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Examiners' Report
June 2023

GCE Chemistry 9CH0 01

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Introduction

This paper provided candidates with the opportunity to demonstrate their knowledge and understanding of the key concepts in Topics 1 to 8 and 10 to 15 of the A Level specification.

Examiners reported that some answers were almost illegible. Candidates should be encouraged to write their answers clearly so that examiners can read them easily and award the correct marks.

The two main topics that stood out with many candidates not understanding them were Bonding and Structure and Energetics I. Many candidates did not understand how structure and bonding affect properties such as melting temperature as they were unable to identify the correct bonding or intermolecular forces present in the substances. Quite a lot of candidates were confused between ionisation energy and melting temperature. There was a lot of confusion between positive and negative signs in enthalpy changes and interpreting them as exothermic and endothermic reactions. Many candidates did not know that they needed to add a minus sign in the calculation of an enthalpy change for an exothermic reaction. Many candidates thought that energy was needed to form bonds.

Successful candidates:

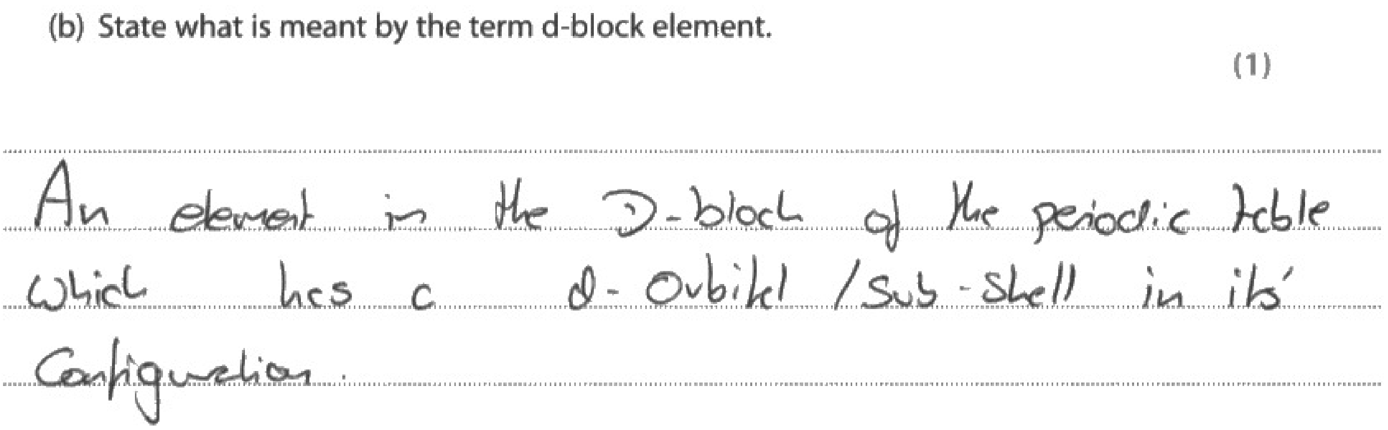
- read the questions carefully and answered the questions as they were set
- understood and used correct terminology
- could explain physical properties in terms of particles, bonding and structure
- understood the difference between exothermic and endothermic reactions
- could carry out unstructured calculations.

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

- did not read the questions carefully and gave answers that were related to the topic being tested, but did not answer the question
- did not use correct scientific terminology, for example, they interchanged atoms, molecules and ions or orbital, subshell and energy level without understanding what the correct words should be
- wasted time repeating the question and/or repeating the same points
- did not have a clear understanding of particles, bonding and structure
- did not have a clear understanding of enthalpy changes.

Question 1 (b)

Very few candidates gave the best meaning of a d-block element as shown in the mark scheme. However, many candidates scored a mark as other descriptions, such as the last electron is in a d orbital, were allowed. Some candidates just stated that the outer orbital is a d orbital and did not mention electrons and others just stated that there are electrons in the d-subshell. A few candidates gave the general properties of transition metals, such as variable oxidation states.



(b) State what is meant by the term d-block element.

(1)

An element in the D-block of the periodic table which has a d-orbital / sub-shell in its' configuration.

ResultsPlus
Examiner Comments

This candidate knows about d orbitals and d-subshells but has not understood that a d-block element has its last electron added to a d-subshell.

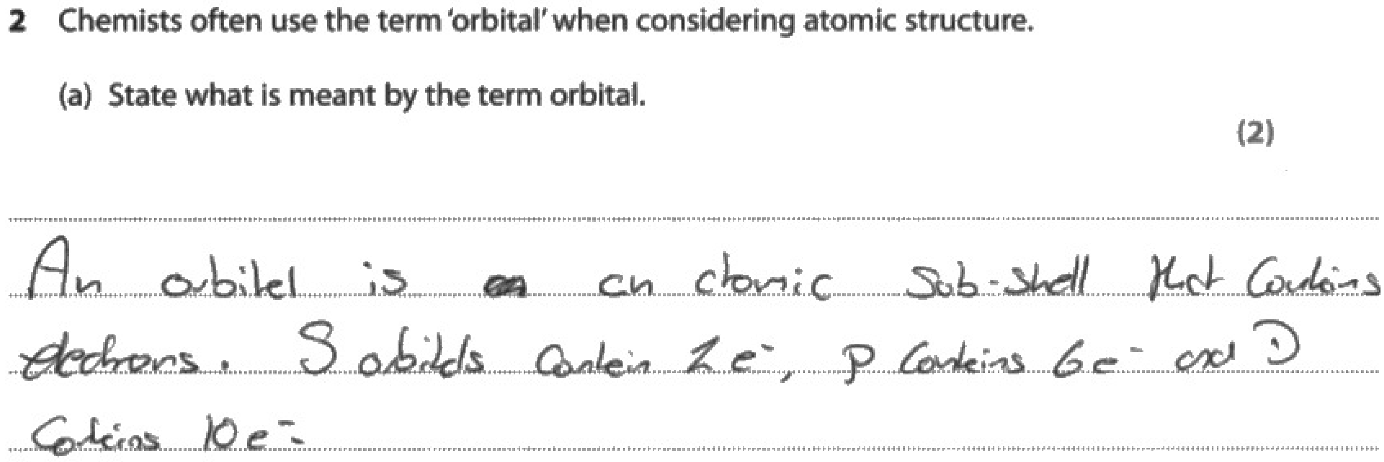
This response scored 0.

