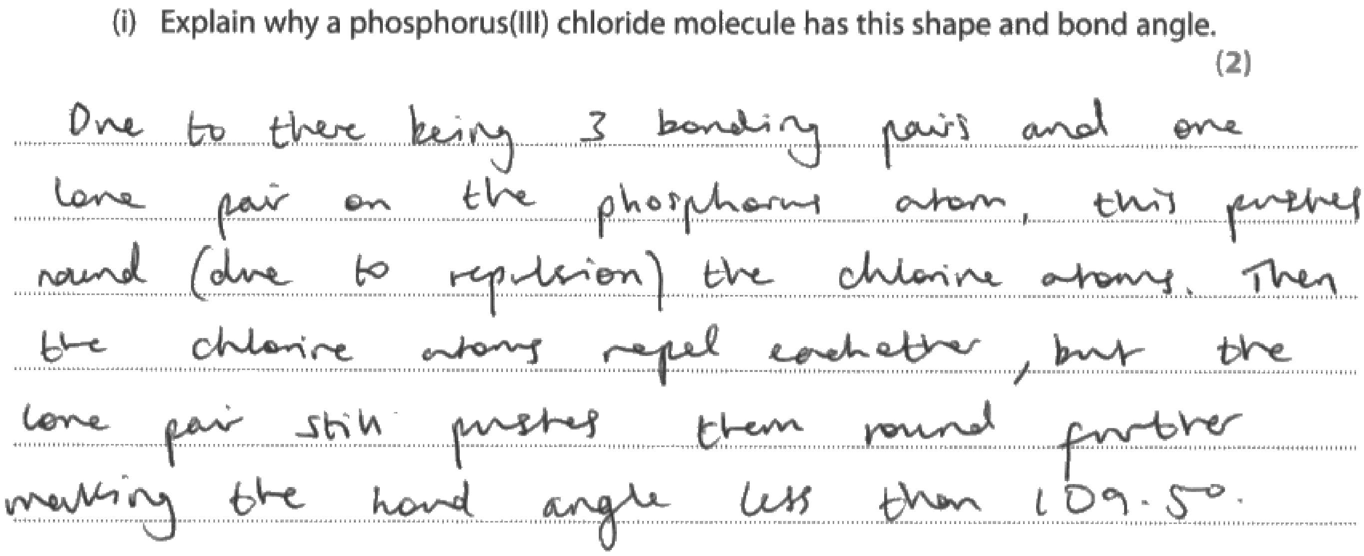
- read the questions carefully and answered the questions clearly and concisely
- used correct scientific terminology in their answers
- could carry out unstructured calculations
- could write balanced ionic equations.

Less successful candidates:

- did not read the question carefully and gave answers that were related to the topic being tested but did not answer the question
- did not use correct scientific terminology: for example, they interchanged atoms, ions and molecules without understanding what the correct word should be
- could not carry out some of the calculations being tested or gave answers that could not possibly be correct but they did not check where they had gone wrong
- rounded numbers too early in the calculation or rounded numbers incorrectly, for example, 0.67 rounded to 0.6
- were unable to write balanced ionic equations
- were careless in completing a Born-Haber cycle by omitting some state symbols and not multiplying some energy changes by 2 when 2 mol of the substance was needed
- were unable to draw a dot-and-cross diagram of an ionic compound.

Question 1 (b) (i)

It was disappointing to see many poor answers to this question on a fundamental AS topic. Too many candidates discussed repulsion between electrons, bonds or atoms and some even thought that phosphorus(III) chloride is ionic. Few candidates explained that the shape was due to minimising repulsion or maximum separation between electron pairs, although some confused these terms and wrote about maximising repulsion. However, more candidates scored the second point as they did realise that lone pairs of electrons repel more than bonding pairs.



(i) Explain why a phosphorus(III) chloride molecule has this shape and bond angle.

(2)

Due to there being 3 bonding pairs and one lone pair on the phosphorus atom, this pushes round (due to repulsion) the chlorine atoms. Then the chlorine atoms repel eachother, but the lone pair still pushes them round further making the bond angle less than 109.5°.

ResultsPlus

Examiner Comments

This candidate has the idea that repulsion is relevant when considering the shape of a molecule. However, they have written about repulsion between chlorine atoms, which is incorrect. This response scored 0.

ResultsPlus

Examiner Tip

The shapes of molecules and ions are predicted using the electron pair repulsion theory. When you explain the shape of a molecule or ion, you must write about repulsion between **electron pairs**.

(i) Explain why a phosphorus(III) chloride molecule has this shape and bond angle.

(2)

3 bonding pairs ←

1 lone pair ←

~~$~~4 electron pairs repel each other ensure maximum repulsion (repulsion between lone pair a bond pair bigger than repulsion between 2 b.pairs ∴ lone pair reduces the angle to 105.5° and as it has 3 b.p 1 L.p

Shape is pyramidal

ResultsPlus

Examiner Comments

This candidate has correctly identified that there are 3 bond pairs and 1 lone pair around the phosphorus atom. They have also mentioned repulsion between electron pairs, which is correct. However, the electron pairs are arranged to minimise repulsion, not to ensure maximum repulsion, as stated in this answer. The comparison of repulsion between bond pairs and lone pairs is correct so this response scored 1 mark.

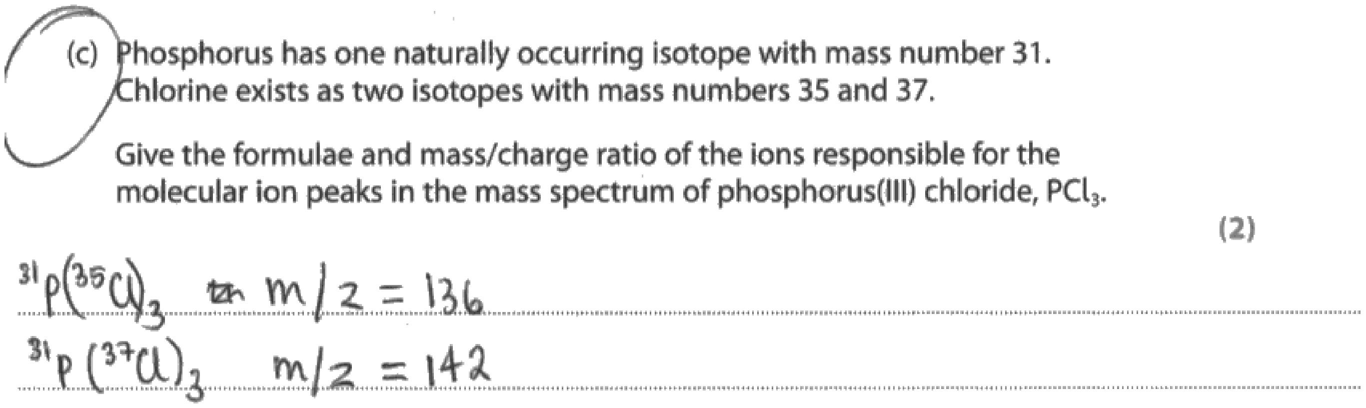
ResultsPlus

Examiner Tip

Remember that electron pairs are arranged to minimise repulsion.

Question 1 (c)

There were many clear answers to this question and it was acceptable to represent the different combinations of chlorine isotopes in many different ways. A number of candidates only identified two ions formed, one with all ^{35}Cl atoms and the other with all ^{37}Cl atoms. Unfortunately, some candidates ignored the word 'ion' in the question so they showed neutral molecules and lost a mark. Some candidates seemed unfamiliar with the term 'molecular ion' so they just gave the different isotopes of chlorine and omitted phosphorus. Other fragments were seen, such as PCl^+ and PCl_2^+.



(c) Phosphorus has one naturally occurring isotope with mass number 31.
Chlorine exists as two isotopes with mass numbers 35 and 37.

Give the formulae and mass/charge ratio of the ions responsible for the molecular ion peaks in the mass spectrum of phosphorus(III) chloride, PCl_3.

(2)

$^{31}P(^{35}Cl)_3$ ~~tn~~ $m/z = 136$

$^{31}P(^{37}Cl)_3$ $m/z = 142$

ResultsPlus

Examiner Comments

This candidate has shown two of the ions with their mass/charge values. However, they have not shown that they are positive ions so cannot score the mark.

ResultsPlus

Examiner Tip

Remember that the ions produced in a mass spectrometer always have a positive charge.

(c) Phosphorus has one naturally occurring isotope with mass number 31.
Chlorine exists as two isotopes with mass numbers 35 and 37.

Give the formulae and mass/charge ratio of the ions responsible for the molecular ion peaks in the mass spectrum of phosphorus(III) chloride, PCl_3.

(2)

PCl_3^+ : [illegible] M/z ratio : 136

PCl_3^+ : M/z ratio : 138

PCl_3^+ : M/z ratio : 140

PCl_3^+ : M/z ratio : 142

ResultsPlus
Examiner Comments

This candidate has given the four correct mass/charge values and knows they are from PCl_3^+ ions. However, they have not shown which chlorine isotopes are in each ion. This response scored 1 mark.

ResultsPlus
Examiner Tip

Give a full answer to each question.

(c) Phosphorus has one naturally occurring isotope with mass number 31.
Chlorine exists as two isotopes with mass numbers 35 and 37.

Give the formulae and mass/charge ratio of the ions responsible for the molecular ion peaks in the mass spectrum of phosphorus(III) chloride, PCl_3.

(2)

$[PCl_3]^+$ = 136 m/z = $(P\text{-}Cl^{35}\text{-}Cl^{35}\text{-}Cl^{35})^+$

$(PCl_3)^+$ = 14~~8~~2 m/z = $(P\text{-}Cl^{37}\text{-}Cl^{37}\text{-}Cl^{37})^+$

$(PCl_3)^+$ = 138 m/z $(P\text{-}Cl^{35}\text{-}Cl^{37}\text{-}Cl^{37})$

$(PCl_3)^+$ = 140 m/z $(P\text{-}Cl^{35}\text{-}Cl^{35}\text{-}Cl^{37})^+$

ResultsPlus
Examiner Comments

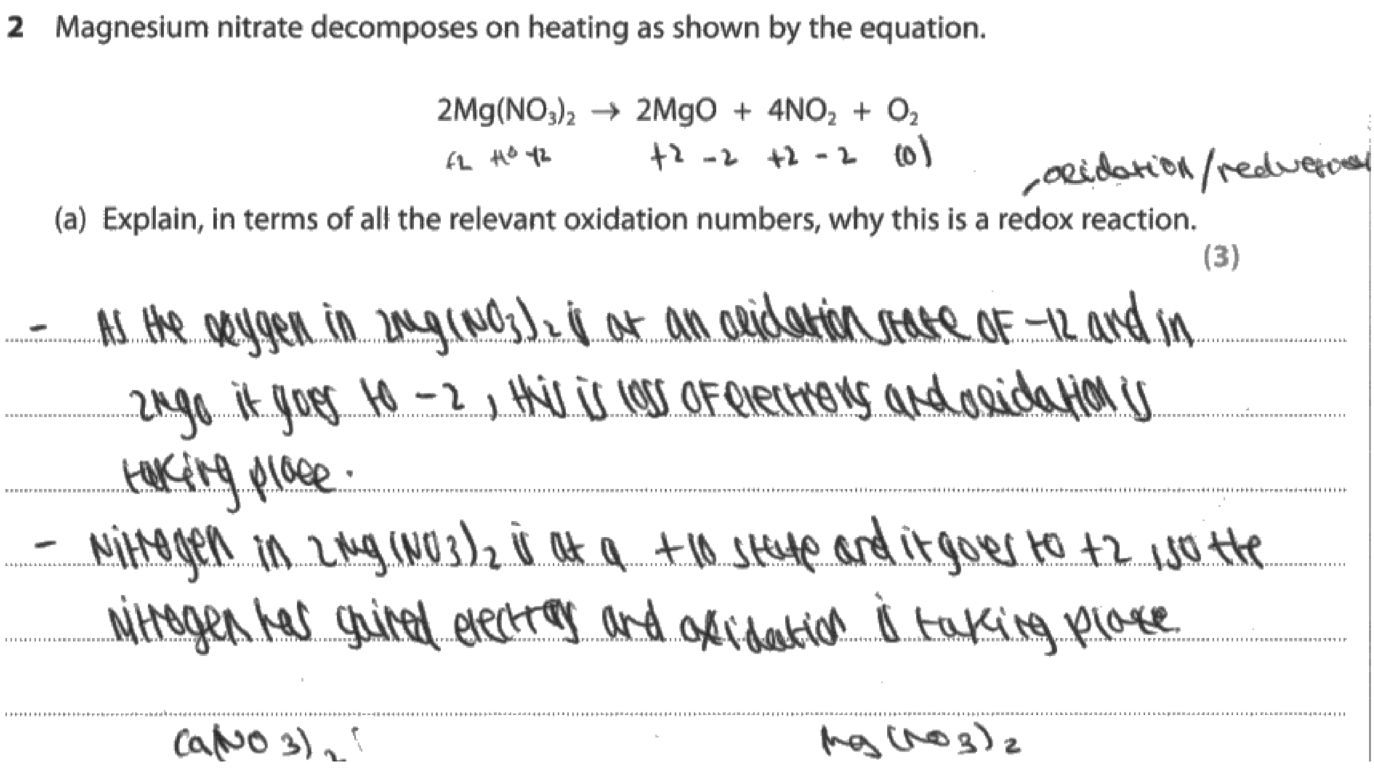
This is an example of a clear answer that scored 2 marks. The candidate has shown the four mass/charge values and the isotopes that are present in each ion.

ResultsPlus
Examiner Tip

Give detailed answers, as in this example.

Question 2 (a)

The majority of candidates demonstrated excellent understanding of redox in this question. Some candidates would benefit from more practice at determining oxidation numbers of an element in different species as +6 was a common incorrect oxidation number for nitrogen in magnesium nitrate and a few candidates gave the total of the oxidation numbers of the three oxygens in magnesium nitrate as -6 instead of the individual oxidation number. Some candidates gave the correct oxidation numbers but forgot to state which was oxidised and which was reduced while a very small minority thought that the oxidation number of magnesium was changing. Reference to 'charge' was accepted on this occasion, but candidates should be made aware that the elements do not have this charge and it would be better in future to refer to oxidation numbers. References to gain and loss of electrons were frequently seen and these were ignored as they were irrelevant to this question.



2 Magnesium nitrate decomposes on heating as shown by the equation.

$$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$$

+2 +10 -12 +2 -2 +2 -2 (0)

oxidation / reduction

(a) Explain, in terms of all the relevant oxidation numbers, why this is a redox reaction.

(3)

- As the oxygen in 2Mg(NO3)2 is at an oxidation state of -12 and in 2MgO it goes to -2, this is loss of electrons and oxidation is taking place.
- Nitrogen in 2Mg(NO3)2 is at a +10 state and it goes to +2, so the nitrogen has gained electrons and oxidation is taking place

Ca(NO3)2 Mg(NO3)2

ResultsPlus
Examiner Comments

The only correct oxidation number is that of oxygen in magnesium oxide. The candidate seems to have given the total oxidation numbers of nitrogen and oxygen in $2Mg(NO_3)_2$, instead of the individual atoms. The question asks for an explanation of why this is a redox reaction in terms of oxidation numbers so the discussion of gain or loss of electrons is irrelevant. This answer scored 0.

ResultsPlus
Examiner Tip

In a redox reaction, one species is oxidised and another is reduced.

Revise how to determine oxidation numbers and how their changes relate to oxidation and reduction.

2 Magnesium nitrate decomposes on heating as shown by the equation.

$$2\underset{+4}{\mathrm{Mg}}(\overset{+4}{\mathrm{N}}\underset{-2}{\overset{-2}{\mathrm{O}}}_3)_2 \rightarrow 2\overset{+2}{\mathrm{Mg}}\overset{-2}{\mathrm{O}} + 4\overset{+4}{\mathrm{N}}\overset{-2}{\mathrm{O}}_2 + \overset{0}{\mathrm{O}}_2$$

(a) Explain, in terms of all the relevant oxidation numbers, why this is a redox reaction.

(3)

The Magnesium is ~~oxidised~~ reduced, ~~losing~~ gaining two electrons ~~to~~ and going from an oxidation number of +4 to +2 whereas the oxygen is ~~reduced~~ oxidised going from a charge of −2 to 0, ~~gaining~~ losing two electrons. As a species is oxidised while another is reduced in the reaction it is therefore redox.

ResultsPlus

Examiner Comments

The oxidation number of magnesium does not change so the first part of the answer is incorrect. The oxidation numbers of oxygen are correct so 1 mark is scored.

ResultsPlus

Examiner Tip

Metals in group 2 always have +2 oxidation number in compounds.

2 Magnesium nitrate decomposes on heating as shown by the equation.

+5 −5

$$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$$

+2 −1 −1 +2 −2 +4 −2 −2 0

(a) Explain, in terms of all the relevant oxidation numbers, why this is a redox reaction.

(3)

This is a redox reaction because N has been reduced from +5 in NO_3^- to +4 in NO_2, which is reflected by its decrease in oxidation number. O has been oxidised from −5 to −2 as shown by the increase of its oxidation number. Since both reduction and oxidation has occurred, this is a redox reaction.

ResultsPlus

Examiner Comments

The statement about nitrogen is correct. The candidate has given an incorrect oxidation number for oxygen at the start; however, they have correctly identified the process as oxidation so scored 2 marks.

ResultsPlus

Examiner Tip

Check to make sure that you can work out the oxidation numbers of elements in different species.

2 Magnesium nitrate decomposes on heating as shown by the equation.

+2 +5 −2 +2 −2 +4 −2 0

$$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$$

(a) Explain, in terms of all the relevant oxidation numbers, why this is a redox reaction.

(3)

The magnesium's oxidation state stays at +2 throughout. However nitrogen is in state +5 at the beginning and is reduced to +4. Oxygen is in a state −2 at the start but is oxidised to 0. This reduction and oxidation occuring at the same time means that the reaction is redox.

ResultsPlus

Examiner Comments

This is an example of a clear answer that scored 3 marks. It was not necessary to write about magnesium to score full marks.

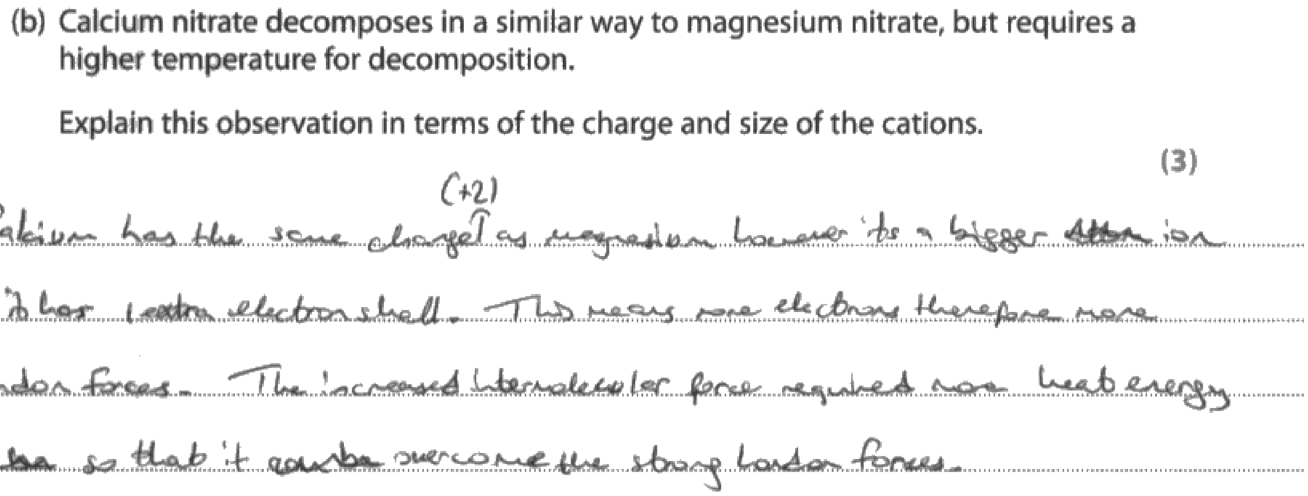
ResultsPlus

Examiner Tip

When you discuss redox reactions in terms of oxidation numbers, make sure that you include the oxidation numbers at the start and end and also state whether it is oxidation or reduction.

Question 2 (b)

There were many excellent answers to this question, showing that the majority of candidates had clear knowledge and understanding of the thermal decomposition of Group 2 nitrates. Common errors included incorrect terminology - referring to calcium atoms instead of ions or calcium nitrate molecules and confusion about which ion does the polarising. Some candidates wrote about the bond between the cation and anion being polarised, which is incorrect; it is the N-O bonds in the nitrate ion that are polarised and weakened. Some candidates stated that calcium has a larger ionic radius but then negated this mark by stating it also has a higher charge density. A small number of candidates confused their answer with ionisation energy as they discussed shielding while others discussed intermolecular forces as they confused ease of thermal decomposition with difference in melting points.



(b) Calcium nitrate decomposes in a similar way to magnesium nitrate, but requires a higher temperature for decomposition.

Explain this observation in terms of the charge and size of the cations.

(3)

Calcium has the same charge (+2) as magnesium however its a bigger ~~atom~~ ion as it has 1 extra electron shell. This means more electrons therefore more London forces. The increased intermolecular force required more heat energy ~~taken~~ so that it ~~can be~~ overcome the strong London forces.

ResultsPlus
Examiner Comments

This response scored 1 mark for the idea that calcium is a bigger ion than magnesium. The rest of the answer is about intermolecular forces and is not relevant to this question.

ResultsPlus
Examiner Tip

Read the question carefully to make sure you understand what is required in the answer.

The ease of decomposition of nitrates and carbonates of Group 1 and 2 elements is an important part of AS Chemistry.

(b) Calcium nitrate decomposes in a similar way to magnesium nitrate, but requires a higher temperature for decomposition.

Explain this observation in terms of the charge and size of the cations.

(3)

Calcium nitrate has a larger cation due to a greater number of electrons resulting in additional shielding. This reduces electron density meaning the cation can not be polarised as easily to disturb the molecule and decompose it. Magnesium has smaller cations meaning the molecule can be polarised easier due to greater charge density.

ResultsPlus

Examiner Comments

This response scored 1 mark for the statement that calcium nitrate has a larger cation. However, this candidate has confused ideas about polarisation as they think the cation is polarised, which is incorrect.

ResultsPlus

Examiner Tip

Remember that cations polarise anions.

(b) Calcium nitrate decomposes in a similar way to magnesium nitrate, but requires a higher temperature for decomposition.

Explain this observation in terms of the charge and size of the cations.

(3)

Calcium ions have a larger ionic radius than magnesium, given that they both have the same 2+ charge. Calcium ion (Ca^{2+}) is less electron dense than Magnesium ion (Mg^{2+}). This means Ca^{2+} ion is less polarising than Mg^{2+} so the Calcium Nitrate bond is more stronger than Magnesium nitrate bond since Mg^{2+} ions are more polarising, so ~~more~~ higher temperature (more energy is need to decompose the Ca-N bond).

(Total for Question 2 = 6 marks)

ResultsPlus

Examiner Comments

This answer scored the first 2 marks from the mark scheme. However, there is no 'bond' between calcium and nitrate as they are ions so are just held together by electrostatic attraction. It is the N-O bonds in the nitrate ion that are weakened.

ResultsPlus

Examiner Tip

Revise the reasons for the differences in thermal decomposition of nitrates.

Question 3 (a)

There were many excellent answers to this question as the majority of candidates were aware of the link between the increasing number of electrons and the strength of the London forces. A small number of candidates did not relate the strength of the London forces to the energy needed to overcome these forces and separate the molecules. A few candidates just referred to intermolecular forces, without specifying the type of force and a few stated or implied that the covalent bonds break.

3 This question is about halogens and redox reactions.

(a) The boiling temperatures of three halogens are shown in the table.

Halogen	Boiling temperature / °C
chlorine	−35
bromine	59
iodine	184

Explain why the boiling temperatures increase from chlorine to iodine.

(2)

The boiling temperature increase because iodine is such a large atom that it has powerful london forces holding the atoms together holding it requirde more energy in the form of heat to break down

ResultsPlus

Examiner Comments

This candidate thinks that London forces are holding the atoms together and that more energy is needed to break them down. This implies that the bonds between the atoms are breaking, which is incorrect so this response scored 0.

ResultsPlus

Examiner Tip

It is important to use the correct terminology.

There are strong covalent bonds holding the atoms together in the diatomic molecules. These bonds do not break when the halogens boil. There are weaker London forces between the molecules and energy is needed to overcome the intermolecular London forces to separate the molecules as the halogens boil.

3 This question is about halogens and redox reactions.

(a) The boiling temperatures of three halogens are shown in the table.

Halogen	Boiling temperature / °C
chlorine	−35
bromine	59
iodine	184

Explain why the boiling temperatures increase from chlorine to iodine.

(2)

- Atomic radius of the halogens increases
- Therefore intermolecular forces (London forces) become stronger and more energy is required to break them (and boil the diatomic halogens)

ResultsPlus
Examiner Comments

This answer scored the second mark in the mark scheme. Increasing atomic radius is not sufficient for explaining the increasing strength of the London forces.

ResultsPlus
Examiner Tip

Remember that London forces increase in strength as the number of electrons increases.

3 This question is about halogens and redox reactions.

(a) The boiling temperatures of three halogens are shown in the table.

Halogen	Boiling temperature / °C
chlorine	−35
bromine	59
iodine	184

Explain why the boiling temperatures increase from chlorine to iodine.

(2)

Because there are more electrons as you go down group 7 so there are more and stronger London forces so more energy is required to break the london forces as you go down group 7

ResultsPlus
Examiner Comments

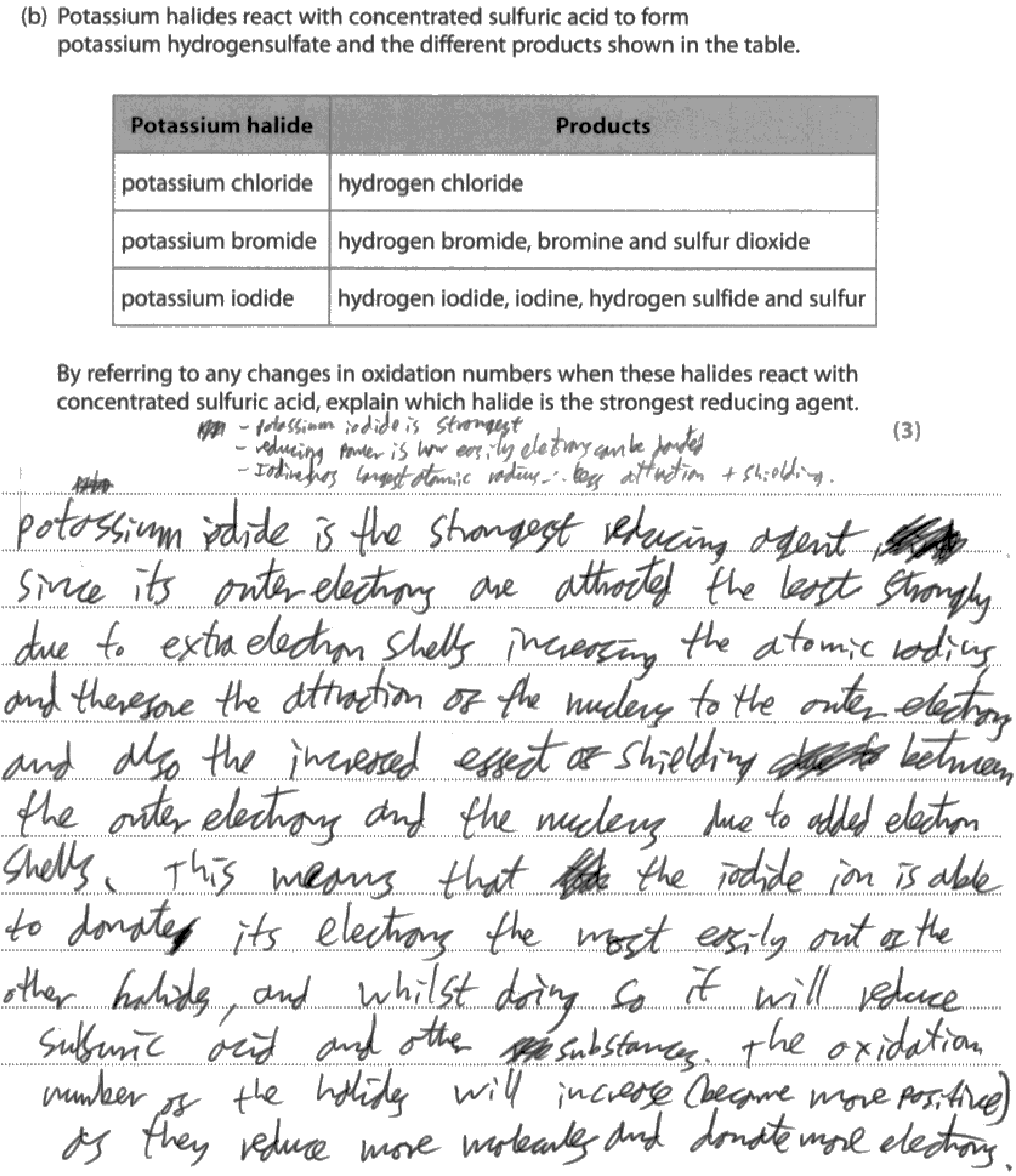
This is an example of an answer that scored 2 marks. The candidate has correctly referred to the number of electrons, intermolecular forces and the energy needed.

ResultsPlus
Examiner Tip

Remember that the strength of London forces mainly depends on the number of electrons present.

Question 3 (b)

There were many excellent answers to this question. Some candidates did not read the question and did not refer to oxidation numbers: even though they wrote in detail about iodide ions losing electrons they could not score any marks. Some candidates gave an incorrect oxidation number, the most common being +2 for sulfur in hydrogen sulfide, so they lost a mark. A few candidates omitted to state that chloride ions do not reduce sulfur. Candidates are advised to write about all of the substances given in a question.



(b) Potassium halides react with concentrated sulfuric acid to form potassium hydrogensulfate and the different products shown in the table.

Potassium halide	Products
potassium chloride	hydrogen chloride
potassium bromide	hydrogen bromide, bromine and sulfur dioxide
potassium iodide	hydrogen iodide, iodine, hydrogen sulfide and sulfur

By referring to any changes in oxidation numbers when these halides react with concentrated sulfuric acid, explain which halide is the strongest reducing agent.

(3)

- potassium iodide is strongest
- reducing power is how easily electrons can be donated
- Iodine has largest atomic radius ∴ less attraction + shielding.

potassium iodide is the strongest reducing agent, since its outer electrons are attracted the least strongly due to extra electron shells increasing the atomic radius and therefore the attraction of the nucleus to the outer electrons and also the increased effect of shielding between the outer electrons and the nucleus due to added electron shells. This means that the iodide ion is able to donate its electrons the most easily out of the other halides, and whilst doing so it will reduce sulfuric acid and other substances. The oxidation number of the halides will increase (become more positive) as they reduce more molecules and donate more electrons.

ResultsPlus

Examiner Tip

Read the question carefully and make sure that you include everything you are asked for.

There are no marks for making up your own questions!

ResultsPlus

Examiner Comments

This response scored 0. There is a detailed answer but the candidate has not read the question carefully. They were asked to refer to changes in oxidation numbers and this answer does not mention any specific oxidation numbers.

$\overset{+2}{H_2}\overset{+6}{S}\overset{-8}{O_4}$

(b) Potassium halides react with concentrated sulfuric acid to form potassium hydrogensulfate and the different products shown in the table.

K-H

Potassium halide	Products
potassium chloride	hydrogen chloride HCl
potassium bromide	hydrogen bromide, bromine and sulfur dioxide HBr Br_2 SO_2
potassium iodide	hydrogen iodide, iodine, hydrogen sulfide and sulfur HI I_2 H_2S S

By referring to any changes in oxidation numbers when these halides react with concentrated sulfuric acid, explain which halide is the strongest reducing agent.

(3)

The strongest reducing agent would lose electrons most easily in order to reduce the [illegible] [illegible] reactant. The strongest reducing agent is [illegible] iodine which is shown as the product hydrogen sulfide is formed. This is reduced from an oxidation number of +6 to −2, meaning it has gained the most electrons and was reduced the most. [illegible] This occurs as iodine is the largest of the listed halides and thus loses electrons most readily.

ResultsPlus
Examiner Comments

This candidate has given a correct change in oxidation number when iodide ions are used so this answer scored 1 mark.

ResultsPlus
Examiner Tip

The question asks about the three halide ions so to achieve full marks, you must write about each of them.

(b) Potassium halides react with concentrated sulfuric acid to form potassium hydrogensulfate and the different products shown in the table.

+1 −1 +6 2−

Potassium halide	Products
potassium chloride	hydrogen chloride
potassium bromide	hydrogen bromide, bromine and sulfur dioxide
potassium iodide	hydrogen iodide, iodine, hydrogen sulfide and sulfur

By referring to any changes in oxidation numbers when these halides react with concentrated sulfuric acid, explain which halide is the strongest reducing agent.

(3)

Iodide is the strongest reducing agent as it reduces sulfur the furthest. Chloride does not reduce sulfur at all and sulfurs oxidation number remains the same. Bromide reduces sulfur from an oxidation number of +6 to +4 so a change of −2. Iodide reduces sulfur from +6 to +2 (in hydrogen sulfide) and 0 in pure sulfur. ~~It~~ Changes of −4 and −6 respectively which are greater than any of the other halides.

ResultsPlus
Examiner Comments

This is a good answer that refers to all three halides ions. However, the oxidation number of sulfur in hydrogen sulfide should be -2, so 2 marks were awarded.

ResultsPlus
Examiner Tip

Learn the oxidation numbers that do not change and practise working out oxidation numbers. Hydrogen is always +1 in compounds, unless it is joined to a metal.

(b) Potassium halides react with concentrated sulfuric acid to form potassium hydrogensulfate and the different products shown in the table.

Potassium halide	Products
potassium chloride	hydrogen chloride
potassium bromide	hydrogen bromide, bromine and sulfur dioxide
potassium iodide	hydrogen iodide, iodine, hydrogen sulfide and sulfur

By referring to any changes in oxidation numbers when these halides react with concentrated sulfuric acid, explain which halide is the strongest reducing agent.

(3)

Let us consider each halide in turn:

- The chloride ion is unable to change the oxidation number of the Sulphur.
- The bromide ion reduces the ~~Sulfur~~ Sulphur from the +6 to the +4 oxidation state.
- The iodide ion reduces the Sulphur from the +6 to the 0 and -2 oxidation state.

The iodide reduces the ~~Sulfur~~ Sulphur by the greatest extent. Hence the iodide is the strongest reducing agent.

ResultsPlus

Examiner Comments

This is a clear answer that scored 3 marks. The candidate has referred to all of the relevant oxidation numbers and come to the correct conclusion.

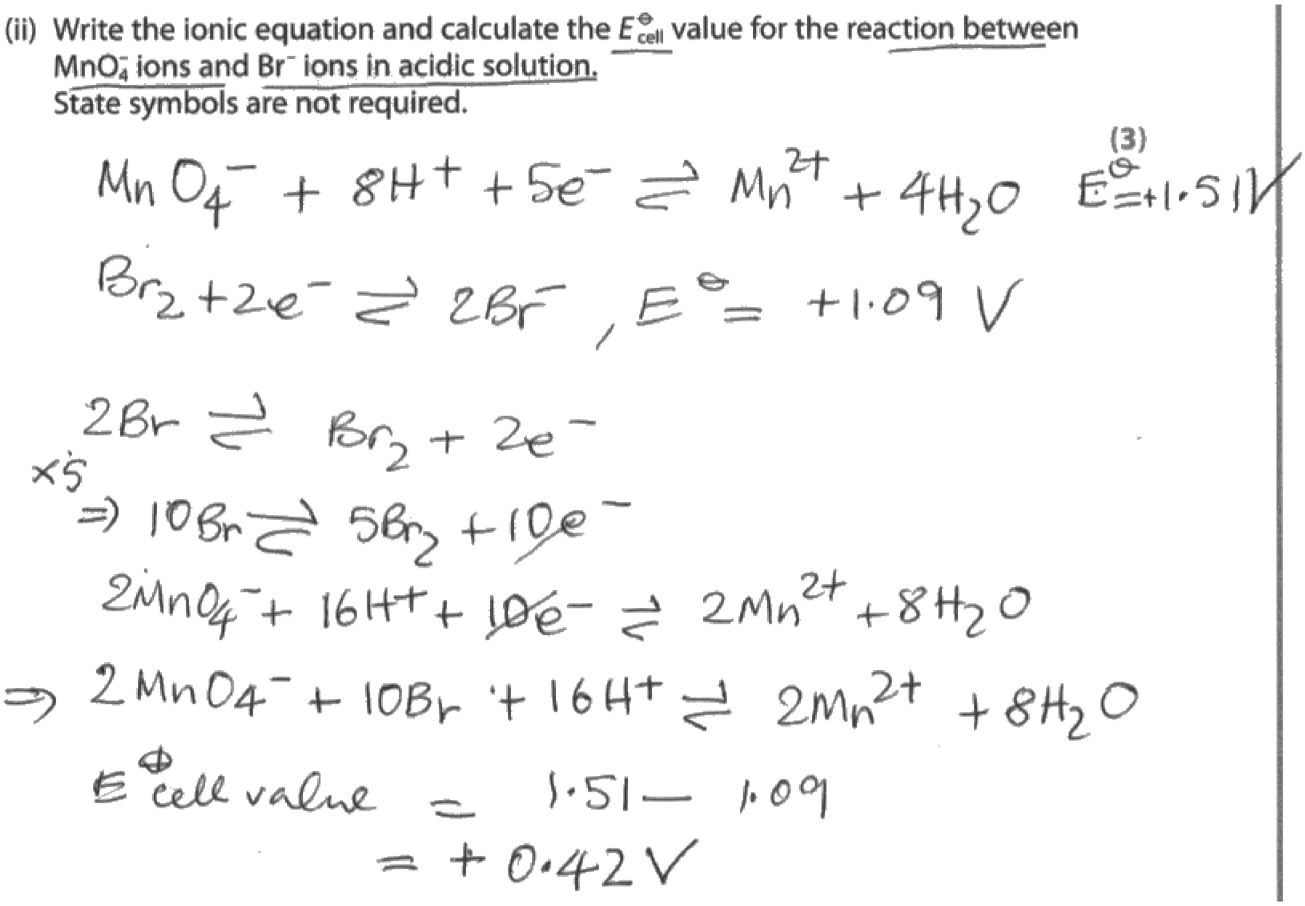
ResultsPlus

Examiner Tip

Try to keep your answers clear and concise, as in this example.

Question 3 (c) (ii)

Although many correct answers were seen, many candidates made careless errors in copying the half-equations from the table. Some candidates left uncancelled electrons in their equations, some wrote the equation in the wrong direction while others tried to react manganate(VII) ions with bromine. A few candidates selected the wrong half-equation for manganese. Some candidates were unable to calculate the E°_{cell} value.



(ii) Write the ionic equation and calculate the $E^\ominus_{cell}$ value for the reaction between MnO_4^- ions and Br^- ions in acidic solution.
State symbols are not required.

(3)

$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O \quad E^\ominus = +1.51V$ ✓

$Br_2 + 2e^- \rightleftharpoons 2Br^- , E^\ominus = +1.09\ V$

$2Br \rightleftharpoons Br_2 + 2e^-$

$\times 5$

$\Rightarrow 10Br \rightleftharpoons 5Br_2 + \cancel{10}e^-$

$2MnO_4^- + 16H^+ + \cancel{10e}^- \rightleftharpoons 2Mn^{2+} + 8H_2O$

$\Rightarrow 2MnO_4^- + 10Br + 16H^+ \rightleftharpoons 2Mn^{2+} + 8H_2O$

$E^\ominus$ cell value $= 1.51 - 1.09$

$= +0.42V$

ResultsPlus

Examiner Comments

This candidate has selected the two correct half-equations, copied them down correctly and multiplied them by 2 or 5 so that the electrons cancel. However, the final equation is incorrect as it does not show the charge on the bromide ion and the bromine molecules are missing. This response scored 1 mark for the calculation.

ResultsPlus

Examiner Tip

Always check ionic equations carefully to make sure that all the species are present and the overall charges balances.

(ii) Write the ionic equation and calculate the $E^{\ominus}_{cell}$ value for the reaction between MnO_4^- ions and Br^- ions in acidic solution.
State symbols are not required.

$Br \times 5$ $MnO_4 \times 2$

(3)

$Br_2 + 2e^- + Mn^{2+} + 4H_2O \rightleftharpoons 2Br^- + MnO_4^- + 8H^+ + 5e^-$

$5Br_2 +$ ~~$10e^-$~~ $+ 2Mn^{2+} + 8H_2O \rightleftharpoons 10Br^- + 2MnO_4^- + 16H^+$ ~~$+10e^-$~~

$\underline{\underline{5Br_2 + 2Mn^{2+} + 8H_2O \rightleftharpoons 10Br^- + 2MnO_4^- + 16H^+}}$

$+1.51V - 1.09V = \underline{\underline{+0.42V}} = E^{\ominus}_{cell}$

ResultsPlus

Examiner Comments

The overall equation is correct but is written in the reverse direction. The question asks for the equation for the reaction between manganate(VII) ions and bromide ions not between manganese(II) ions and bromine. The addition of the reversible arrow does not compensate for this. However, 1 mark was awarded for the correct balancing and 1 mark for the calculation.

ResultsPlus

Examiner Tip

Always write equations in the direction they are asked for.

(ii) Write the ionic equation and calculate the $E^\ominus_{cell}$ value for the reaction between MnO_4^- ions and Br^- ions in acidic solution.
State symbols are not required.

(3)

~~$2Br^- \rightarrow Br_2 + 2e^-$~~

$10Br^- \longrightarrow 5Br_2 + 10e^-$ $\qquad E^\ominus = -1.09V$

$2MnO_4^- + 16H^+ + 10e^- \longrightarrow 2Mn^{2+} + 8H_2O$ $\qquad E^\ominus = +1.51V$

$2MnO_4^- + 16H^+ + 10Br^- \longrightarrow 5Br_2 + 2Mn^{2+} + 8H_2O$

$\therefore E^\ominus = 1.51 - 1.09 = +\underline{\underline{0.42V}}$

ResultsPlus

Examiner Tip

When working out overall ionic equations from half-equations, it is a good idea to show your working clearly, as in this example, so that you don't leave out any species.

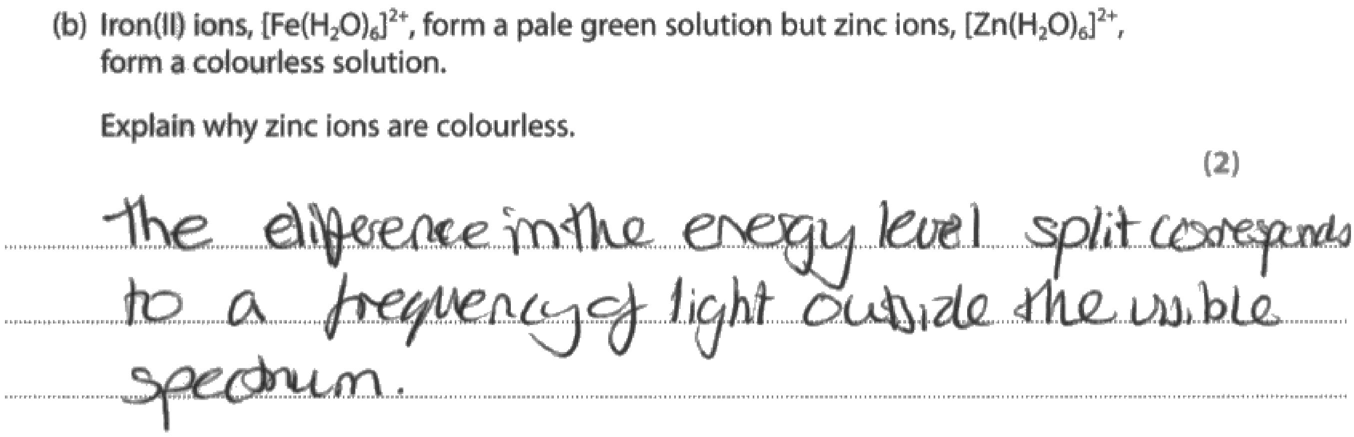
ResultsPlus

Examiner Comments

This is an excellent answer that scored 3 marks.