ResultsPlus
Examiner Tip

Make sure that you understand what is meant by an s-block, a p-block and a d-block element.

Question 2 (a)

Although many candidates understood what is meant by the term 'orbital', a significant number were unable to use the correct terminology to describe a region, space or area where an electron is most likely to be found. Quite a lot of candidates omitted to mention that an orbital can hold two electrons with opposite spins. Some candidates thought that a p orbital could hold 6 electrons and a d orbital 10 electrons., showing confusion between orbitals and subshells.



2 Chemists often use the term 'orbital' when considering atomic structure.

(a) State what is meant by the term orbital.

(2)

An orbitel is an atomic sub-shell that contains electrons. S orbitals contain $2e^-$, p contains $6e^-$ and D contains $10e^-$

ResultsPlus
Examiner Comments

This response scored 0.

The candidate is clearly confused between subshells and orbitals.

ResultsPlus
Examiner Tip

Make sure that you understand the difference between energy levels, subshells and orbitals and can use the correct terminology in your answers.

2 Chemists often use the term 'orbital' when considering atomic structure.

(a) State what is meant by the term orbital.

(2)

A region where an electron is most likely to be found.

ResultsPlus
Examiner Comments

This response scored 1 mark.

A better answer would have stated that orbitals can hold a maximum of two electrons with opposite spins.

ResultsPlus
Examiner Tip

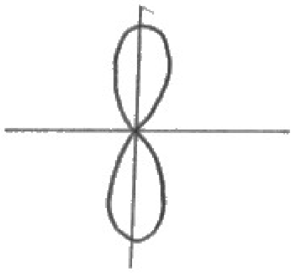
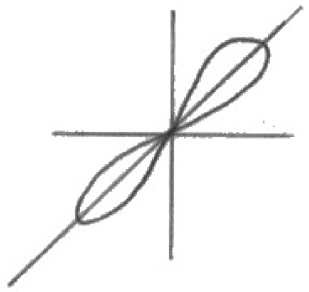
Look at the number of marks allocated to each question and use this as a guide for the amount of detail required in your answer.

Question 2 (b)

Many candidates knew the shapes of an s orbital and a p orbital, but they could not all draw them accurately. For example, it was not acceptable to draw the s orbital as an oval and the two lobes of the p orbital had to be similar in size.

(b) Draw diagrams to show the shape of an s and a p orbital.

(2)

s orbital	p orbital
	

ResultsPlus
Examiner Comments

This response scored 1 mark for the correct shape of a p orbital.

The s orbital drawn is just another p orbital.

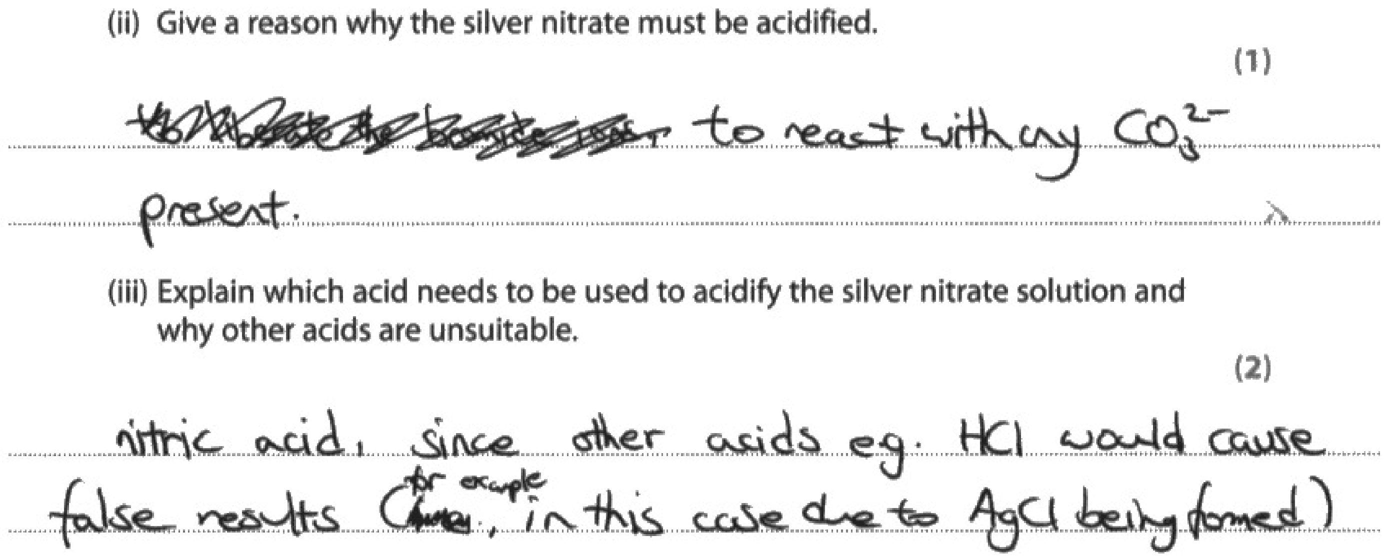
ResultsPlus
Examiner Tip

Make sure that you can draw the shapes of s and p orbitals.