Question 4 (b)

Many candidates did not score marks for this question as their terminology was not clear enough. Stating that zinc ions have a full d orbital is not acceptable for the idea that all the d orbitals are full. Candidates are advised to use the term 'd subshell' to avoid this problem. A common misconception is that when the d orbitals are full, they cannot split in energy. Some candidates wrote that the electrons cannot be excited to a higher energy level and this is not clear enough as energy level usually refers to quantum shell. 'd-d transitions cannot take place' is a useful phrase for candidates to include in an answer like this. A few candidates were confused with a flame test and wrote about emission of light while others thought the electromagnetic radiation transmitted would be outside the visible spectrum.



(b) Iron(II) ions, $[Fe(H_2O)_6]^{2+}$, form a pale green solution but zinc ions, $[Zn(H_2O)_6]^{2+}$, form a colourless solution.

Explain why zinc ions are colourless.

(2)

the difference in the energy level split corresponds to a frequency of light outside the visible spectrum.

ResultsPlus

Examiner Comments

This is a fairly common incorrect answer that scored 0.

ResultsPlus

Examiner Tip

Although it is possible that some ligands cause a split to the 3d subshell that will give frequency of light outside of the visible spectrum, this does not happen with water ligands.

Revise the reasons for why transition metal ions are coloured and consider why zinc ions in solution are colourless.

(b) Iron(II) ions, $[Fe(H_2O)_6]^{2+}$, form a pale green solution but zinc ions, $[Zn(H_2O)_6]^{2+}$, form a colourless solution.

Explain why zinc ions are colourless.

(2)

Zinc ions form a full 3d subshell so the orbitals in the 3d subshell cannot split.

ResultsPlus
Examiner Comments

This response scored 1 mark for saying that the 3d subshell is full of electrons. However, the ligands still split the d orbitals so the last statement is incorrect.

ResultsPlus
Examiner Tip

Ligands will always cause splitting of the 3d subshell.

(b) Iron(II) ions, $[Fe(H_2O)_6]^{2+}$, form a pale green solution but zinc ions, $[Zn(H_2O)_6]^{2+}$, form a colourless solution.

Explain why zinc ions are colourless.

(2)

Zn^{2+} ions have ~~elec~~ electronic configuration of $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ so it has a completely filled 3d subshell so -no d-d transitions are possible.

ResultsPlus
Examiner Comments

This is an excellent answer that scored 2 marks.

ResultsPlus
Examiner Tip

"d-d transitions" is an acceptable and simple way of referring to electrons being promoted from a d orbital of lower energy to a d orbital of higher energy.

Question 4 (c) (i)

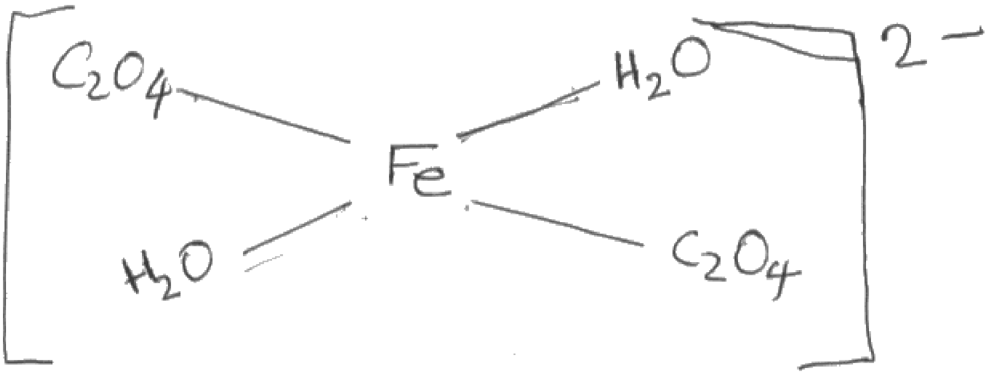
There were many clear diagrams that scored both marks. Some candidates ignored the instruction to show all of the bonds. We did allow the bonds in the water ligands not to be shown, provided they were attached to the Fe^{2+} ions through the oxygen atoms. Some candidates were unable to work out that ethanedioate ions are formed from ethanedioic acid and are bidentate ligands.

(c) Hydrated iron(II) ions react with ethanedioate ions, $C_2O_4^{2-}$, to form a complex ion.

$$[Fe(H_2O)_6]^{2+} + 2C_2O_4^{2-} \rightleftharpoons [Fe(C_2O_4)_2(H_2O)_2]^{2-} + 4H_2O$$

(i) Draw a structure of the $[Fe(C_2O_4)_2(H_2O)_2]^{2-}$ ion, showing **all** of the bonds.

(2)



ResultsPlus

Examiner Comments

This is a poor diagram that scored 0. The question asks for all the bonds to be shown and this candidate ignored that statement. Although we did allow the bonds in the water molecules not to be shown, the water molecules needed to be shown linked correctly to the metal ion through the oxygen atom. This candidate has shown the water on the right joined through the hydrogen atom.

ResultsPlus

Examiner Tip

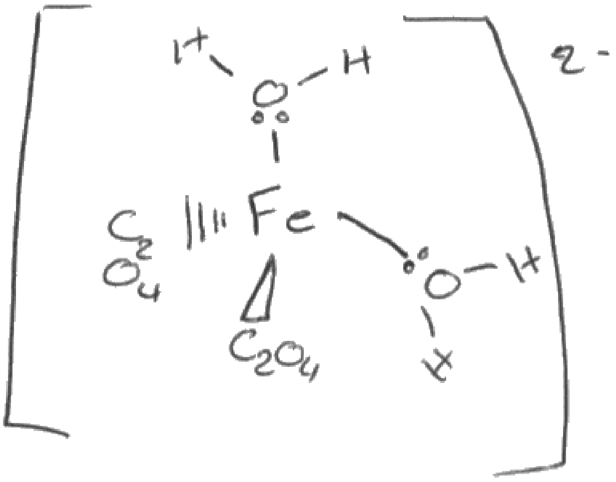
Read the question carefully.

This candidate may have scored 1 mark if they had shown all the bonds in the water ligands as they would probably have joined them through the oxygen atoms.

(c) Hydrated iron(II) ions react with ethanedioate ions, $C_2O_4^{2-}$, to form a complex ion.

$$[Fe(H_2O)_6]^{2+} + 2C_2O_4^{2-} \rightleftharpoons [Fe(C_2O_4)_2(H_2O)_2]^{2-} + 4H_2O$$

(i) Draw a structure of the $[Fe(C_2O_4)_2(H_2O)_2]^{2-}$ ion, showing **all** of the bonds. **(2)**



ResultsPlus

Examiner Comments

This response scored 1 mark for the two water ligands attached to the iron ion using oxygen atoms. They have not shown the bonds in the ethanedioate ions.

ResultsPlus

Examiner Tip

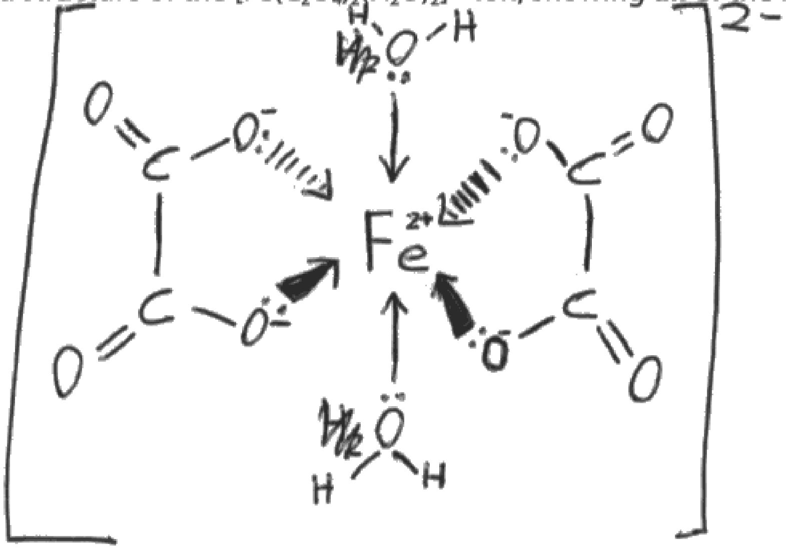
Ethanediaote ions are formed from ethanedioc acid. They are a bidentate ligand.

(c) Hydrated iron(II) ions react with ethanedioate ions, $C_2O_4^{2-}$, to form a complex ion.

$$[Fe(H_2O)_6]^{2+} + 2C_2O_4^{2-} \rightleftharpoons [Fe(C_2O_4)_2(H_2O)_2]^{2-} + 4H_2O$$

(i) Draw a structure of the $[Fe(C_2O_4)_2(H_2O)_2]^{2-}$ ion, showing **all** of the bonds.

(2)



ResultsPlus

Examiner Comments

This is a clear diagram showing all the bonds in the ligands so it scored 2 marks.

ResultsPlus

Examiner Tip

Practice drawing structures of complex ions using a mixture of monodentate and bidentate ligands so that you can represent them clearly, as in this example.

Question 4 (c) (ii)

This question was answered well by the majority of candidates: they correctly identified the increased number of particles on the right-hand side so there would be an increase in entropy. Some candidates used incorrect terminology and referred to the particles as molecules while others wrote about disorder but did not mention entropy. Just stating that 'entropy is positive' was not sufficient for the second mark.

(ii) Explain, in terms of entropy, why this reaction is feasible.

(2)

As you move from 3 moles of reactant to 5 moles of product, you release two simple water molecules for each larger ethanedioate ion, showing it becomes more disordered

ResultsPlus

Examiner Comments

This response scored 1 mark as the candidate shows that the number of moles has increased but they have only referred to the system being more disordered and have not mentioned entropy.

ResultsPlus

Examiner Tip

Check your answer to make sure that you have included everything you are asked for.

(ii) Explain, in terms of entropy, why this reaction is feasible.

(2)

on the left side of the equation there are 3 molecules whereas on the right side there are 5 molecules. This means there is an d increase in disorder so ΔS_{system} would be positive so the reaction is feasible.

ResultsPlus

Examiner Comments

This candidate scored 1 mark for the increase in Δs_{system}. However, they did not score the mark for the increase in number of particles as they have used molecules. There are a combination of ions and molecules in this reaction so molecules is incorrect terminology.

ResultsPlus

Examiner Tip

Use the correct terminology for particles. In this example, the candidate would have scored the mark if they had referred to an increase in the number of moles, particles or species.

Question 4 (d)

Many correct equations were seen: however, it was clear that a significant minority of candidates did not understand that they should start and end with Fe^{2+} ions. A common error was not balancing the equations in terms of charges. Some candidates attempted to write equations in which both reactants were oxidised or both were reduced, while others introduced Fe, Fe^{+} and other complexes involving Fe, S, O and I.

(d) Iodide ions, I^-, react with peroxodisulfate(VI) ions, $S_2O_8^{2-}$

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

This reaction is catalysed by iron(II) ions, $Fe^{2+}(aq)$.

Write **two** ionic equations to show how iron(II) ions act as a catalyst in this reaction. State symbols are not required.

(2)

$$2I^- + Fe^{2+} \rightarrow I_2 + Fe^{3+}$$

$$S_2O_8^{2-} + Fe^{3+} \rightarrow 2SO_4^{2-} + Fe^{2+}$$

ResultsPlus

Examiner Comments

This response scored 0. The two equations balance in terms of atoms but not in terms of charges. The first equation shows both species being oxidised and the second equation shows both species being reduced.

ResultsPlus

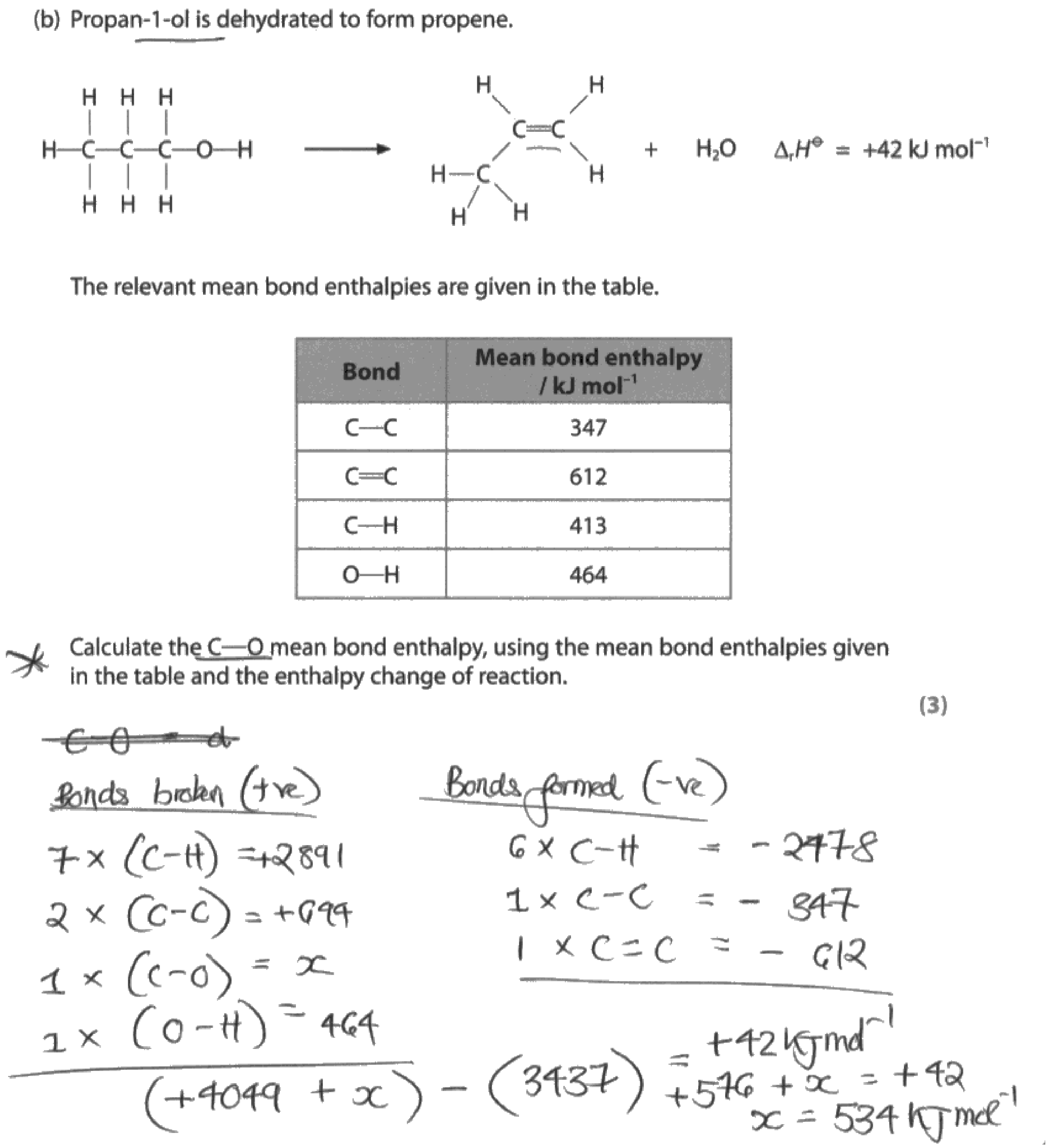
Examiner Tip

Check that ionic equations are balanced in terms of atoms and charges.

In a redox reaction, one species is oxidised and another is reduced.

Question 5 (b)

There were many correct answers to this calculation. Almost all candidates attempted to calculate the energy needed to break all bonds and the energy released in forming all bonds, rather than selecting the specific bonds that are broken and made, and as a consequence, many arithmetical errors were seen. Some candidates omitted some of the bonds, particularly the two O-H bonds in water and some of the C-C bonds. Some put the 42 on the wrong side of the equation and some omitted 42 from their calculation. A common incorrect formula used was C-O = 42 - products + reactants. Candidates should show their working clearly and use a few words to explain the working so that examiners can award transferred error marks if they make a mistake.



(b) Propan-1-ol is dehydrated to form propene.

+ H_2O $\Delta_r H^\ominus$ = +42 kJ mol^{-1}

The relevant mean bond enthalpies are given in the table.

Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C=C	612
C—H	413
O—H	464

* Calculate the C—O mean bond enthalpy, using the mean bond enthalpies given in the table and the enthalpy change of reaction.

(3)

~~C−O = d~~

Bonds broken (+ve)

$7 \times (C-H) = +2891$

$2 \times (C-C) = +694$

$1 \times (C-O) = x$

$1 \times (O-H) = 464$

Bonds formed (−ve)

$6 \times C-H = -2478$

$1 \times C-C = -347$

$1 \times C=C = -612$

$(+4049 + x) - (3437) = +42$ kJ mol^{-1}

$+576 + x = +42$

$x = 534$ kJ mol^{-1}

ResultsPlus

Examiner Comments

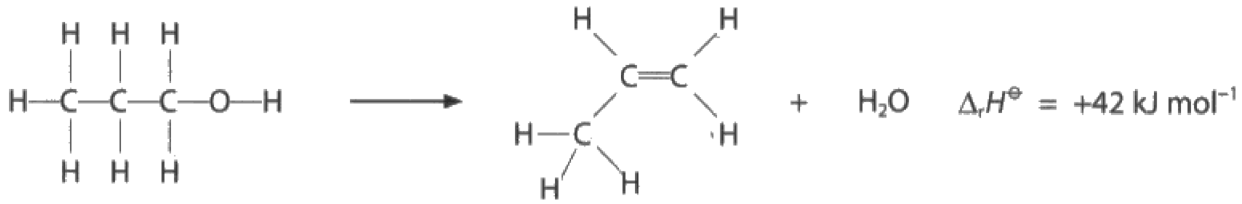
This response scored 1 mark for the correct total energy needed to break bonds. The candidate has omitted the two O-H bonds in the water molecule for the energy released when bonds are formed. The overall calculation at the end is also incorrect.

ResultsPlus

Examiner Tip

Check to make sure that you have included all the bonds in the molecules in the equation.

(b) Propan-1-ol is dehydrated to form propene.



The relevant mean bond enthalpies are given in the table.

Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C=C	612
C—H	413
O—H	464

Calculate the C—O mean bond enthalpy, using the mean bond enthalpies given in the table and the enthalpy change of reaction.

(3)

$(347 \times 2) + (7 \times 413) + 464 + x$

$= 612 + 347 + (6 \times 413) + (2 \times 464)$

274

$4049 + x = 4365$

$x = 316 \qquad 316 - 42 =$

$x = 274$ kJ mol^{-1}

ResultsPlus

Examiner Comments

This candidate has included all the bonds and calculated the correct energies involved in bond making and bond breaking. However, the final calculation is incorrect as 42 is on the wrong side of the equation. This response scored 2 marks.

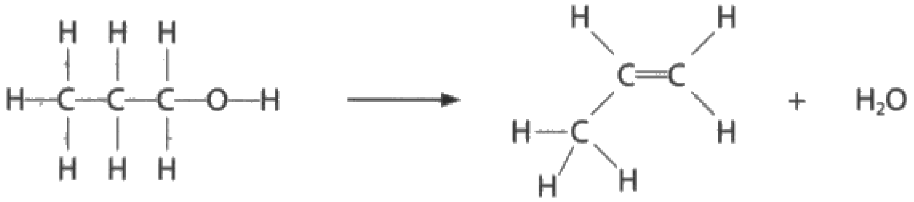
ResultsPlus

Examiner Tip

enthalpy change = energy needed to break bonds - energy released in forming bonds

1 mole produce

(b) Propan-1-ol is dehydrated to form propene.



$\Delta_r H^\ominus = +42\ \text{kJ mol}^{-1}$

The relevant mean bond enthalpies are given in the table.

Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C=C	612
C—H	413
O—H	464

Calculate the C—O mean bond enthalpy, using the mean bond enthalpies given in the table and the enthalpy change of reaction.

(3)

$\Delta_r H = (\text{bonds broken} - \text{bonds made})$

C-H

bonds broken = $(413 \times 7) + 464 + x + (2 \times 347)$

$\hookrightarrow 4049 + x$

bonds made = $(413 \times 6) + 347 + 612 + (2 \times 464)$

$\hookrightarrow 4365$

$42 = (4049 + x) - (4365)$

$+4365 - 4049 \quad - 4049 \quad + 4365$

$\boxed{x = 358\ \text{kJmol}^{-1}}$

ResultsPlus

Examiner Comments

This is an example of a correct calculation scoring 3 marks.

ResultsPlus

Examiner Tip

Remember to check that you have included all the bonds and that you have used the correct formula, as shown in the top line of this answer.

Question 5 (e)

The majority of candidates scored 3 marks for this question. A few candidates did not convert the units of ΔS or Δ*H* so they were both the same. Some candidates lost a mark as they gave entropy units for Δ*G* and a few omitted to state why the reaction is not feasible at 298 K. A small number of candidates incorrectly rounded 1078.8 to 1078 K so lost a mark.

(e) Calcium carbonate decomposes on heating.

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

$\Delta_r H = +178 \text{ kJ mol}^{-1}$

$\Delta S_{system} = +165 \text{ J mol}^{-1} \text{ K}^{-1}$

Show, by calculating the value for the free energy change, ΔG, that this decomposition is not feasible at 298 K, and then calculate the minimum temperature to which calcium carbonate must be heated to make it decompose.

(3)

$\Delta G = -RT \ln K$

$\Delta G = -R(298) \ln K$

~~$+178 = K \frac{[CO_2]}{C}$~~

$+178 = K [CO_2]$

ResultsPlus
Examiner Comments

This candidate has tried to use the incorrect formula for calculating Δ*G* so scored 0.