Question 3 (b)(ii-iii)

Many candidates gave vague answers to (ii), such as to provide H^+ ions or to remove impurities. Good answers identified the impurities as carbonate ions or hydroxide ions.

In part (iii), the majority of candidates knew that the only acceptable acid is nitric acid. However, many of them could not explain that other acids contain anions that react with silver ions to form a precipitate. Some candidates referred to the formation of silver chloride when hydrochloric acid is used but did not state the significance of this is that it is also a precipitate. Quite a few candidates referred to 'false positives' in their answers but did not state that other precipitates would form.



(ii) Give a reason why the silver nitrate must be acidified.

(1)

to react with any CO_3^{2-} present.

(iii) Explain which acid needs to be used to acidify the silver nitrate solution and why other acids are unsuitable.

(2)

nitric acid, since other acids eg. HCl would cause false results (for example, in this case due to AgCl being formed)

ResultsPlus
Examiner Comments

(ii) This is a correct answer that scored 1 mark.

(ii) This answer scored 1 mark for identifying nitric acid. However, just stating that HCl would cause false results is not sufficient. The answer could be improved by stating the false result is that a precipitate of silver chloride would form.

ResultsPlus
Examiner Tip

Learn the tests for the common ions in the specification and make sure that you understand the reason for each part of the test.

Question 3 (c)(i)

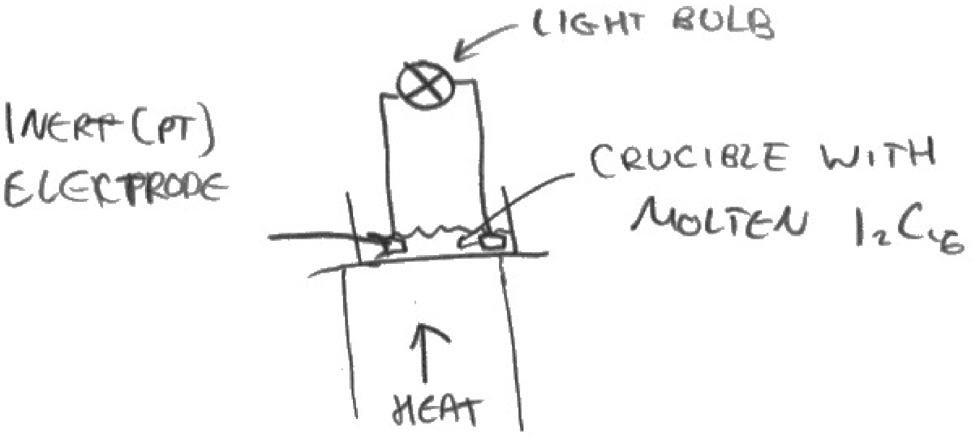
Many candidates struggled to deduce a simple experiment to show that ions are produced in the dissociation of I_2Cl_6. There were examples of heating to obtain gases and adding solutions to form precipitates. Candidates should read the question carefully as the ions are shown in the equation, so the experiment needs to test whether the molten compound conducts an electric current. Some very poor circuit diagrams were seen, including many with a missing cell or power supply. The result of the experiment was often missing or vague, such as two different colours form. The simplest observation is to include a bulb in the circuit and it will light up if ions are present. However, many other observations were accepted.

(c) Iodine trichloride forms a dimer, I_2Cl_6, in the solid state.
When molten, it is suggested that it breaks down as shown.

$$I_2Cl_6 \rightleftharpoons ICl_2^+ + ICl_4^-$$

(i) Draw a labelled diagram of a simple experiment to confirm this dissociation has occurred, stating the positive result.

(2)



Result Light bulb turns on

ResultsPlus
Examiner Comments

This candidate has the right idea about testing whether the molten compound conducts an electric current. However, they have omitted to include a cell or power supply in the circuit so nothing would happen.

However, this error was not penalised twice so this response scored 1 mark for the result that the light bulb turns on.

ResultsPlus
Examiner Tip

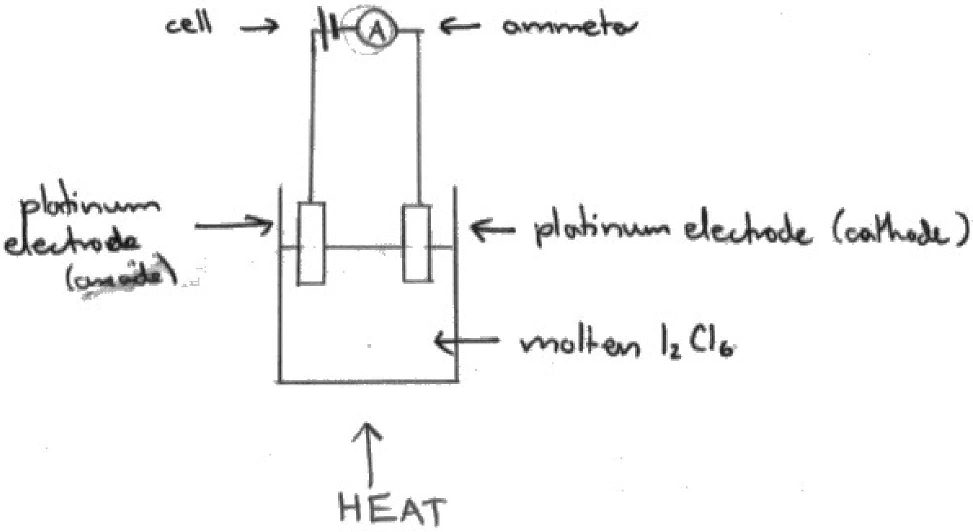
Always check diagrams of apparatus to make sure that they would work.