ResultsPlus
Examiner Tip

Look at the data given in the question to help you to decide which formula to use. You are not given the value of *R* or the equilibrium constant, but you are given the values for Δ*H* and ΔS_{system} so you need to use $\Delta G = \Delta H - T\Delta S_{system}$.

(e) Calcium carbonate decomposes on heating.

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

$\Delta_r H = +178 \text{ kJ mol}^{-1}$

$\Delta S_{system} = +165 \text{ J mol}^{-1} \text{ K}^{-1}$

Show, by calculating the value for the free energy change, ΔG, that this decomposition is not feasible at 298 K, and then calculate the minimum temperature to which calcium carbonate must be heated to make it decompose.

(3)

$$\Delta S_{surroundings} = \frac{-178}{298} = -597.315 \text{ Jmol}^{-1}$$

$$\therefore \Delta G = \Delta H - T \Delta S_{surround.}$$

$$\Delta G = 178000 - 298(-597.315) \simeq 355994.9$$

$\therefore \Delta G > 0 \therefore$ its not feasible

$$T = \frac{\Delta H}{\Delta S} = \frac{178000}{-597.315} = -298 \text{ K}$$

$$\Delta S = -\frac{\Delta H}{T}$$

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

$$T = \frac{\Delta H}{\Delta S_{surround}}$$

ResultsPlus

Examiner Comments

This candidate has calculated $\Delta S_{surroundings}$, which is not needed here. The value of ΔS_{system} should be used and this is given in the question. The statement that $\Delta G > 0$ so the reaction is not feasible scores 1 mark. The correct formula is used to calculate the temperature at which the reaction becomes feasible but the answer does not score a mark as it is impossible to have a negative temperature measured in kelvin.

ResultsPlus

Examiner Tip

Use the data given in the question.

If you get an impossible answer, go back and check your working as you must have done something wrong.

(e) Calcium carbonate decomposes on heating.

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

$\Delta_r H = +178 \text{ kJ mol}^{-1}$

$\Delta S_{system} = +165 \text{ J mol}^{-1} \text{ K}^{-1}$

Show, by calculating the value for the free energy change, ΔG, that this decomposition is not feasible at 298 K, and then calculate the minimum temperature to which calcium carbonate must be heated to make it decompose.

(3)

$\Delta G = \cancel{\Delta G}\ \Delta H - T\Delta S$

$= $ [illegible] $128830 \text{ J mol}^{-1} \text{ K}^{-1}$

$\Delta G = 0$

$\Delta H = T\Delta S$

$\frac{\Delta H}{\Delta S} = T$

$= 1078.78 \text{ K}$

$= 1079 \text{ K}$

ResultsPlus

Examiner Comments

This candidate has carried out two correct calculations. However, the mark is not awarded for the calculation of Δ*G* as the units are incorrect. The candidate has not explained that the reaction is not feasible because Δ*G* is positive. This response scored 1 mark for calculating the temperature at which the reaction becomes feasible.

ResultsPlus

Examiner Tip

Check you have the correct units for all calculations.

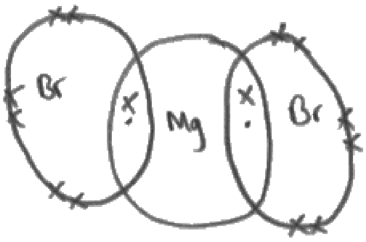
Question 6 (a) (i)

Although many candidates scored a mark for this simple question, it was disappointing that a significant minority showed a covalent molecule, even though they were told it is ionic in the first sentence!

6 Magnesium bromide, $MgBr_2$, is an ionic compound.

(a) (i) Draw a dot-and-cross diagram to show the bonding in magnesium bromide. Only outer shell electrons are required.

(1)



ResultsPlus
Examiner Comments

This is an example of many answers that showed a covalent molecule and scored 0.

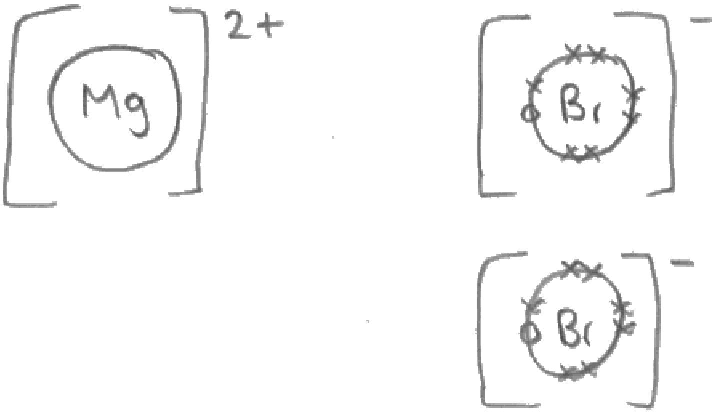
ResultsPlus
Examiner Tip

Read the question carefully. On the first line, it states that magnesium bromide is an ionic compound. This means that it consists of ions not molecules.

6 Magnesium bromide, $MgBr_2$, is an ionic compound.

(a) (i) Draw a dot-and-cross diagram to show the bonding in magnesium bromide. Only outer shell electrons are required.

(1)



ResultsPlus
Examiner Comments

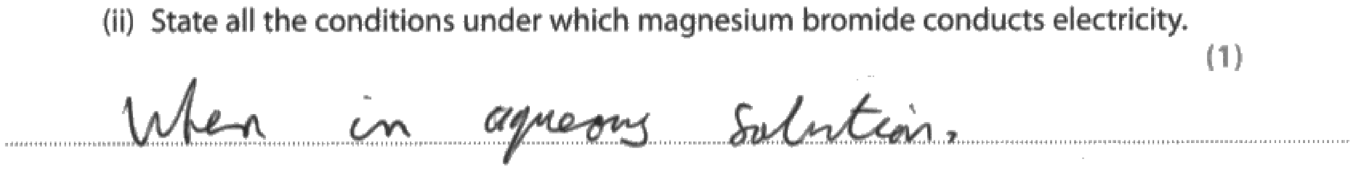
This is an excellent answer that scored 1 mark.

ResultsPlus
Examiner Tip

Show the ions in square brackets with the charges outside.

Question 6 (a) (ii)

The majority of candidates scored 1 mark for this question. Some candidates just stated molten, or just in aqueous solution, so they did not score the mark as they were asked for all the conditions under which magnesium bromide conducts electricity. A few candidates stated molten and liquid, possibly thinking that these are two different states. A small number of candidates negated the mark by adding 'so delocalised electrons can flow' to their answer.



(ii) State all the conditions under which magnesium bromide conducts electricity.

(1)

When in aqueous solution.

ResultsPlus

Examiner Comments

This response scored 0. The question asks for all the conditions under which magnesium bromide conducts electricity and aqueous solution is just one of the conditions.

ResultsPlus

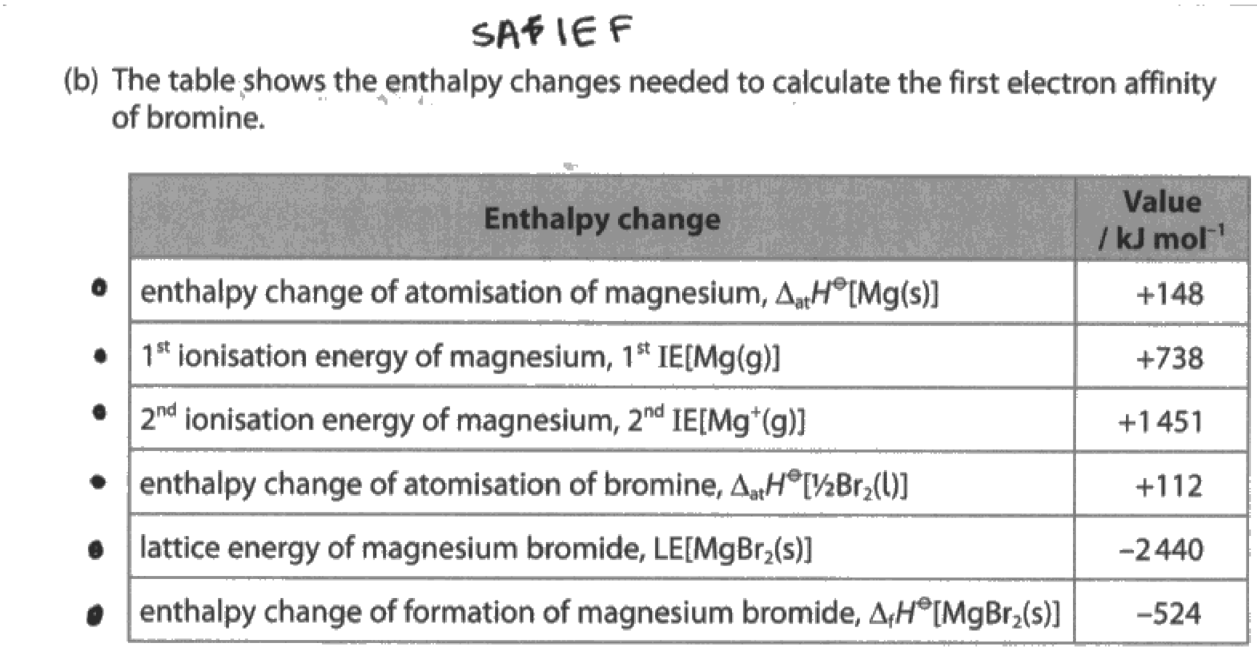
Examiner Tip

When you are asked for conditions, you must include more than one.

Question 6 (b)

The majority of candidates made a good attempt at completing the Born-Haber cycle. Errors occurred in omitting some state symbols, not showing that the bromine enthalpy changes need to be multiplied by 2 and showing that during atomisation, bromine forms Br_2(g). Candidates should give clear labels for the enthalpy changes and not just x for electron affinity. A few candidates seemed unfamiliar with the Born-Haber cycle shown in the question and they wrote the equations for the enthalpy changes in the boxes. It was rare to see the arrows in the wrong directions.

Many candidates scored both marks for calculating the first electron affinity of bromine, although many candidates omitted to double one or both of the bromine enthalpy changes, even when they were correct on the cycle.



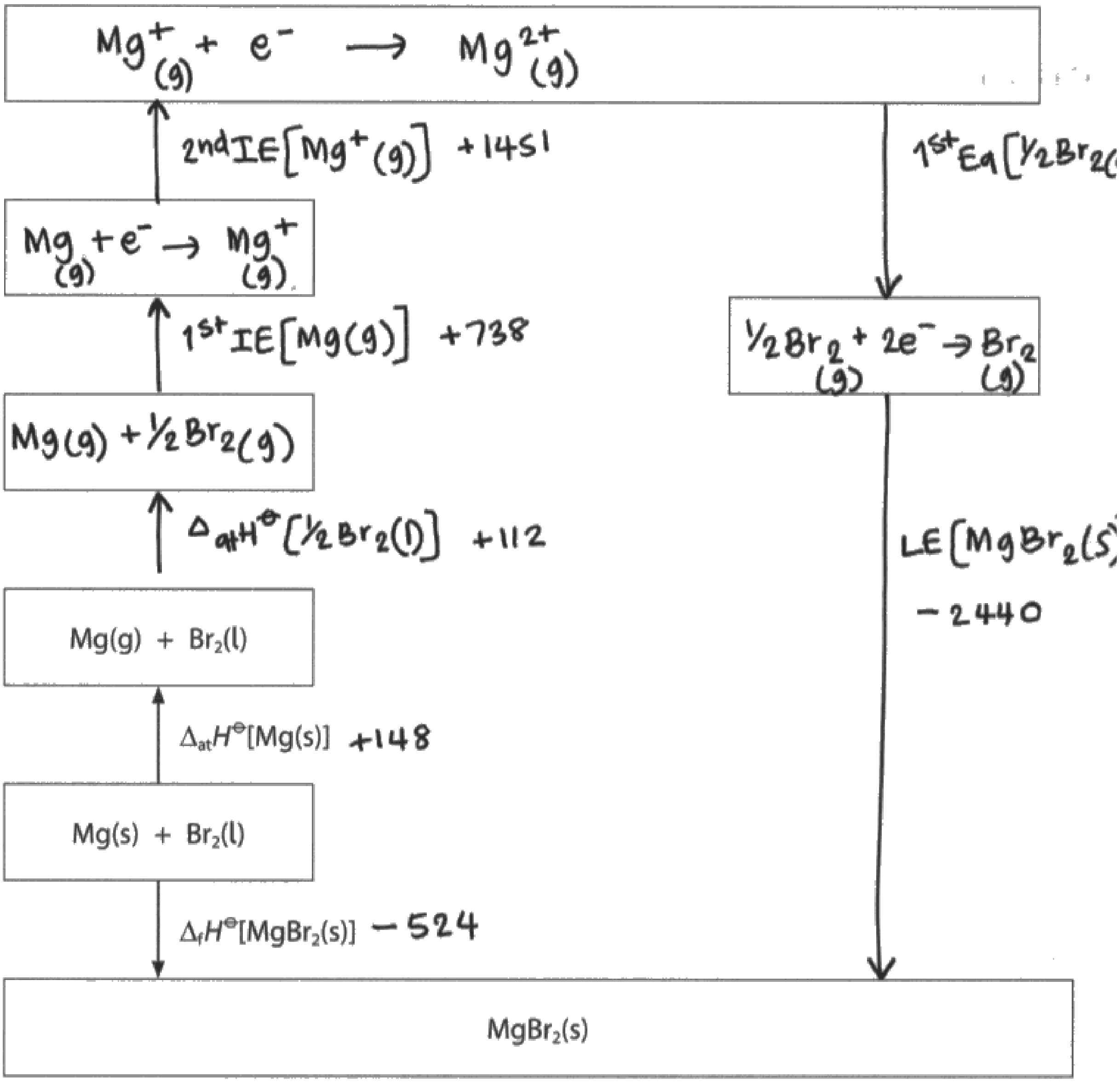
SAf IE F

(b) The table shows the enthalpy changes needed to calculate the first electron affinity of bromine.

	Enthalpy change	Value / kJ mol^{-1}
●	enthalpy change of atomisation of magnesium, $\Delta_{at}H^\ominus$[Mg(s)]	+148
●	1st ionisation energy of magnesium, 1st IE[Mg(g)]	+738
●	2nd ionisation energy of magnesium, 2nd IE[Mg^+(g)]	+1451
●	enthalpy change of atomisation of bromine, $\Delta_{at}H^\ominus$[½Br_2(l)]	+112
●	lattice energy of magnesium bromide, LE[$MgBr_2$(s)]	−2440
●	enthalpy change of formation of magnesium bromide, $\Delta_fH^\ominus$[$MgBr_2$(s)]	−524

(i) Complete the Born-Haber cycle for magnesium bromide with formulae, electrons and labelled arrows. The cycle is not drawn to scale.

(3)



(ii) Calculate the first electron affinity of bromine, in kJ mol^{-1}.

(2)

$+524 + 148 + 112 + 738 + 1451 - 2440 = x$

$533 = x$

533 kJ mol^{-1}

ResultsPlus

Examiner Comments

The only correct arrow and label on this diagram is for the lattice energy. The enthalpy changes for bromine have not been doubled and during atomisation, bromine forms 2Br(g) not 1/2Br_2(g). The ionisation energies of magnesium are acceptable but the bromine species have been omitted from the boxes. The calculation is incorrect as both 2s are missing for the bromine changes and it should have a negative sign. This answer scored 1 mark for (i) and 0 for (ii).

ResultsPlus

Examiner Tip

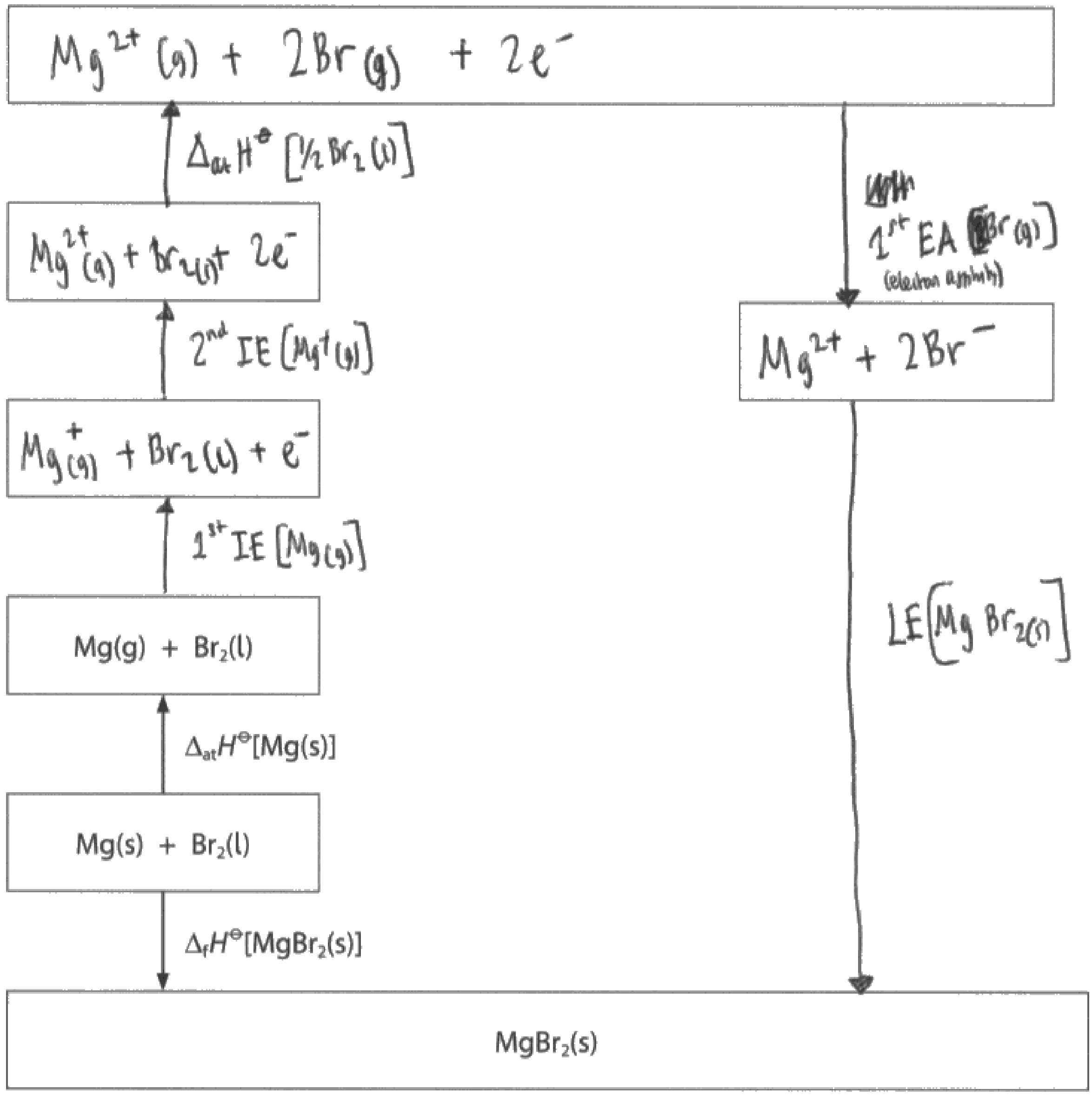
Practice drawing Born-Haber cycles for ionic compounds and use them to calculate the unknown energy change.

(b) The table shows the enthalpy changes needed to calculate the first electron affinity of bromine.

Enthalpy change	Value / kJ mol^{-1}
enthalpy change of atomisation of magnesium, $\Delta_{at}H^{\ominus}$[Mg(s)]	+148
1st ionisation energy of magnesium, 1st IE[Mg(g)]	+738
2nd ionisation energy of magnesium, 2nd IE[Mg^+(g)]	+1 451
enthalpy change of atomisation of bromine, $\Delta_{at}H^{\ominus}$[½Br_2(l)]	+112
lattice energy of magnesium bromide, LE[$MgBr_2$(s)]	−2 440
enthalpy change of formation of magnesium bromide, $\Delta_f H^{\ominus}$[$MgBr_2$(s)]	−524

(i) Complete the Born-Haber cycle for magnesium bromide with formulae, electrons and labelled arrows. The cycle is not drawn to scale.

(3)



(ii) Calculate the first electron affinity of bromine, in kJ mol^{-1}.

(2)

1st EA of bromine = x

$\Delta H_f = \Delta H_1 + \Delta H_{latt}$

$-524 = -2440 + (148 + 738 + 1451 + 2(112) + 2x)$

$-524 = 121 + 2x$

$2x = -645$

$x = -322.5$

1st EA $[Br^-_{(g)}] = -322.5$ kJmol^{-1}

ResultsPlus

Examiner Comments

This Born-Haber cycle scored 1 mark. The candidate has not shown that the enthalpy changes for bromine must be doubled and they have omitted state symbols from the species in the box on the right. The calculation is correct and scored 2 marks.

ResultsPlus

Examiner Tip

Remember to include state symbols by all species in a Born-Haber cycle.