(c) Iodine trichloride forms a dimer, I_2Cl_6, in the solid state.
When molten, it is suggested that it breaks down as shown.

$$I_2Cl_6 \rightleftharpoons ICl_2^+ + ICl_4^-$$

(i) Draw a labelled diagram of a simple experiment to confirm this dissociation has occurred, stating the positive result.

(2)



Result A current shown on the ammeter.

ResultsPlus
Examiner Comments

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

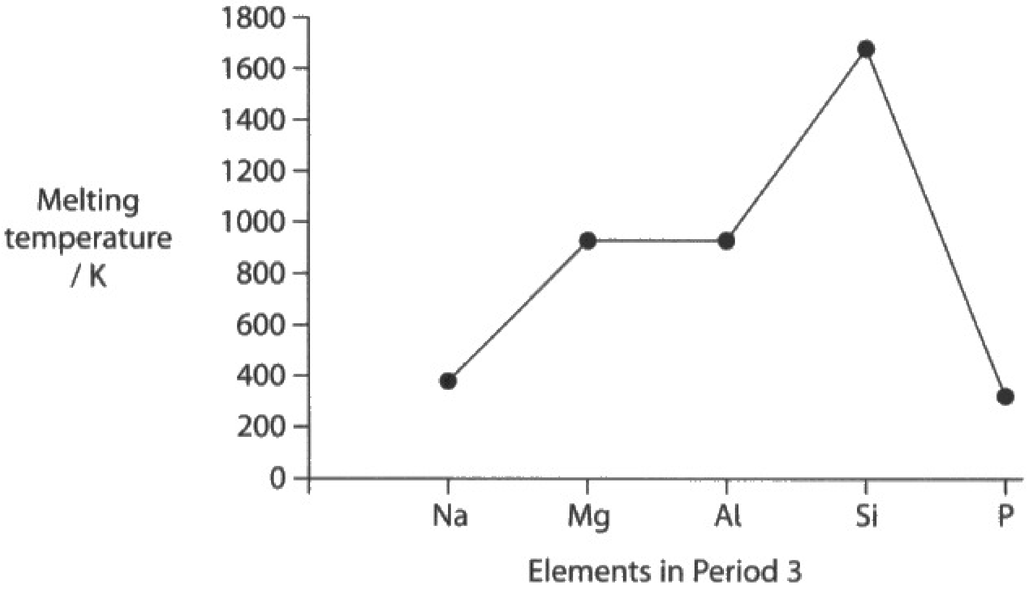
ResultsPlus
Examiner Tip

Try to draw neat, clearly labelled diagrams of apparatus.

Question 4

Candidates who had a good knowledge and understanding of how melting temperatures are affected by structure and bonding scored high marks for this question. Unfortunately, there were many candidates who did not understand structure and bonding and they used poor terminology, for example, referring to molecules of sodium. Many candidates referred to London forces in all of the elements. A significant minority thought that the weak covalent bonds in phosphorus would be broken when it melts and some thought that it had ionic bonding. Some candidates thought that melting temperature is affected by ionisation energy and they discussed how easy it is for those elements to lose an electron.

4 The graph shows the melting temperatures of some elements in Period 3.



Explain the variations in melting temperature across the period in terms of the structure and bonding in these elements.

(6)

Sodium, magnesium and aluminium are all metals, so have (strong) metallic bonding. Sodium ions have a +1 charge whereas magnesium ions have ~~has~~ a +2 charge. Therefore there is a greater force of attraction between the magnesium ions and delocalised ~~ions~~ electrons than there is between the sodium ions and delocalised electrons, so more energy required to overcome the force, so a higher melting temperature. Aluminium ~~ha~~ ions have a 3+ charge so has a slightly higher melting temperature than sodium, ~~but lesser~~ Silicon has a much greater melting temperature as it forms a giant covalent structure which contains many strong covalent bonds which require a lot of energy to break and hence has a much higher melting temperature. Phosphorus is only a simple molecule, so has strong covalent bonds, but a lot less than that in silicon so requires less energy to break, so a lower melting temperature.

ResultsPlus
Examiner Comments

This is a very good answer that scored 5 marks.

The only point that the candidate did not make is that there are weak London forces between phosphorus molecules. The answer implies that it is the covalent bonds in the small molecules that are broken.

ResultsPlus
Examiner Tip

Make sure that you understand that small molecules have strong covalent bonds within the molecules that are holding the atoms together. However, there are weak intermolecular forces and it is these that are broken when the substance melts or boils.

Question 5 (a)(i-ii)

(i) The graph was drawn correctly by the majority of the candidates. The common errors included: numbering the y axis in the wrong direction and not choosing a suitable scale for the x axis so that the plotted points occupied more than half of the graph paper.

(ii) Candidates who used the equation given to deduce that the gradient of the graph is equal to $-\Delta S_{system}$ were usually able to compile the calculation and score 3 marks. Many candidates just tried to rearrange the equation and were unable to eliminate ΔH. A few candidates were successful at using two simultaneous equations but most who tried that method forgot to convert the units of ΔG into J mol^{-1}.