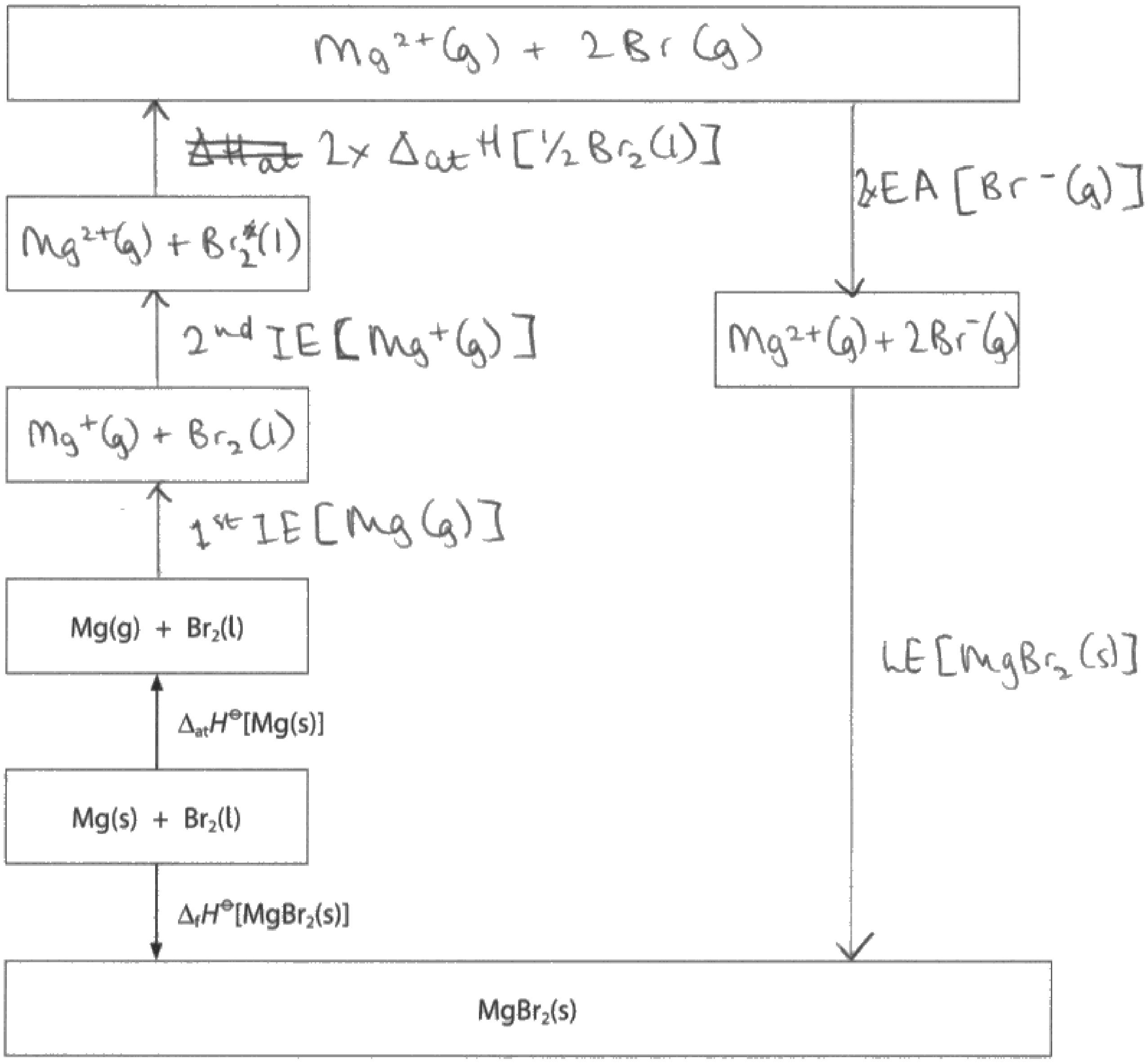
Remember to indicate if any enthalpy changes need to be doubled.

(b) The table shows the enthalpy changes needed to calculate the first electron affinity of bromine.

	Enthalpy change	Value / kJ mol^{-1}
✓	enthalpy change of atomisation of magnesium, $\Delta_{at}H^\ominus$[Mg(s)]	+148
✓	1^{st} ionisation energy of magnesium, 1^{st} IE[Mg(g)]	+738
✓	2^{nd} ionisation energy of magnesium, 2^{nd} IE[Mg^+(g)]	+1 451
	enthalpy change of atomisation of bromine, $\Delta_{at}H^\ominus$[½Br_2(l)]	+112
✓	lattice energy of magnesium bromide, LE[$MgBr_2$(s)]	−2 440
✓	enthalpy change of formation of magnesium bromide, $\Delta_fH^\ominus$[$MgBr_2$(s)]	−524

(i) Complete the Born-Haber cycle for magnesium bromide with formulae, electrons and labelled arrows. The cycle is not drawn to scale.

(3)



(ii) Calculate the first electron affinity of bromine, in kJ mol^{-1}.

(2)

$-2 \times \Delta_{at}H[\frac{1}{2}Br_2] \overset{-}{\cancel{+}} 2^{nd}\ IE \overset{-}{\cancel{+}} 1^{st}\ IE - \Delta H_{at}[Mg]$
$+ \Delta_f H - LE$

$= -2 \times 112 - 1451 - 738 - 148 - 524 + 2440$

$= -645$ kJ mol^{-1}

$EA\ [Br^-(g)] = -322.5$ kJ mol^{-1}

ResultsPlus

Examiner Comments

This is an excellent answer. The candidate has completed the Born-Haber cycle by inserting all the correct species, with state symbols, the arrows are in the right directions and labelled correctly. The calculation is also correct. (i) scored 3 marks and (ii) scored 2 marks.

ResultsPlus

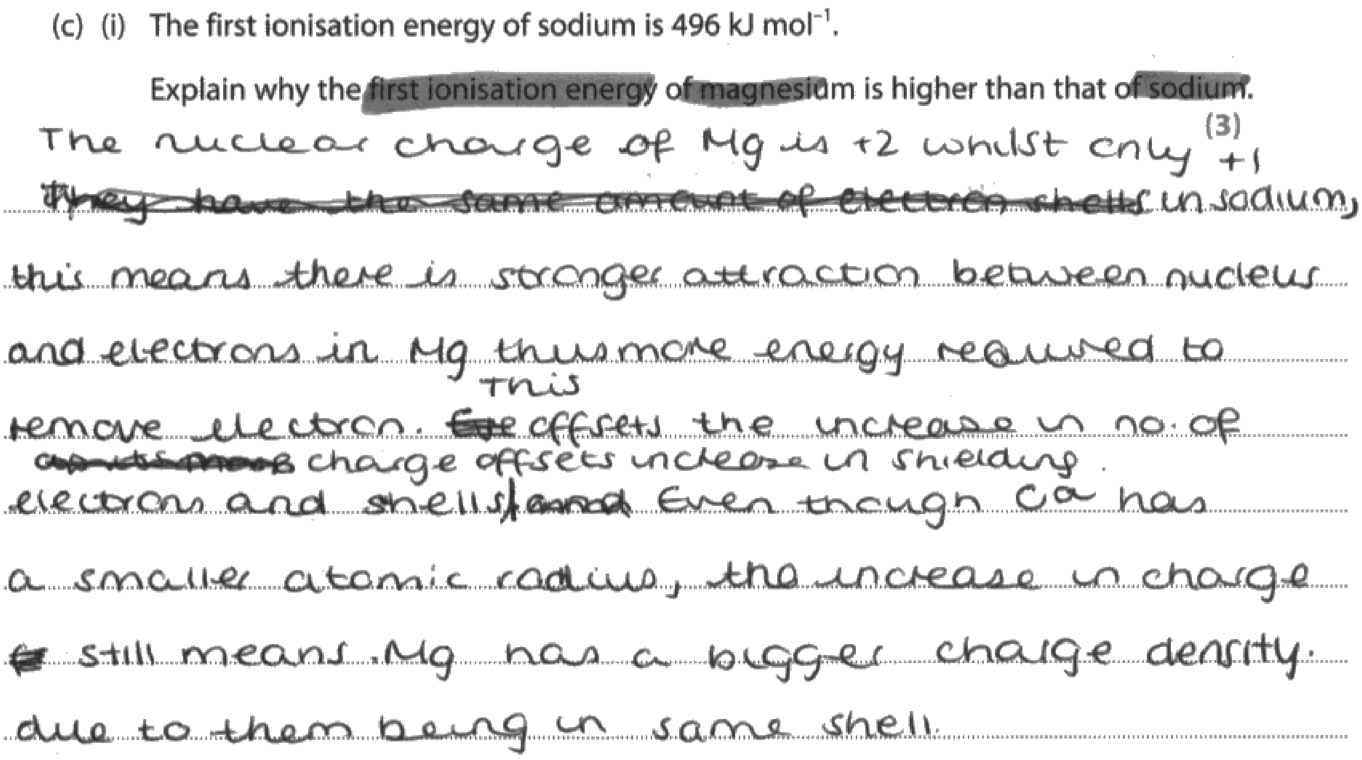
Examiner Tip

Remember to include state symbols by all species in any reactions involving enthalpy changes. Also remember to double any quantities when 2 moles of a substance are needed.

Question 6 (c) (i)

Many candidates scored 3 marks for this question and gave clear explanations about the difference in ionisation energy. Some candidates wrote about the increase in nuclear charge and greater force of attraction between the nucleus and the outer electron but they often omitted to mention that the shielding will be very similar. A significant minority of candidates were confused and wrote about sodium and magnesium ions, thinking that the nuclear charge would be +1 or +2, or they wrote about charge density without understanding what it means.

Candidates could save time and space by not repeating the question in their answer.



(c) (i) The first ionisation energy of sodium is 496 kJ mol^{-1}.

Explain why the first ionisation energy of magnesium is higher than that of sodium.

(3)

The nuclear charge of Mg is +2 whilst only +1
~~They have the same amount of electron shells~~ in sodium,
this means there is stronger attraction between nucleus
and electrons in Mg thus more energy required to
remove electron. ~~[illegible]~~ This offsets the increase in no. of
~~[illegible]~~ charge offsets increase in shielding
electrons and shells ~~and~~ Even though Ca has
a smaller atomic radius, the increase in charge
~~[illegible]~~ still means Mg has a bigger charge density.
due to them being in same shell.

ResultsPlus
Examiner Comments

This answer is quite confused and scored 0. The candidate seems to be writing about ions as they have referred to magnesium with a charge of +2 and sodium with a charge of +1. This incorrect chemistry negates the possible mark for the idea of the stronger attraction between the nucleus and electrons.

ResultsPlus
Examiner Tip

This question is about first ionisation energy. The candidate should be writing about the atoms, not the ions.

(c) (i) The first ionisation energy of sodium is 496 kJ mol^{-1}.

Explain why the first ionisation energy of magnesium is higher than that of sodium.

(3)

~~Magnesium has two electrons in its outer shell whereas Sodium has only one.~~ Magnesium has a more positively charged nucleus than that of Sodium and so a smaller atomic radius than Sodium. Therefore, Mg's first outer electron is closer to its +ve nucleus than that of Sodium so more energy is needed to remove the first outer electron

ResultsPlus

Examiner Comments

This candidate has scored 1 mark for magnesium having a more positively charged nucleus than sodium. There is no mention of shielding or the force of attraction between the nucleus and the outer electron.

ResultsPlus

Examiner Tip

When explaining differences in ionisation energies, you should consider:

nuclear charge

shielding

force of attraction between the nucleus and the electron being removed.

It is acceptable to include a reference to the charge in atomic radius, although that did not score a mark.

(c) (i) The first ionisation energy of sodium is 496 kJ mol^{-1}.

Explain why the first ionisation energy of magnesium is higher than that of sodium.

(3)

→ 1st ionisation energy increases across a period

~~the~~ → nuclear ~~charge~~ attractive force increases because there is an extra proton in the nucleus

→ ~~shin~~ increase in shielding is neglible because still in same energy level

~~m~~ ∴ 1st ionisation energy increases because increase in nuclear attraction outwieghs increase in shielding

ResultsPlus

Examiner Comments

This response scored 2 marks. The extra proton and increase in shielding are worthy of credit. This response almost scored 3 marks. Although the candidate has mentioned the nuclear attractive force, they have not stated what it is attracting. Also, the candidate has not referred to sodium and magnesium but has just given a general trend across the period.

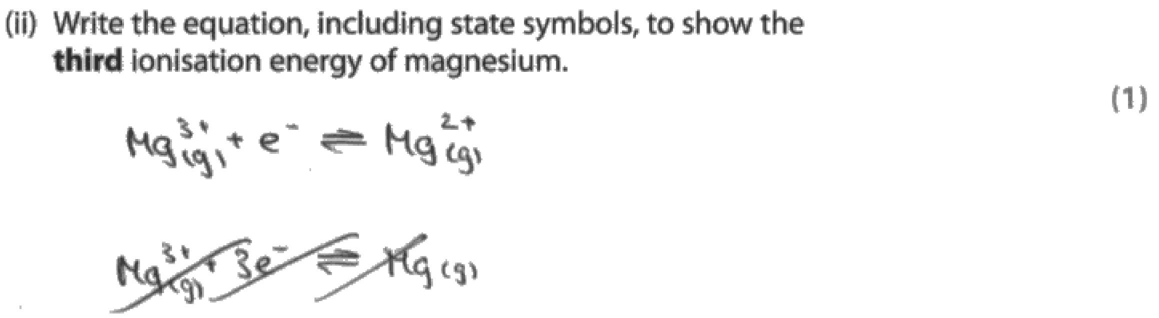
ResultsPlus

Examiner Tip

Check your answer to make sure that it refers to the substances in the question.

Question 6 (c) (ii)

The majority of candidates could write a correct equation to show the third ionisation energy of magnesium. Some lost a mark as they did not include state symbols or showed the incorrect symbols (aq) or (s), while others thought that a magnesium atom would lose three electrons. Some candidates tried to show electron bombardment to produce the Mg^{3+} ion but that is not acceptable in an equation to represent an ionisation energy. A few candidates wrote the electron on the wrong side of the equation.



(ii) Write the equation, including state symbols, to show the **third** ionisation energy of magnesium.

(1)

$Mg^{3+}_{(g)} + e^- \rightleftharpoons Mg^{2+}_{(g)}$

~~$Mg^{3+}_{(g)} + 3e^- \rightleftharpoons Mg_{(g)}$~~

ResultsPlus

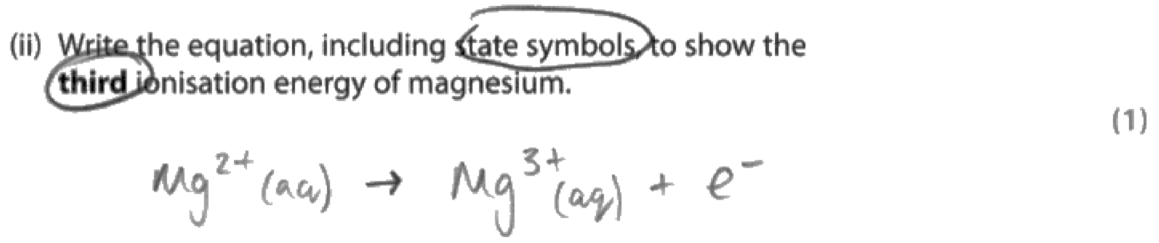
Examiner Comments

This response scored 0 as the equation is written in the reverse direction for the third ionisation energy.

ResultsPlus

Examiner Tip

Write equations in the direction asked for in the question.



(ii) Write the equation, including state symbols, to show the **third** ionisation energy of magnesium.

(1)

$Mg^{2+}(aq) \rightarrow Mg^{3+}(aq) + e^-$

ResultsPlus

Examiner Comments

This equation is correct but the state symbols are incorrect, so this response scored 0.

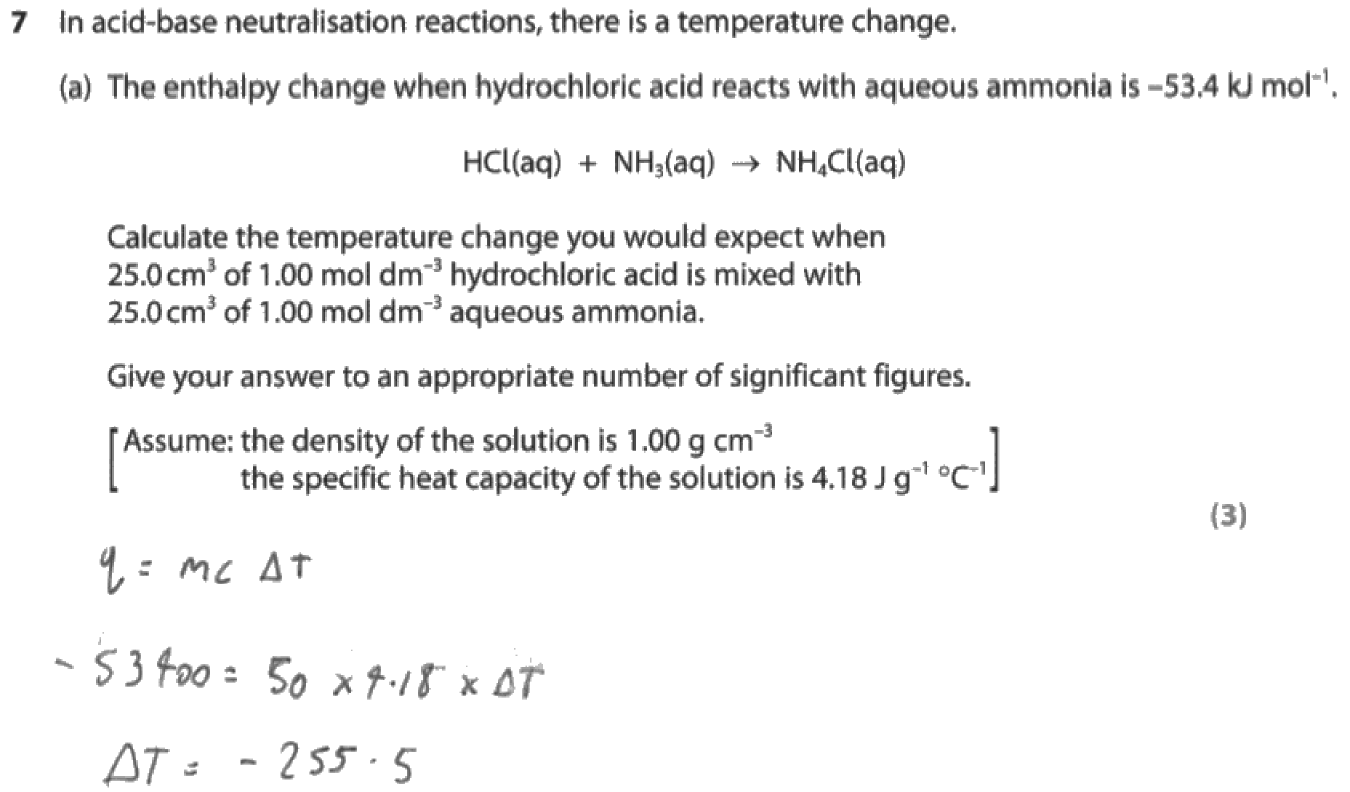
ResultsPlus

Examiner Tip

Ionisation energies always refer to species in the gaseous state.

Question 7 (a)

Many candidates scored 3 marks for this calculation. They should have given their final answer to 2 significant figures as school laboratory thermometers cannot measure more accurately than that, however, we did allow 3 significant figures on this occasion. Some candidates added the moles of acid and alkali together so their final answer was twice as large as it should be. Some candidates ignored the number of moles and calculated a temperature change of 256°C. Those candidates should realise that is an unrealistic temperature rise so should go back and check to see where they have made a mistake. Some candidates showed a fall in temperature, even though the reaction is exothermic.



7 In acid-base neutralisation reactions, there is a temperature change.

(a) The enthalpy change when hydrochloric acid reacts with aqueous ammonia is –53.4 kJ mol^{-1}.

$$HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(aq)$$

Calculate the temperature change you would expect when 25.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid is mixed with 25.0 cm^3 of 1.00 mol dm^{-3} aqueous ammonia.

Give your answer to an appropriate number of significant figures.

[Assume: the density of the solution is 1.00 g cm^{-3}
the specific heat capacity of the solution is 4.18 J g^{-1} °C^{-1}]

(3)

$q = mc\,\Delta T$

$-53400 = 50 \times 4.18 \times \Delta T$

$\Delta T = -255.5$

ResultsPlus

Examiner Comments

This response scored 0. The candidate does know the correct formula to use for the calculation and has converted kJ to J, however a temperature fall of 255°C is impossible.

ResultsPlus

Examiner Tip

Think about your final answer. If it does not make sense, check your working to see where you have gone wrong.

7 In acid-base neutralisation reactions, there is a temperature change.

(a) The enthalpy change when hydrochloric acid reacts with aqueous ammonia is –53.4 kJ mol^{-1}.

$$HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(aq)$$

Calculate the temperature change you would expect when 25.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid is mixed with 25.0 cm^3 of 1.00 mol dm^{-3} aqueous ammonia.

$Q = MC\Delta T$

Give your answer to an appropriate number of significant figures.

[Assume: the density of the solution is 1.00 g cm^{-3}
the specific heat capacity of the solution is 4.18 J g^{-1} °C^{-1}]

(3)

$10^3(-53.4) = 50 \times 4.18 \times (\Delta T)$

~~na~~ $n\ HCl = \frac{25}{1000} \times 1 = 0.025 mol$

$n\ NH_3 = \frac{25}{1000} \times 1 = 0.025 mol$

$\therefore \Delta T = \frac{10^3(-53.4)}{50 \times 4.18}$

$= -255.5023923k$

$\Delta T = -256 k \ (3 sf)$

ResultsPlus
Examiner Comments

This candidate has calculated an unrealistic temperature fall. However, they have also calculated the number of moles of acid used so scored 1 mark.

ResultsPlus
Examiner Tip

Use all the data given in the question. If you are given the volume and concentration of a solution, you can calculate the number of moles of solute.

7 In acid-base neutralisation reactions, there is a temperature change.

(a) The enthalpy change when hydrochloric acid reacts with aqueous ammonia is –53.4 kJ mol^{-1}.

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Give your answer to an appropriate number of significant figures.

[Assume: the density of the solution is 1.00 g cm^{-3}
the specific heat capacity of the solution is 4.18 J g^{-1} °C^{-1}]

(3)

$Q = mc\Delta t$

~~$Q = mc\Delta t$~~ $\Delta H = \frac{-Q}{\text{mol}}$

mol of HCl & NH_3 $= \frac{25}{1000} \times 1 = 0.025$

total moles in solution $= 0.05$

$\Delta H = \frac{-Q}{\text{mol}}$

$-(-53400 \times 0.05) = Q$

$Q = 2670 \text{ J}$

$\Delta t = \frac{Q}{mc}$

* density = $\frac{\text{mass}}{\text{volume}}$

* mass of solution = density × volume

$= 1 \times \frac{50}{\cancel{78}}$

$= 50\text{g}$

$\Delta t = \frac{2670}{50 \times 4.18} = 12.8°\text{C}$

ResultsPlus

Examiner Comments

This candidate has calculated the number of moles of acid and alkali but has then added them together, which is incorrect. The rest of the calculation is consequentially correct, so 2 marks were awarded.