5 This question is about the decomposition of dinitrogen tetroxide. The reaction eventually reaches equilibrium.

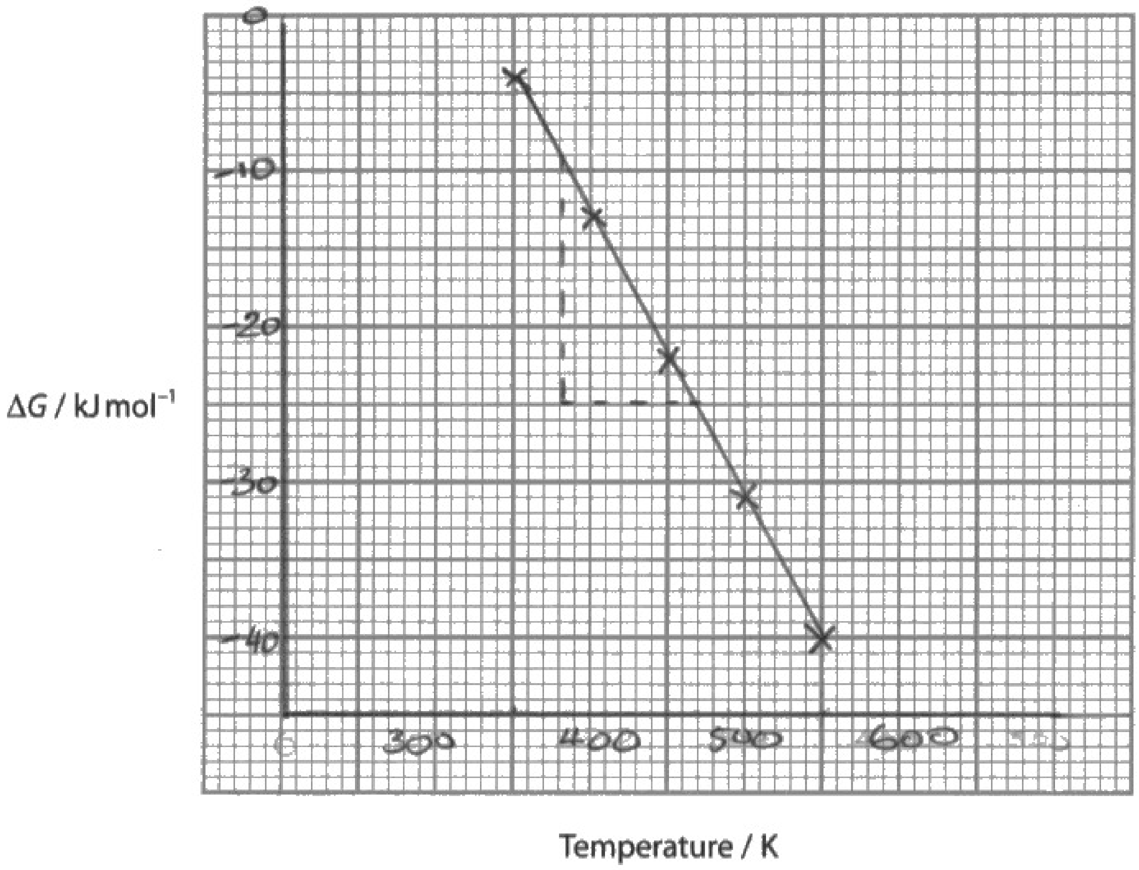
$$\underset{\text{colourless}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown}}{2NO_2(g)}$$

(a) The table shows values of ΔG at different temperatures for this reaction.

Temperature / K	ΔG / kJ mol^{-1}
350	–4.0
400	–13
450	–22
500	–31
550	–40

(i) Plot a graph of ΔG against temperature.

(2)



(ii) Calculate the entropy change of the system, ΔS_{system}, in J K^{-1} mol^{-1}, using your straight line from the graph in (a)(i) and the equation shown.

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

(3)

$m = \Delta S_{system}$.

$$m = \frac{-9 - -25}{380 - 470} = \frac{16}{-90} = -\frac{8}{45} \; (kJmol^{-1}K^{-1})$$

$$-\frac{8}{45} \times 1000 = -177.8 \; JK^{-1}mol^{-1}$$

$$\text{So} \quad \Delta S_{system} = -177.8 \; JK^{-1} mol^{-1}$$

ResultsPlus
Examiner Comments

(i) This graph scored 1 mark for plotting the points accurately and drawing the line of best fit. The candidate has chosen an unsuitable scale for the x axis. The points must cover at least half the available space in both directions.

(ii) The candidate has written that the gradient is equal to ΔS_{system} and has omitted the minus sign. The final answer should be positive. However, 2 marks are awarded for transferred errors.

ResultsPlus
Examiner Tip

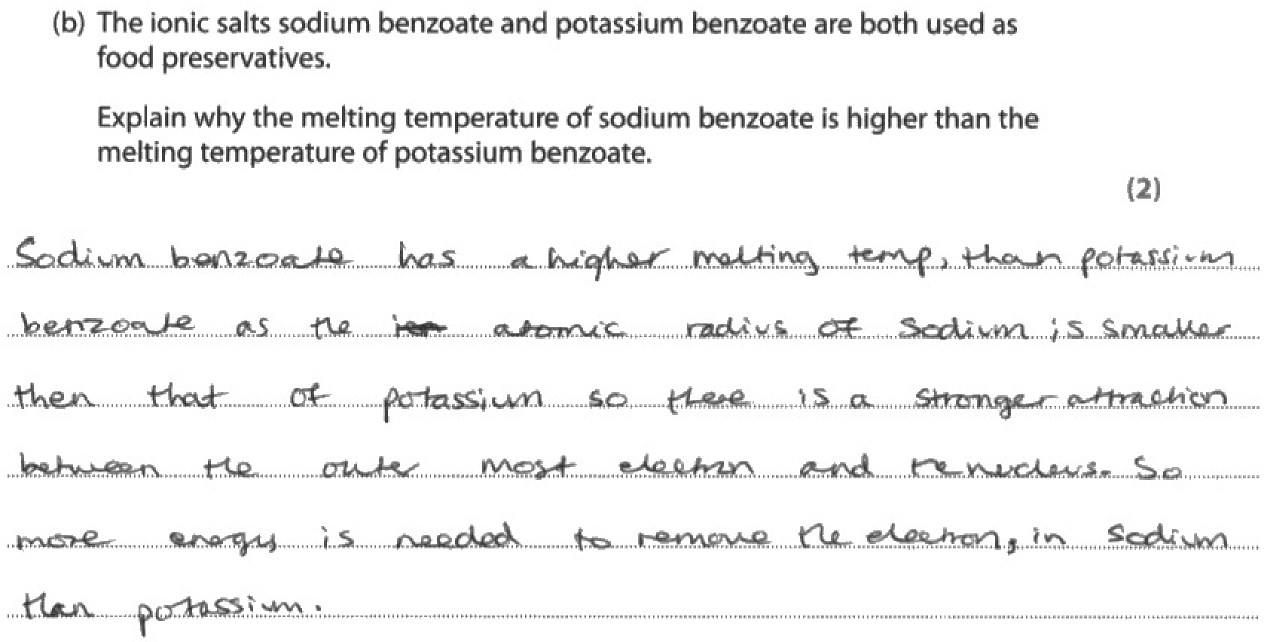
Chose suitable scales for the axes when you draw a graph to ensure that the points cover at least half the available space in both directions.

Check your answers to see whether they should be positive or negative.

Question 6 (b)

This question was quite poorly answered. Many candidates knew that the ionic radius of the sodium ions is less than that of the potassium ions, but they were then unable to deduce that there would be a stronger attraction between the sodium ion and the benzoate ion than between the potassium ion and the benzoate ion. Some candidates referred to the ionic radius of sodium benzoate and others referred to atomic radius, even though the question stated that these are ionic salts. Some discussed the attraction between the nucleus and the outer electron in sodium.

A significant minority discussed polarisation of the benzoate ion, although they were not penalised for this.



(b) The ionic salts sodium benzoate and potassium benzoate are both used as food preservatives.

Explain why the melting temperature of sodium benzoate is higher than the melting temperature of potassium benzoate.

(2)

Sodium benzoate has a higher melting temp, than potassium benzoate as the ~~ion~~ atomic radius of sodium is smaller then that of potassium so there is a stronger attraction between the outer most electron and the nucleus. So more energy is needed to remove the electron, in sodium than potassium.

ResultsPlus
Examiner Comments

This response scored 0 as the candidate has misunderstood the question and discussed ionisation energy instead of melting temperature.

ResultsPlus
Examiner Tip

Read the question carefully to make sure that you understand what is required. This question is about ionic salts and melting temperature and no electrons are lost in the process. The candidate should have written about the difference in the attraction between the cations and the benzoate ion.

Question 6 (c)(i-ii)

(i) The majority of candidates could write the correct expression for the acid dissociation constant. The common errors included just using HA and A^- instead of using the formula of benzoic acid and the benzoate ion, using the expression with $[H^+]^2$, using $[C_6H_5COOH_2^+]$ and including nitric acid or nitrate ions.

(ii) This calculation was carried out correctly by many candidates. Some candidates were unable to calculate the number of moles of benzoic acid in 250 cm^3 and some used an incorrect relative molecular mass for benzoic acid so lost the final mark. A few candidates rounded their final answer to 1 significant figure and lost the last mark.

(c) The value of K_a for benzoic acid = 6.28×10^{-5} mol dm^{-3}.

(i) Write the expression for the acid dissociation constant, K_a, of benzoic acid.

(1)

$$Ka = \frac{[H^+] \times [C_6H_5COO^-]}{[C_6H_5COOH]}$$

250

(ii) Calculate the mass of benzoic acid needed to prepare 250 cm^3 of a solution with a pH = 3.51

(4)

$$[H^+] = 10^{-3.51} = 3.09 \times 10^{-4} \text{ mol dm}^{-3}$$

$$[C_6H_5COOH] = \frac{(3.09 \times 10^{-4})^2}{6.28 \times 10^{-5}} = 1.52 \times 10^{-3} \text{ mol dm}^{-3}$$

$$n(C_6H_5COOH) = 1.52 \times 10^{-3} \times \frac{250}{1000} = 3\text{-}80 \times 10^{-4} \text{ mols}$$

$$mass(C_6H_5COOH) = 3.8 \times 10^{-4} \times 122 = 0.05g$$

$$Mr(C_6H_5COOH) = \begin{array}{r} 12 \times 7 \\ 1 \times 6 \\ + \quad 16 \times 2 \\ \hline 122 \\ \hline \end{array}$$

$3.801722078 \times 10^{-4}$

ResultsPlus
Examiner Comments

(i) This response scored 1 mark for the correct expression.

(ii) This response scored 3 marks. The candidate has carried out four correct steps in the calculation, but they have lost a mark for giving their answer to 1 significant figure.