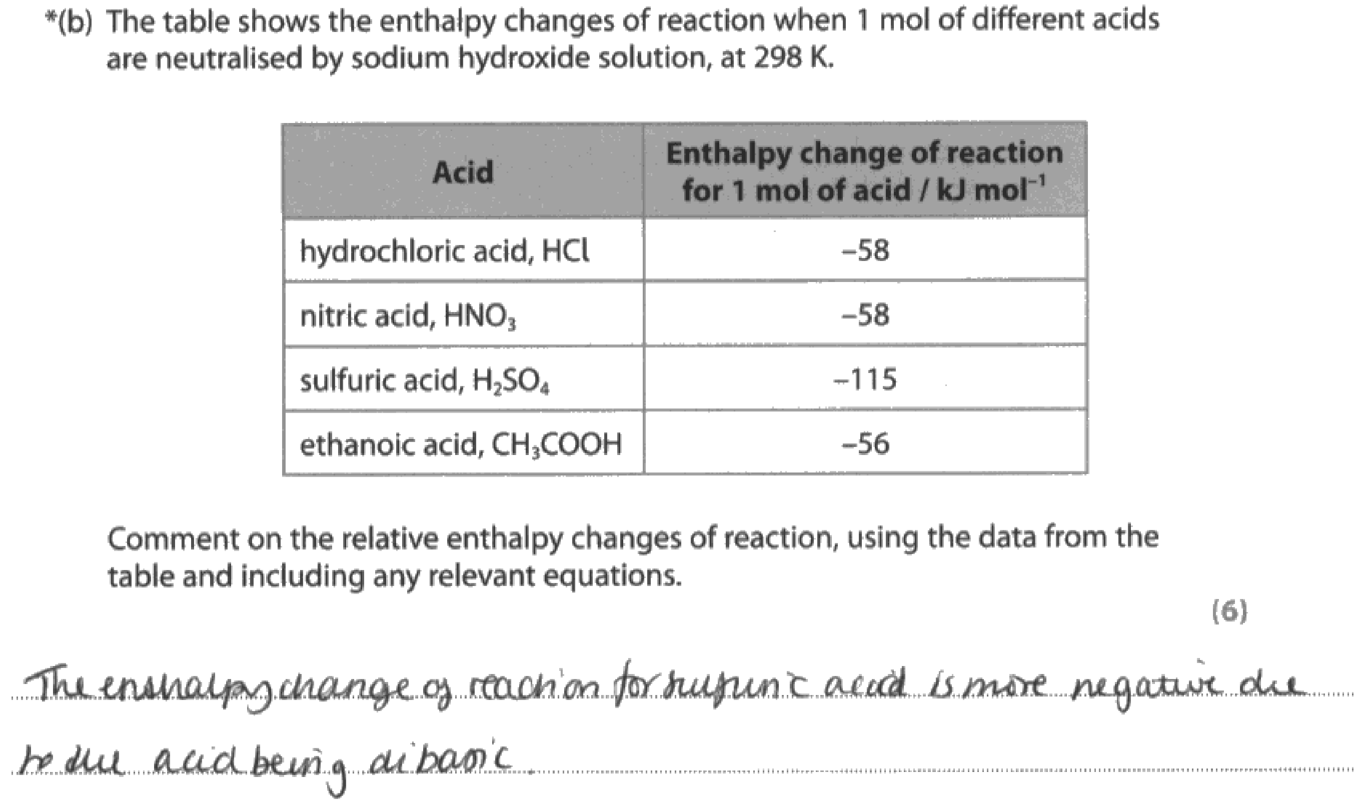
ResultsPlus

Examiner Tip

Always show your working for calculations so that if you make a mistake, you can still be given some of the marks.

Question 7 (b)

This is the first of the new 6-mark questions at A level that have marks available for the structure of the answer and lines of reasoning. Candidates generally performed very well on this question. There were many answers with full marks. Those scoring 5 marks usually did not state that some energy is needed to dissociate ethanoic acid or they did not include an equation for one of the reactions. Some candidates thought that nitric acid was also a weak acid and that weak acids do not fully dissociate so they do not react with as much sodium hydroxide. A few candidates thought that energy is required for neutralisation and others thought that ethanoic acid is the strongest acid as -56 is greater than -115.



*(b) The table shows the enthalpy changes of reaction when 1 mol of different acids are neutralised by sodium hydroxide solution, at 298 K.

Acid	Enthalpy change of reaction for 1 mol of acid / kJ mol^{-1}
hydrochloric acid, HCl	–58
nitric acid, HNO_3	–58
sulfuric acid, H_2SO_4	–115
ethanoic acid, CH_3COOH	–56

Comment on the relative enthalpy changes of reaction, using the data from the table and including any relevant equations.

(6)

The enthalpy change of reaction for sulfuric acid is more negative due to due acid being dibasic.

ResultsPlus

Examiner Comments

This answer scored 1 mark for sulfuric acid is dibasic.

ResultsPlus

Examiner Tip

6-mark questions that have an asterisk (*) next to them have marks available for your ability to structure your answer logically showing the points that you make are related or follow on from each other. There are 2 marks available for this but if you only write one statement, you will not gain either of these marks.

You should aim to write in detail for these questions. This question gave you data for four acids so your answer should include all of them.

*(b) The table shows the enthalpy changes of reaction when 1 mol of different acids are neutralised by sodium hydroxide solution, at 298 K.

Acid	Enthalpy change of reaction for 1 mol of acid / kJ mol^{-1}
hydrochloric acid, HCl	–58
nitric acid, HNO_3	–58
sulfuric acid, H_2SO_4	–115
ethanoic acid, CH_3COOH	–56

Comment on the relative enthalpy changes of reaction, using the data from the table and including any relevant equations.

(6)

- The ~~Largest~~ Most exothermic enthalpy change is when $H_2SO_4(aq)$ is neutralised : $H_2SO_4 + NaOH \rightarrow NaHSO_4 + H_2O$ This is because the New bonds forming are very exothermic compared to those breaking.
- In hydrochloric acid & nitric acid the enthalpy change is less exothermic, ~~this is~~ than in sulfuric acid because the energy relased from the formation of the new bonds is less than in the reaction with $H_2SO_4(aq)$. The ~~most~~ neutralisations with $HCl(aq)$ & $HNO_3(aq)$ are very similar :

$HCl + NaOH \rightarrow H_2O + NaCl$

~~HCl +~~ $HNO_3 + NaOH \rightarrow H_2O + NaNO_3$

this causes them to both have an enthalpy change of -58kJ mol^{-1}.

- Lastly, ethanoic acid is the weakest acid & reacts least with NaOH so has smallest enthalpy change : $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$.

ResultsPlus

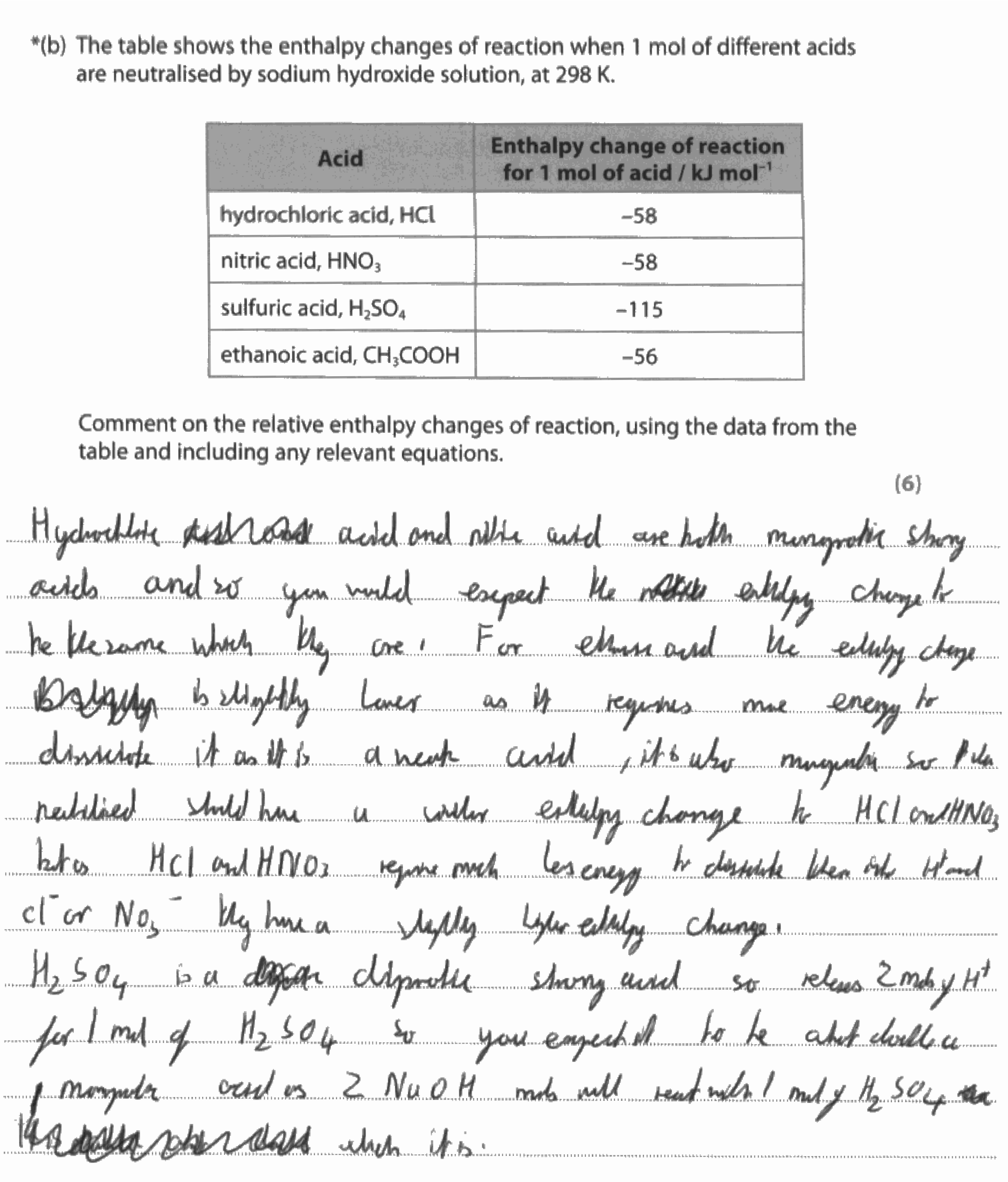
Examiner Comments

This response scored 2 marks. Although the candidate has filled the page, there is little that is worthy of credit. The equations for the reactions of hydrochloric acid and nitric acid with sodium hydroxide are correct as is the statement that ethanoic acid is a weak acid.

ResultsPlus

Examiner Tip

Try to give more specific information. For example, in this answer there is no mention of sulfuric acid as a dibasic / diprotic acid and hydrochloric acid and nitric acid having the same value as they are strong acids.



*(b) The table shows the enthalpy changes of reaction when 1 mol of different acids are neutralised by sodium hydroxide solution, at 298 K.

Acid	Enthalpy change of reaction for 1 mol of acid / kJ mol^{-1}
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nitric acid, HNO_3	−58
sulfuric acid, H_2SO_4	−115
ethanoic acid, CH_3COOH	−56

Comment on the relative enthalpy changes of reaction, using the data from the table and including any relevant equations.

(6)

Hydrochloric [illegible] acid and nitric acid are both monoprotic strong acids and so you would expect the [illegible] enthalpy change to be the same which they are. For ethanoic acid the enthalpy change [illegible] is slightly lower as it requires more energy to dissociate it as it is a weak acid, it's also monoprotic so when neutralised should have a similar enthalpy change to HCl and HNO_3 but as HCl and HNO_3 require much less energy to dissociate then the H^+ and Cl^- or NO_3^- they have a slightly higher enthalpy change.

H_2SO_4 is a [illegible] diprotic strong acid so releases 2 moles of H^+ for 1 mol of H_2SO_4 so you expect it to be about double a monoprotic acid as 2 NaOH mols will react with 1 mol of H_2SO_4 [illegible] which it is.

ResultsPlus

Examiner Comments

This is a very good answer that includes all the indicative points from the mark scheme. However, it was only awarded 5 marks as there are no equations.

ResultsPlus

Examiner Tip

Read the question carefully. If you are told to include equations, you cannot score full marks if you omit them.

*(b) The table shows the enthalpy changes of reaction when 1 mol of different acids are neutralised by sodium hydroxide solution, at 298 K.

Acid	Enthalpy change of reaction for 1 mol of acid / kJ mol^{-1}
hydrochloric acid, HCl	–58
nitric acid, HNO_3	–58
sulfuric acid, H_2SO_4	–115
ethanoic acid, CH_3COOH	–56

Comment on the relative enthalpy changes of reaction, using the data from the table and including any relevant equations.

(6)

HCl and HNO_3 are both strong, monoprotic acids : (they fully dissociate)

$HCl + NaOH \rightarrow NaCl + H_2O$

$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$. This means they have the exact same enthalpy change of reaction. Sulfuric acid is a diprotic acid, the first [illegible] dissociates fully ($H_2SO_4 \rightarrow H^+ + HSO_4^-$) but the second [illegible] does not dissociate, fully, so is a weak acid ($HSO_4^- \rightleftharpoons H^+ + SO_4^{2-}$). Since there are two hydrogen ions per molecule for H_2SO_4, ~~when~~ it requires twice as much NaOH and so the enthalpy change of reaction is approximately double that of HCl ($2 \times -58 = -116$).

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$. Ethanoic acid is a weak acid that does not fully dissociate. This means the value is less exothermic, because energy is absorbed in order to dissociate the molecules in order for the reaction to occur. $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

ResultsPlus

Examiner Comments

This is an example of an excellent answer that was awarded 6 marks.

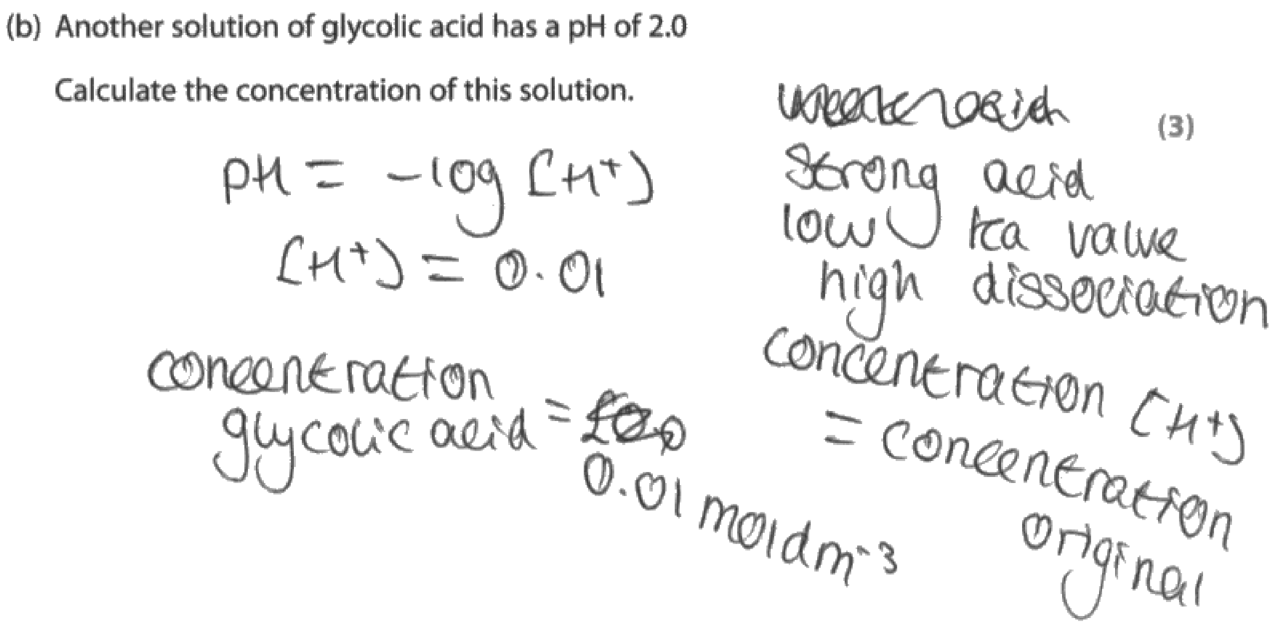
ResultsPlus

Examiner Tip

Try to structure your answers to this style of question in a similar way. You need to make sure that you refer to all the data in the question, include everything you are asked for, such as equations, and structure your answer in a logical way.

Question 8 (b)

The majority of candidates scored full marks for this calculation. Some candidates thought that glycolic acid is a strong acid so they did not attempt to use K_a. A few candidates got the expression the wrong way round and a small number rounded their final answer to 1 significant figure or rounded it incorrectly.



(b) Another solution of glycolic acid has a pH of 2.0

Calculate the concentration of this solution.

(3)

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

$[H^+] = 0.01$

concentration glycolic acid = 0.01 moldm^{-3}

~~weak acid~~

Strong acid

low Ka value

high dissociation

concentration [H+] = concentration original

ResultsPlus

Examiner Comments

This answer scored 1 mark for calculating the concentration of H^+ ions from the pH. However, glycolic acid is a weak acid so the concentration of glycolic acid is less than this and you need to use K_a to calculate it.

ResultsPlus

Examiner Tip

Revise how to calculate the pH of a weak acid of known concentration. Then try to reverse this calculation to find the concentration of the acid when you are given the pH.

(b) Another solution of glycolic acid has a pH of 2.0

Calculate the concentration of this solution.

(3)

$[H^+] = 10^{-2}$

$[H^+] = 0.01$

$Ka = \frac{[H^+]^2}{[HA]}$

a $[HA] = \frac{0.01^2}{1.5 \times 10^{-4}}$

$[HA] =$ [illegible] 0.7 mol dm^{-3}

ResultsPlus

Examiner Comments

This candidate has carried out a correct calculation. However, they have only been awarded 2 marks as they have rounded their final answer to 1 significant figure.

ResultsPlus

Examiner Tip

The data has been given to 2 significant figures so you should give your answer to 2 significant figures.

(b) Another solution of glycolic acid has a pH of 2.0

Calculate the concentration of this solution.

(3)

$$K_a = \frac{[H^+][A^-]}{[HA]} \Rightarrow K_a = \frac{[H^+]^2}{[HA]}$$

$$[H^+] = 10^{-pH} \Rightarrow [H^+] = 10^{-2} \Rightarrow 0.01 \text{ mol dm}^{-3}$$

$$[HA] = \frac{[H^+]^2}{\cancel{o}\, K_a} \Rightarrow \frac{0.01}{1.5 \times 10^{-4}} = 66.6 \text{ mol dm}^{-3}$$

$$\Rightarrow 66.7 \text{ mol dm}^{-3}$$

ResultsPlus

Examiner Comments

This response scored 2 marks. The candidate has correctly calculated the concentration of H^+ ions and given the correct expression to determine the concentration of glycolic acid. However, although they have shown $[H^+]^2$ in the expression, they have not squared the value.

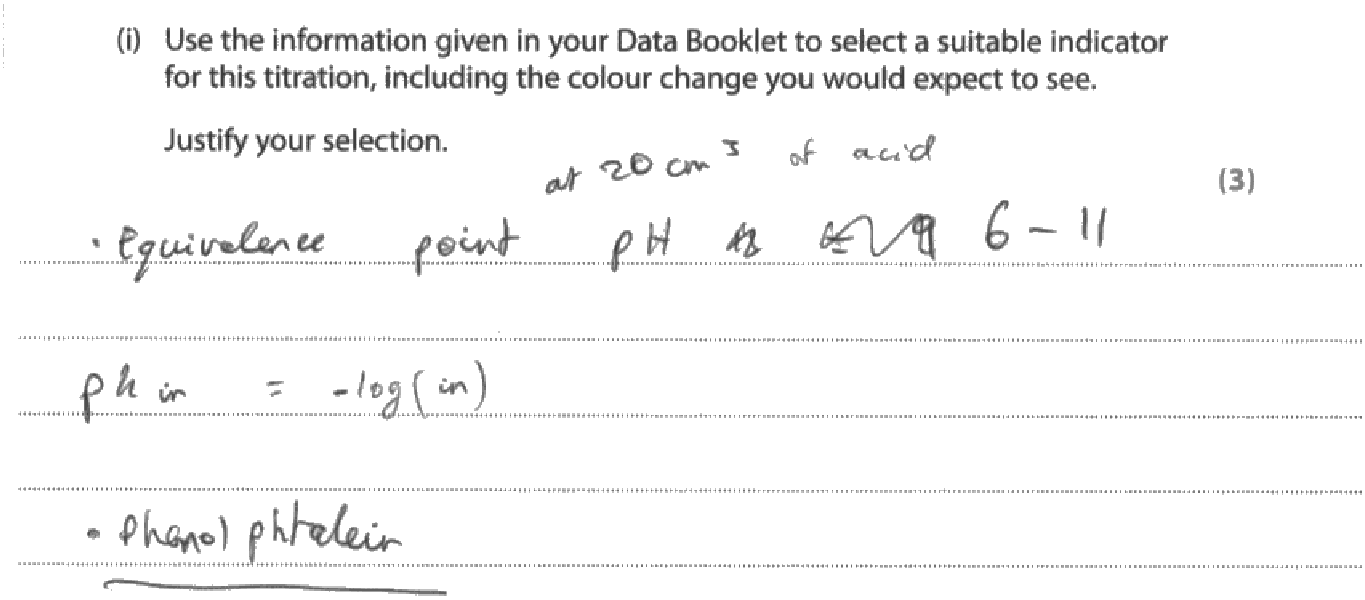
ResultsPlus

Examiner Tip

66.7 mol dm^{-3} is an extremely high concentration so check your working to see where you have made a mistake.

Question 8 (c) (i)

The majority of candidates scored 3 marks for this question. Some did not give a clear enough justification for their choice of indicator and some omitted the colour change or gave it the wrong way around. Very few candidates selected an unsuitable indicator.



(i) Use the information given in your Data Booklet to select a suitable indicator for this titration, including the colour change you would expect to see.

Justify your selection.

(3)

at 20 cm^3 of acid

· Equivalence point pH ~~is~~ ~~[illegible]~~ 6 – 11

$ph_{in} = -\log(in)$

· Phenol phtalein

ResultsPlus

Examiner Comments

This candidate has selected a suitable indicator. They have stated the pH range from the vertical section of the graph but have not used it to explain why this indicator is suitable. They have also not given the colour change of the indicator. This answer scored 1 mark.

ResultsPlus

Examiner Tip

When you are asked to justify something you have selected, you should do so in much more detail than this candidate.

(i) Use the information given in your Data Booklet to select a suitable indicator for this titration, including the colour change you would expect to see.

Justify your selection.

(3)

I would use phenolphalein (in ethanol), as the pH in the graph changes between 6 and 10 and the pH range for this indicator is 8.2 - 10. This means that the colour change will happen at the appropriate point.

ResultsPlus

Examiner Comments

This candidate has selected a suitable indicator and given a reason for their choice. However, they have not stated the colour change at the end point. This response scored 2 marks.

ResultsPlus

Examiner Tip

Check to make sure that you have included everything you have been asked for.

(i) Use the information given in your Data Booklet to select a suitable indicator for this titration, including the colour change you would expect to see.

Justify your selection.

(3)

Weak acid strong base. Vertical section is between 10.8 and 6.0 so a suitable indicator is phenolphthalein as its pH range is 8.2-10.0 which is fully within the vertical section. The colour change will be red to colourless.

ResultsPlus

Examiner Comments

This is an example of an excellent answer that scored 3 marks. The candidate has selected a suitable indicator, given a clear reason for their choice and stated the colour change.

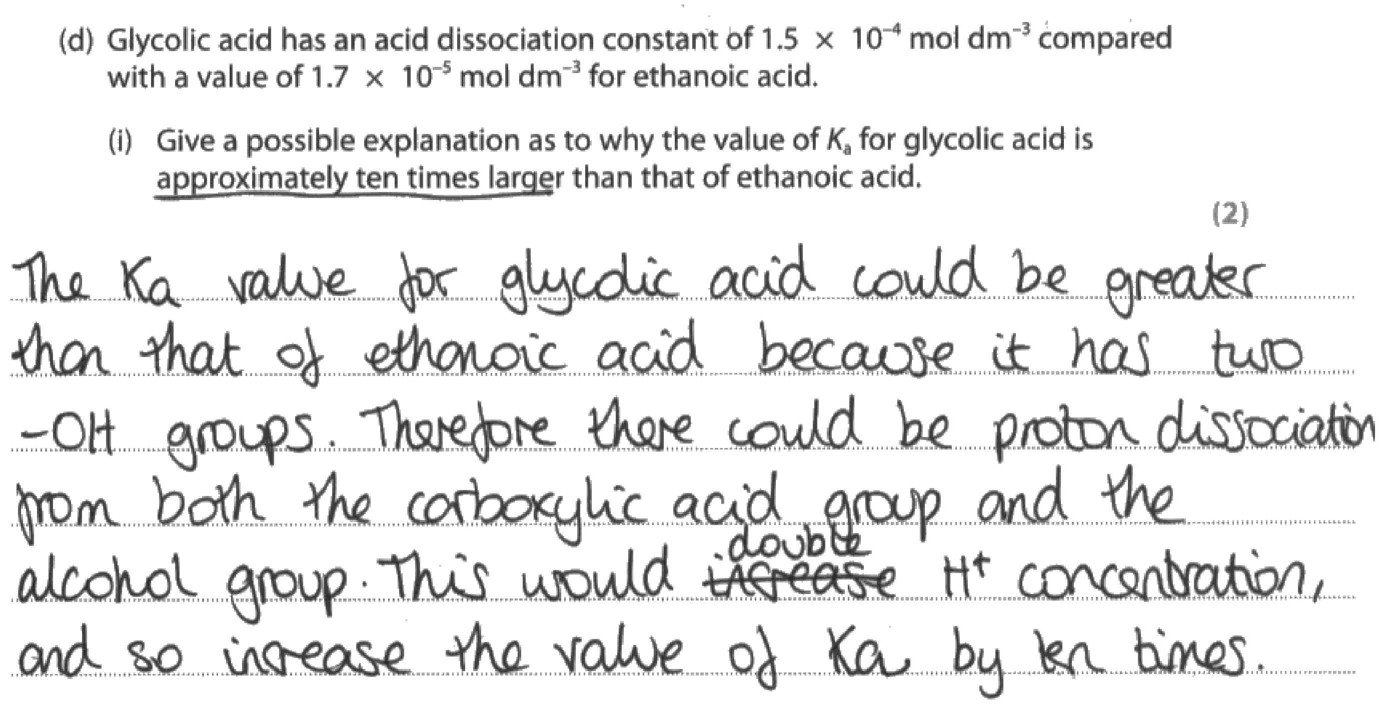
ResultsPlus

Examiner Tip

Try to structure you answers in a clear and concise way, as in this example.

Question 8 (d) (i)

This was the most difficult question on the paper and it was intended to challenge the candidates at the top of the ability range. Candidates were not expected to know the answer but to apply their knowledge and understanding. It was encouraging to see some excellent answers in terms of the extra oxygen atom withdrawing electrons from the O-H bond, the O-H bond being weaker, the anion being stabilised or the possibility of intramolecular hydrogen bonding. The most common incorrect answer was stating that glycolic acid is dibasic.



(d) Glycolic acid has an acid dissociation constant of 1.5 × 10^{-4} mol dm^{-3} compared with a value of 1.7 × 10^{-5} mol dm^{-3} for ethanoic acid.

(i) Give a possible explanation as to why the value of K_a for glycolic acid is approximately ten times larger than that of ethanoic acid.

(2)

The Ka value for glycolic acid could be greater than that of ethanoic acid because it has two -OH groups. Therefore there could be proton dissociation from both the carboxylic acid group and the alcohol group. This would ~~increase~~ double H^+ concentration, and so increase the value of Ka by ten times.

ResultsPlus

Examiner Comments

This is a common incorrect answer that scored 0.

ResultsPlus

Examiner Tip

There are two OH groups but only the one as part of the carboxylic acid group will dissociate in water. You need to think of a reason why the H^+ ion dissociates more readily from glycolic acid than ethanoic acid.

(d) Glycolic acid has an acid dissociation constant of 1.5 × 10^{-4} mol dm^{-3} compared with a value of 1.7 × 10^{-5} mol dm^{-3} for ethanoic acid.

(i) Give a possible explanation as to why the value of K_a for glycolic acid is approximately ten times larger than that of ethanoic acid.

(2)

This is down to the extra OH group on the Glycolic acid. This oxygen is electronegative and therefore would cause a increased dipole with the δ^+ Hydrogen. Which would increase the readiness to donate that hydrogen as it has a weaker bond so is lost easier.

ResultsPlus
Examiner Comments

This is a good answer that scored 1 mark. The candidate just needed to explain the effect of the electronegative oxygen atom i.e. that it withdraws electrons from the O-H bond, then it would have scored 2 marks.

ResultsPlus
Examiner Tip

Compare the structures of ethanoic acid and glycolic acid. The main difference is the extra oxygen atom as part of the OH group on glycolic acid, so this gives you a clue about where to start your explanation.

(d) Glycolic acid has an acid dissociation constant of 1.5 × 10^{-4} mol dm^{-3} compared with a value of 1.7 × 10^{-5} mol dm^{-3} for ethanoic acid.

(i) Give a possible explanation as to why the value of K_a for glycolic acid is approximately ten times larger than that of ethanoic acid.

(2)

Due to glycolic acid having an OH group attached to a carbon on the alkyl group, the very electronegative oxygen atom will withdraw e^- from the carboxylic acid group & counteract any alkyl inductive effect. This makes the region surrounding COOH less negative ∴ the carboxylate ion is more likely to as it is more stable ∴ H^+ will dissociate more readily & equilibrium constant shows this. CH_3COOH is weaker acid bc alkyl electron pushing effect makes ion less likely to form ∴ K_a is smaller as the acid is weaker.

ResultsPlus

Examiner Comments

This is an excellent answer that scored 2 marks.

ResultsPlus

Examiner Tip

We would not expect all candidates to be able to give an answer like this, but one of the ideas from here, such as the oxygen atom withdrawing electrons or that the anion would be more stable, is something to consider in the future.

Question 8 (d) (ii)

(ii) Complete the equation to show the conjugate acid-base pairs that would be produced when pure samples of glycolic acid and ethanoic acid are mixed.

(1)

$CH_2OHCOOH + CH_3COOH \rightarrow$ $CH_2OH\,COOH^+$ + CH_3COO^-

acid base

ResultsPlus

Examiner Comments

This response scored 0 as the candidate did not realise that glycolic acid is a stronger acid than ethanoic acid so it will donate its proton.

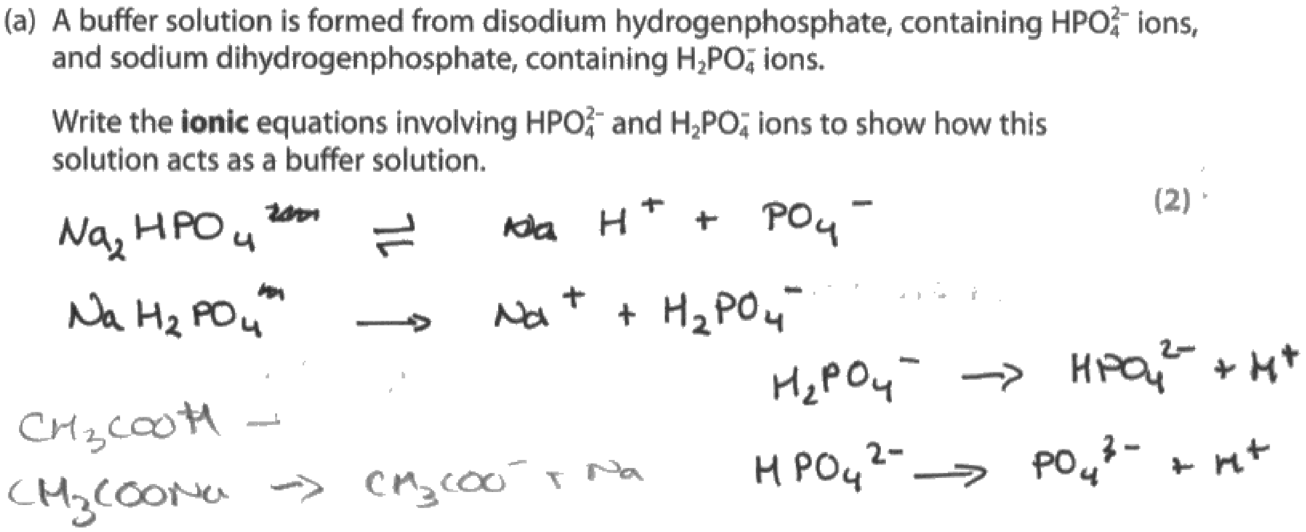
ResultsPlus

Examiner Tip

Remember that the larger the K_a value, the stronger the acid.

Question 9 (a)

Candidates did not find it easy to write two ionic equations to show the mixture of disodium hydrogenphosphate and sodium dihydrogenphosphate acts as a buffer solution. They should have written one equation where one of the ions reacts with H^+ ions and another where the other ion reacts with OH^- ion. Many equations were seen that did not include H^+ and OH^- as reactants. Some candidates lost marks by copying the formulae of the ions incorrectly from the question and some attempted to write non-ionic equations.



(a) A buffer solution is formed from disodium hydrogenphosphate, containing HPO_4^{2-} ions, and sodium dihydrogenphosphate, containing $H_2PO_4^-$ ions.

Write the **ionic** equations involving HPO_4^{2-} and $H_2PO_4^-$ ions to show how this solution acts as a buffer solution.

(2)

$Na_2HPO_4 \rightleftharpoons Na\ H^+ + PO_4^-$

$NaH_2PO_4 \longrightarrow Na^+ + H_2PO_4^-$

$H_2PO_4^- \longrightarrow HPO_4^{2-} + H^+$

$CH_3COOH \rightarrow$

$CH_3COONa \rightarrow CH_3COO^- + Na$

$HPO_4^{2-} \longrightarrow PO_4^{3-} + H^+$

ResultsPlus

Examiner Comments

This candidate has attempted to write equations to show how the sodium salts split up into ions, although this was not necessary as the formulae of the ions are given in the question. Also, the first equation is incorrect. They have then shown how those ions dissociate to release H^+ ions. This scored 0 as they have not written equations to show how the mixture in the question can act as a buffer solution.

ResultsPlus

Examiner Tip

A buffer solution contains large amounts of a weak acid and its conjugate base. The acid reacts with OH^- ions and the base reacts with H^+ ions.

(a) A buffer solution is formed from disodium hydrogenphosphate, containing HPO_4^{2-} ions, and sodium dihydrogenphosphate, containing $H_2PO_4^-$ ions.

Write the **ionic** equations involving HPO_4^{2-} and $H_2PO_4^-$ ions to show how this solution acts as a buffer solution.

(2)

$$H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_2O$$

$$HPO_4^{2-} + H^+ \rightarrow H_2PO_4^{2-}$$

ResultsPlus

Examiner Comments

The first equation is correct but the second equation is not balanced so this response scored 1 mark.

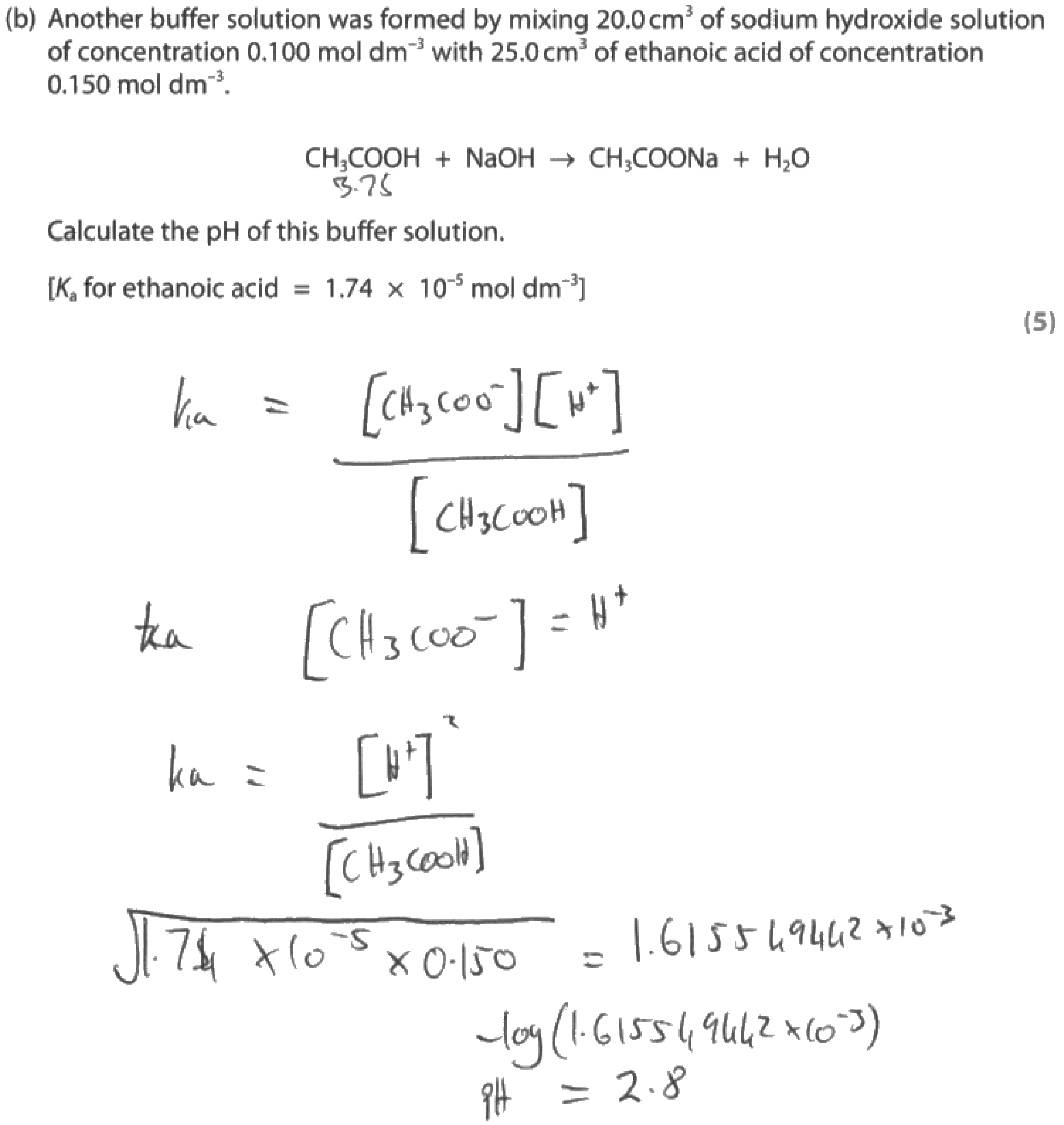
ResultsPlus

Examiner Tip

Check that ionic equations are balanced in terms of charges as well as atoms.

Question 9 (b)

Although many excellent answers scoring 5 marks were seen, many candidates seemed unfamiliar with this style of calculation for the pH of a buffer solution. It was intended to be a demanding calculation as the candidates had to work out that the sodium hydroxide solution would react with some of the ethanoic acid to form the salt and there would be some ethanoic acid left in excess. A common incorrect answer was pH 4.49 as candidates did not use a subtraction to work out the amount of ethanoic acid left over, however, those candidates still scored 4 marks. Some candidates just worked out the pH of ethanoic acid and a significant number assumed that $K_a = [H^+]^2/[HA]$. Many candidates would benefit from more practice at buffer solution calculations.



(b) Another buffer solution was formed by mixing 20.0 cm^3 of sodium hydroxide solution of concentration 0.100 mol dm^{-3} with 25.0 cm^3 of ethanoic acid of concentration 0.150 mol dm^{-3}.

$$\underset{3.75}{CH_3COOH} + NaOH \rightarrow CH_3COONa + H_2O$$

Calculate the pH of this buffer solution.

[K_a for ethanoic acid = 1.74×10^{-5} mol dm^{-3}]

(5)

$$ka = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

$$ka \quad [CH_3COO^-] = H^+$$

$$ka = \frac{[H^+]^2}{[CH_3COOH]}$$

$$\sqrt{1.74 \times 10^{-5} \times 0.150} = 1.615549442 \times 10^{-3}$$

$$-\log(1.615549442 \times 10^{-3})$$

$$pH = 2.8$$

ResultsPlus

Examiner Comments

This candidate has not used the information given in the question and has calculated the pH of the ethanoic acid solution. This answer scored 1 mark for calculating the pH from [H$^+$].

ResultsPlus

Examiner Tip

Revise how to calculate the pH of a buffer solution.

(b) Another buffer solution was formed by mixing 20.0 cm³ of sodium hydroxide solution of concentration 0.100 mol dm⁻³ with 25.0 cm³ of ethanoic acid of concentration 0.150 mol dm⁻³.

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

Calculate the pH of this buffer solution.

[K_a for ethanoic acid = 1.74×10^{-5} mol dm^{-3}]

(5)

$$ka = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

2×10^{-3} mol OH^- in 20cm³

3.75×10^{-3} mol acid in 25cm³

45 total

45

Salt = 0.0444

acid = 0.08333

$1.74\times10^{-5} = 0.53\,[H^+]$

3.26×10^{-5}

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

4.486

pH = $\underline{4.49}$

ResultsPlus

Examiner Comments

This is an example of a common answer that scored 4 marks. The candidate has worked out the initial numbers of moles of ethanoic acid and ethanoate ions. However, they have not realised that some of the ethanoic acid will have reacted with the sodium hydroxide solution so they have to do a subtraction to work out the moles of ethanoic acid left.

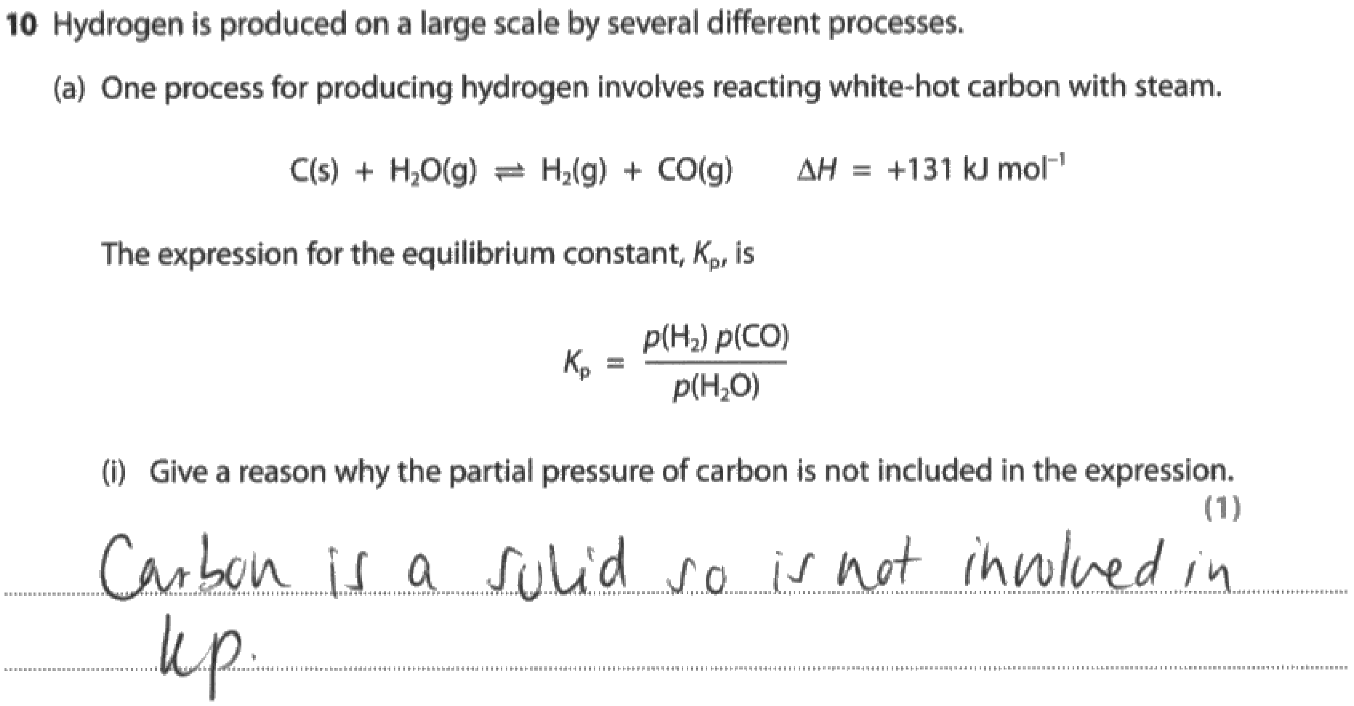
ResultsPlus

Examiner Tip

Practise calculations where a buffer solution is produced by adding a strong alkali to a weak acid.