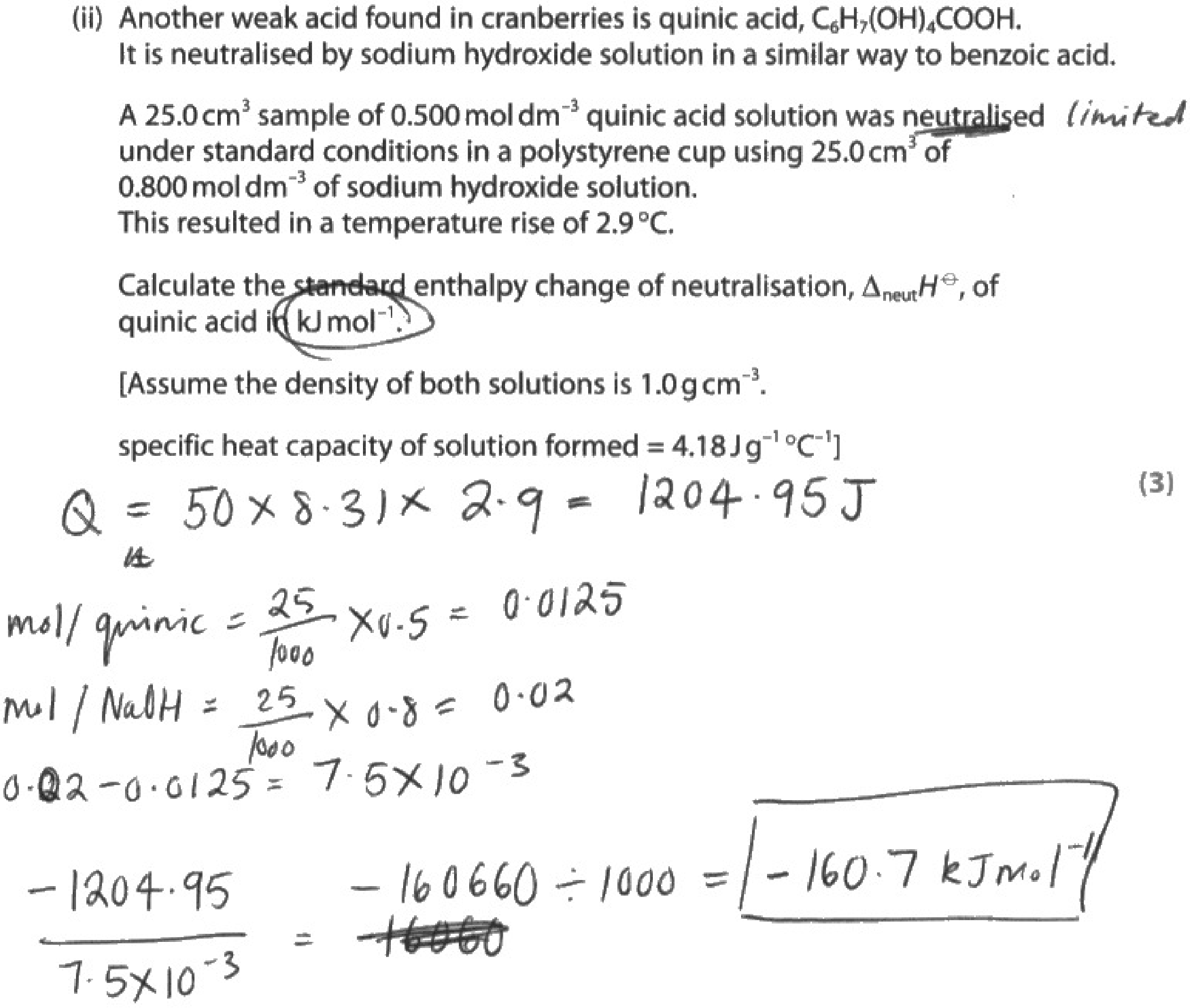
ResultsPlus
Examiner Tip

Give your final answer to calculations to the same number of significant figures given in any data in the question, unless you are told otherwise.

This question gives data to 3 significant figures so the final answer should be 0.0464 g.

Question 6 (d)(ii)

Many candidates were able to calculate the standard enthalpy change of neutralisation calculation. Some candidates just used 25g as the total mass of solution and some converted the temperature into kelvin. Many candidates did not realise that they should use the number of moles of acid and alkali to deduce which was the limiting reagent, so some added them and others subtracted them. A significant number of candidates did not deduce that the reaction is exothermic and omitted the minus sign in their final answer.



(ii) Another weak acid found in cranberries is quinic acid, $C_6H_7(OH)_4COOH$.
It is neutralised by sodium hydroxide solution in a similar way to benzoic acid.

A 25.0 cm³ sample of 0.500 mol dm⁻³ quinic acid solution was neutralised *limited* under standard conditions in a polystyrene cup using 25.0 cm³ of 0.800 mol dm⁻³ of sodium hydroxide solution.
This resulted in a temperature rise of 2.9 °C.

Calculate the ~~standard~~ enthalpy change of neutralisation, $\Delta_{neut}H^{\ominus}$, of quinic acid in kJ mol⁻¹.

[Assume the density of both solutions is 1.0 g cm⁻³.

specific heat capacity of solution formed = 4.18 J g⁻¹ °C⁻¹]

(3)

$Q = 50 \times 8.31 \times 2.9 = 1204.95\,J$

$mol / quinic = \frac{25}{1000} \times 0.5 = 0.0125$

$mol / NaOH = \frac{25}{1000} \times 0.8 = 0.02$

$0.02 - 0.0125 = 7.5 \times 10^{-3}$

$\frac{-1204.95}{7.5 \times 10^{-3}} = -160660 \div 1000 = \boxed{-160.7\ kJ mol^{-1}}$

~~16060~~

ResultsPlus
Examiner Comments

This response scored 1 mark.

The candidate has used the value of the gas constant, R, instead of the specific heat capacity given in the question, so lost the first mark.

The second mark is awarded for the number of moles of quinic acid.

The third mark is lost as the candidate has subtracted the moles of quinic acid from the moles of sodium hydroxide instead of just using the moles of quinic acid.