Question 10 (a) (i)

It was disappointing that many candidates just wrote short answers such as 'carbon is a solid' or 'carbon is not a gas'. The question asks about the partial pressure of carbon so the answer should refer to that. A small number of candidates had the right idea but they referred to carbon having a constant concentration instead of a constant partial pressure so they did not score a mark.



10 Hydrogen is produced on a large scale by several different processes.

(a) One process for producing hydrogen involves reacting white-hot carbon with steam.

$$C(s) + H_2O(g) \rightleftharpoons H_2(g) + CO(g) \qquad \Delta H = +131\ \text{kJ mol}^{-1}$$

The expression for the equilibrium constant, K_p, is

$$K_p = \frac{p(H_2)\,p(CO)}{p(H_2O)}$$

(i) Give a reason why the partial pressure of carbon is not included in the expression.

(1)

Carbon is a solid so is not involved in kp.

ResultsPlus

Examiner Comments

This is an example of a common answer that scored 0.

ResultsPlus

Examiner Tip

The question asks about partial pressure so that should be included in the answer.

10 Hydrogen is produced on a large scale by several different processes.

(a) One process for producing hydrogen involves reacting white-hot carbon with steam.

$$C(s) + H_2O(g) \rightleftharpoons H_2(g) + CO(g) \qquad \Delta H = +131 \text{ kJ mol}^{-1}$$

The expression for the equilibrium constant, K_p, is

$$K_p = \frac{p(H_2)\,p(CO)}{p(H_2O)}$$

(i) Give a reason why the partial pressure of carbon is not included in the expression.
(1)

It is a Solid, so exerts neglible pressure

ResultsPlus
Examiner Comments

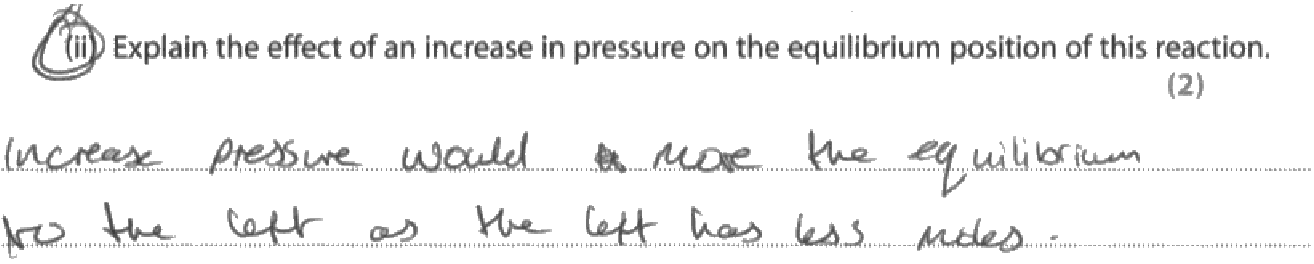
This candidate has given a correct answer related to pressure so scored 1 mark.

ResultsPlus
Examiner Tip

Read the question carefully and check that your answer relates to the information given.

Question 10 (a) (ii)

The majority of candidates scored 2 marks for this question. Some candidates thought there would be no change in the equilibrium position as they stated there are the same number of moles on each side of the equation. Some candidates omitted to mention gas when writing about fewer moles on the left. Some candidates tried to explain this in terms of the quotient but their answers were often confused and they rarely scored full marks. A straightforward answer in terms of fewer moles of gas on the left so the equilibrium position moves to the left is sufficient here. A small number of candidates wrote contradictory statements and lost a mark: for example, they wrote that more reactants are formed so the equilibrium position shifts to the right.



(ii) Explain the effect of an increase in pressure on the equilibrium position of this reaction.
(2)

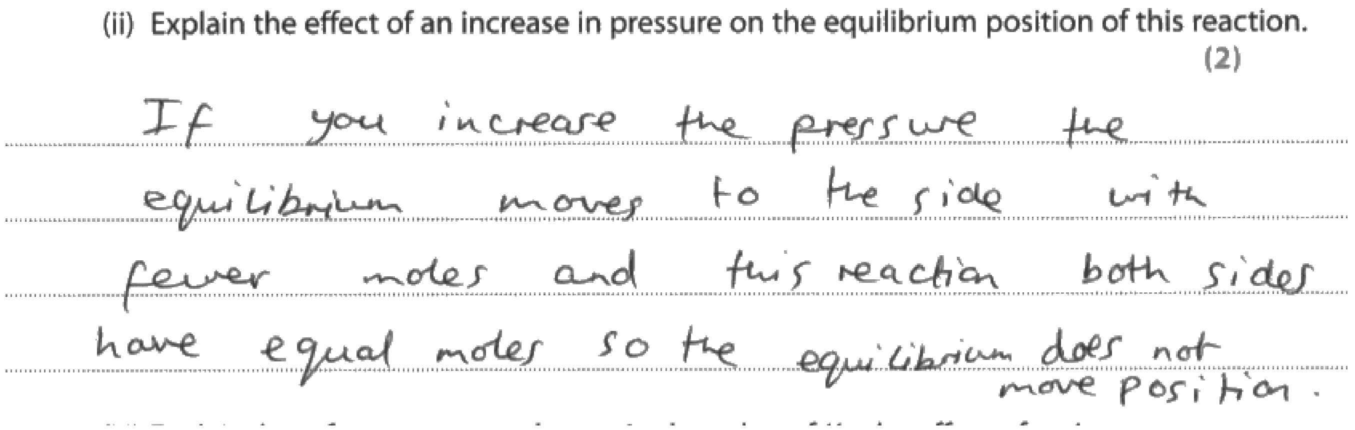
Increase pressure would move the equilibrium to the left as the left has less moles.

ResultsPlus
Examiner Comments

This answer scored 1 mark. The increase in pressure will shift the equilibrium to the left and there is a reason given: 'less moles'. However, this is not sufficient as pressure only has an effect on the moles of **gas**.

ResultsPlus
Examiner Tip

When you write about the effect of pressure on a system in equilibrium, always write about the moles of gas.



(ii) Explain the effect of an increase in pressure on the equilibrium position of this reaction.
(2)

If you increase the pressure the equilibrium moves to the side with fewer moles and this reaction both sides have equal moles so the equilibrium does not move position.

ResultsPlus
Examiner Comments

This candidate has the right idea about fewer moles but does not understand that it is only the number of moles of gas that need to be considered. There are two moles of gas on the right but only one mole of gas on the left. This answer scored 0.

ResultsPlus
Examiner Tip

Revise the effect of pressure on heterogeneous equilibria.

Question 10 (a) (iii)

Many candidates scored 2 marks for this question. Some candidates omitted to state what would happen to the value of the equilibrium constant and some were confused and thought it would decrease. Some candidates realised that K_p would increase but did not relate this to the forward reaction being endothermic.

(iii) Explain, by reference to any change in the value of K_p, the effect of an increase in temperature on the equilibrium position of this reaction.

(2)

Increasing the temperature would cause the equilibrium ~~left~~ right as it is endothermic.

ResultsPlus

Examiner Comments

This response scored 1 mark for relating the shift in equilibrium position to the endothermic reaction. The question also asked for the effect on the value of K_p and there is no mention of this in the answer.

ResultsPlus

Examiner Tip

Check your answers carefully to make sure that you have included everything you have been asked for.

(iii) Explain, by reference to any change in the value of K_p, the effect of an increase in temperature on the equilibrium position of this reaction.

(2)

An increase in temperature will increase the value of Kp as the ~~for~~ forwards reaction is endothermic and more $H_{2(g)}$ and $CO_{(g)}$ will form as a result, increasing their partial pressure and decreasing $H_2O_{(g)}$'s partial pressure.

ResultsPlus

Examiner Comments

This is an excellent answer that scored 2 marks. This candidate knows that K_p increases because the reaction is endothermic and therefore the equilibrium position changes.

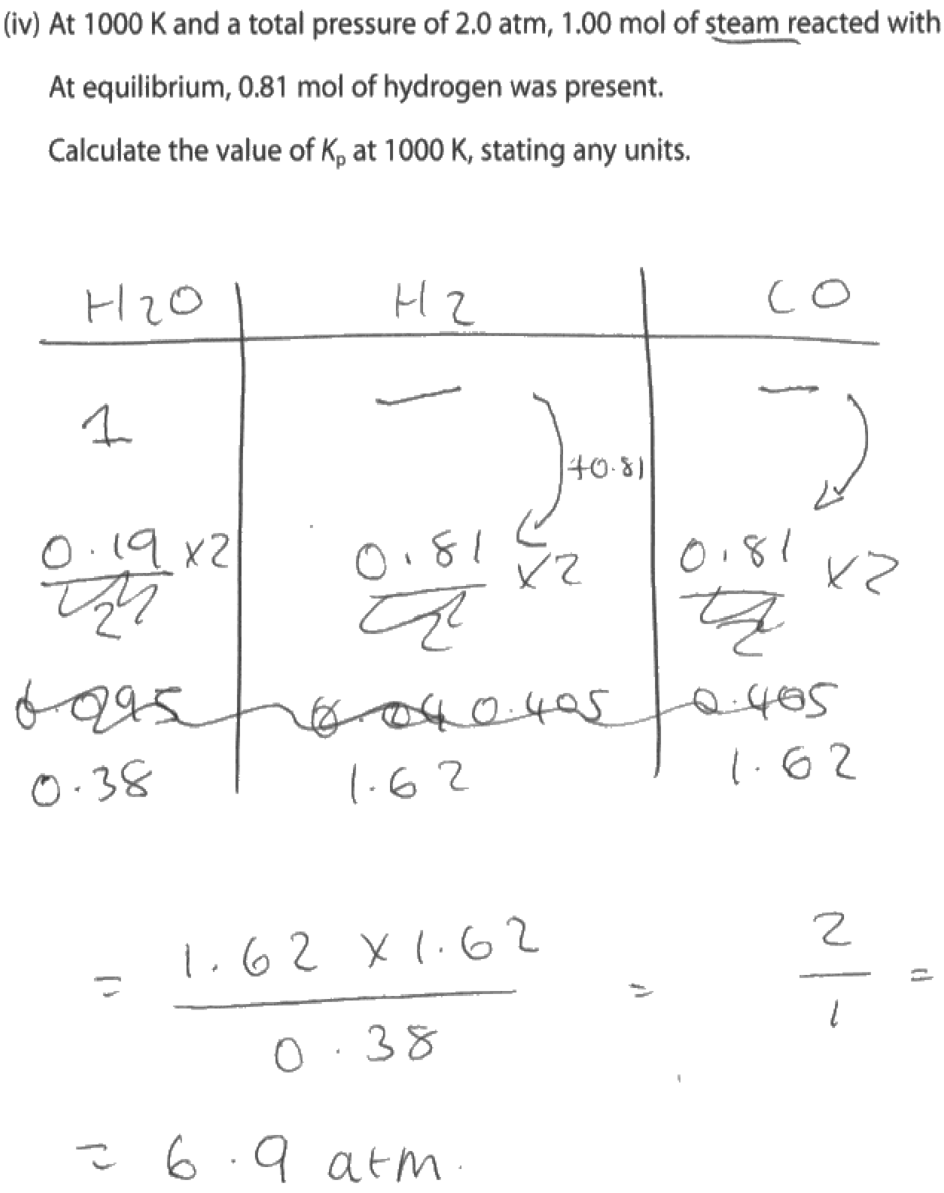
ResultsPlus

Examiner Tip

Try to remember that the equilibrium constant does not change because the equilibrium position changes - it is the other way around.

Question 10 (a) (iv)

The majority of candidates made a very good attempt at this calculation, with many scoring 4 marks. Some candidates were unable to work out the partial pressures correctly but they could still score 3 marks. The use of a table for working, as in the mark scheme, would help candidates to see what they are doing and examiners to award marks when the final answer is incorrect. Some candidates worked out a partial pressure for carbon, even though they were told that it is not included in the expression for K_p. Almost all candidates scored the mark for units, although a few included mol^{-1} and some converted it to Pascals. Candidates are encouraged to convert their answers to decimals and not leave them as fractions.



(iv) At 1000 K and a total pressure of 2.0 atm, 1.00 mol of steam reacted with excess carbon.

At equilibrium, 0.81 mol of hydrogen was present.

Calculate the value of K_p at 1000 K, stating any units.

(4)

H_2O	H_2	CO
1	—	—
	+0.81	
$\frac{0.19}{2} \times 2$	$\frac{0.81}{2} \times 2$	$\frac{0.81}{2} \times 2$
~~0.095~~	~~0.04~~ ~~0.405~~	~~0.405~~
0.38	1.62	1.62

$$= \frac{1.62 \times 1.62}{0.38} = \frac{2}{1} =$$

$$= 6.9 \text{ atm}$$

ResultsPlus

Examiner Comments

This candidate has worked out the number of moles of each substance at equilibrium and has attempted to work out the partial pressures. They have divided the moles by the total pressure but have not divided by the total number of moles. They have used these incorrect values in the final expression and given correct units so this answer scored 3 marks.

ResultsPlus

Examiner Tip

$$\text{partial pressure} = \frac{\text{number of moles of substance}}{\text{total number of moles}} \times \text{total pressure}$$

(iv) At 1000 K and a total pressure of 2.0 atm, 1.00 mol of steam reacted with excess carbon.

At equilibrium, 0.81 mol of hydrogen was present.

Calculate the value of K_p at 1000 K, stating any units.

(4)

	H_2O	H_2	CO_2
initial mol	1[illegible]	0	0
change mol	− 0.81	+ 0.81	+ 0.81
final mol	~~0.19~~ 0.19	0.81	0.81
mole fraction	$\frac{0.19}{1.81}$	$\frac{0.81}{1.81}$	$\frac{0.81}{1.81}$
partial pressure	$2 \times \frac{0.19}{1.81}$ = 0.20994	$2 \times \frac{0.81}{1.81}$ = 0.895028	$2 \times \frac{0.61}{1.81}$ = 0.895028

Total mol = 0.19 + 0.81 + 0.8
= 1.81

$$K_p = \frac{p(H_2)\,p(CO)}{p(H_2O)}$$

$$K_p = \frac{(0.895028 \times 0.895028)}{(0.20994)}$$

$$K_p = 3.81573$$
$$= 3.82 \text{ atm}$$

ResultsPlus
Examiner Comments

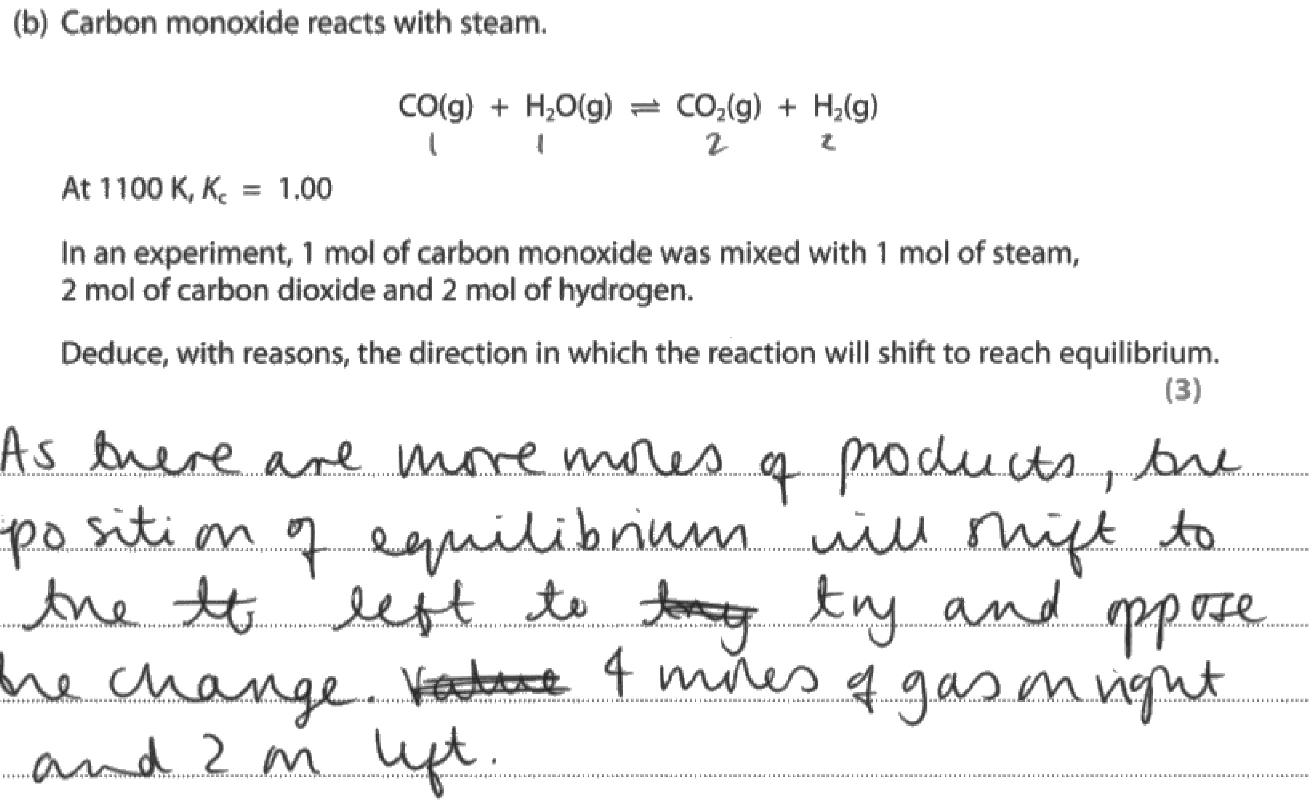
This is an example of a correct calculation that scored 4 marks.

ResultsPlus
Examiner Tip

Try to set out your working for calculations clearly, as in this example.

Question 10 (b)

Candidates found it difficult to express their ideas clearly to explain what would happen in this question. There were many vague answers and candidates should give careful consideration to all the information given. Many candidates did not read the question carefully and assumed that the reaction was at equilibrium at the start and then it would shift left as there are more moles on the right; this idea scored 1 mark. In the best answers, candidates realised that at equilibrium, the numbers of moles of reactants and products must be equal so the number of moles of the products needs to decrease and the number of moles of reactants to increase to achieve this.



(b) Carbon monoxide reacts with steam.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

1 1 2 2

At 1100 K, K_c = 1.00

In an experiment, 1 mol of carbon monoxide was mixed with 1 mol of steam, 2 mol of carbon dioxide and 2 mol of hydrogen.

Deduce, with reasons, the direction in which the reaction will shift to reach equilibrium.

(3)

As there are more moles of products, the position of equilibrium will shift to the ~~tt~~ left to ~~try~~ try and oppose the change. ~~Value~~ 4 moles of gas on right and 2 on left.

ResultsPlus

Examiner Comments

This candidate has given a simple explanation and scored 1 mark.

ResultsPlus

Examiner Tip

Try to use all the information given in the question and give more detail in your explanations.

(b) Carbon monoxide reacts with steam.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

At 1100 K, $K_c = 1.00$

In an experiment, 1 mol of carbon monoxide was mixed with 1 mol of steam, 2 mol of carbon dioxide and 2 mol of hydrogen.

Deduce, with reasons, the direction in which the reaction will shift to reach equilibrium.

(3)

$K_c = 1$ So equal amounts reactants and products should be presen.

As the ratio starts at $\frac{4}{1}$ the reaction shifts left to reach equilibrium

ResultsPlus

Examiner Comments

This candidate has made a better attempt at explaining why the reaction shifts to the left as they have realised that at equilibrium, there must be equal amounts of reactants and products.

ResultsPlus

Examiner Tip

If $K_c = 1$, there must be equal concentrations of reactants and products.

(b) Carbon monoxide reacts with steam.

$$\overset{1}{CO(g)} + \overset{1}{H_2O(g)} \rightleftharpoons \overset{2}{CO_2(g)} + \overset{2}{H_2(g)}$$

At 1100 K, K_c = 1.00

In an experiment, 1 mol of carbon monoxide was mixed with 1 mol of steam, 2 mol of carbon dioxide and 2 mol of hydrogen.

Deduce, with reasons, the direction in which the reaction will shift to reach equilibrium.

(3)

Reaction will shift left in order to reduce the moles of H_2 and CO_2 on the right and increase the moles of CO and H_2O. This is because all of the species react in a 1:1:1:1 ratio, so must be in equal proportions in order for equilibrium to be established.

ResultsPlus

Examiner Comments

This is an example of a very good answer that scored 3 marks. The candidate has given detailed reasons why the reaction moves to the left to reach equilibrium.

ResultsPlus

Examiner Tip

Many candidates missed out the idea that if the number of moles of products decreases then the number of moles of reactants must increase until they are all equal.

Paper Summary

In future, some candidates need more practice in answering these new styles of questions, particularly the different calculations and 6-mark extended-writing questions.

- In order to improve their performance, candidates are offered the following advice:
- read all the information given in the question and use it to help you to answer the question
- after you have written your answer, re-read the question and check that you have answered it fully
- use correct scientific terminology in your answers
- revise the AS content thoroughly as there will be 40 to 50% of the marks based on this work
- practise the different types of calculations in the specification and show your working clearly
- in extended calculations, do not round the intermediate values; keep the number in your calculator and give the final answer to an appropriate number of significant figures, quoting any units
- practise writing balanced ionic equations
- revise buffer solutions and related 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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