ResultsPlus
Examiner Tip

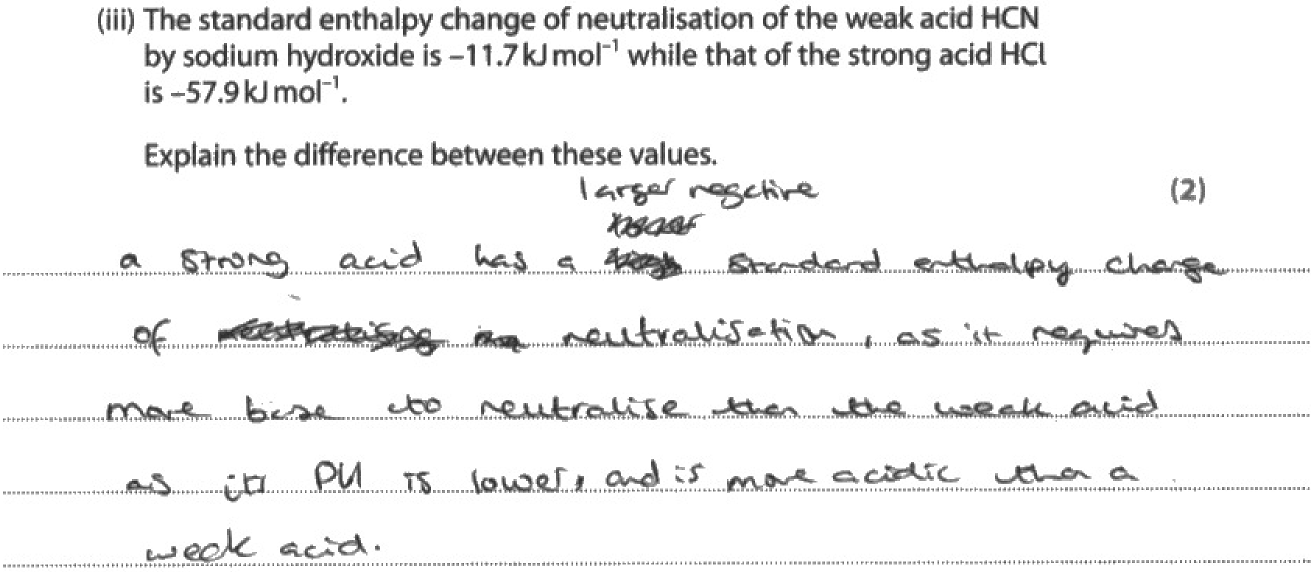
Read the question carefully and use the data given.

Revise how to carry out enthalpy change of neutralisation calculations.

Question 6 (d)(iii)

Many candidates were unable to explain the difference in the standard enthalpy change of neutralisation for a strong acid and a weak acid. The majority of candidates did realise that weak acids only partially dissociate into ions in aqueous solution. A significant misconception was that there are fewer protons to be neutralised from the weak acid as candidates did not understand that the equilibrium would shift so that all protons would be neutralised. but some candidates assumed that a strong acid would need more alkali to neutralise it.

A few candidates were confused by the enthalpy changes and thought that hydrochloric acid required more energy to neutralise it.



(iii) The standard enthalpy change of neutralisation of the weak acid HCN by sodium hydroxide is –11.7 kJ mol^{-1} while that of the strong acid HCl is –57.9 kJ mol^{-1}.

Explain the difference between these values.

(2)

a strong acid has a ~~[illegible]~~ larger negative ~~[illegible]~~ standard enthalpy change of ~~neutralising~~ ~~an~~ neutralisation, as it requires more base to neutralise than the weak acid as its PH is lower, and is more acidic than a weak acid.

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Examiner Comments

This candidate has misunderstood the concept of neutralisation of weak and strong acids. One mole of a monobasic strong acid and one mole of a monobasic weak acid both need one mole of sodium hydroxide for complete neutralisation.

This response scored 0.

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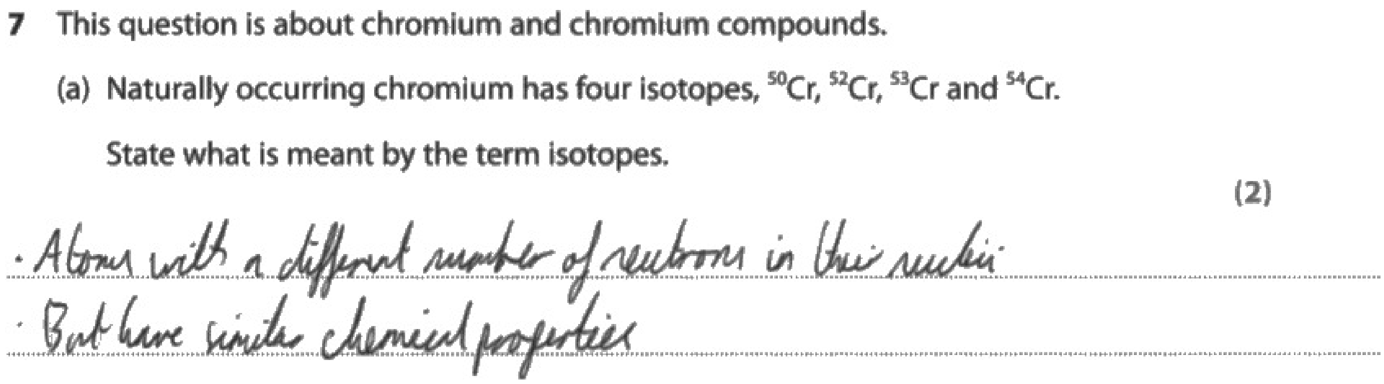
Examiner Tip

Revise the meaning of standard enthalpy change of neutralisation.

Revise the difference between strong and weak acids in terms of their degree of dissociation into ions.

Question 7 (a)

The vast majority of candidates knew the meaning of the term isotopes. Just a few were confused about subatomic particles and thought the atoms contained different numbers of protons or electrons.



7 This question is about chromium and chromium compounds.

(a) Naturally occurring chromium has four isotopes, ^{50}Cr, ^{52}Cr, ^{53}Cr and ^{54}Cr.

State what is meant by the term isotopes.

(2)

· Atoms with a different number of neutrons in their nuclei

· But have similar chemical properties

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Examiner Comments

This candidate knows that isotopes are atoms with different numbers of neutrons in their nuclei so scored 1 mark.

'Similar chemical properties' is not sufficient for a mark. The atoms are of the same element so they must have the same number of protons.

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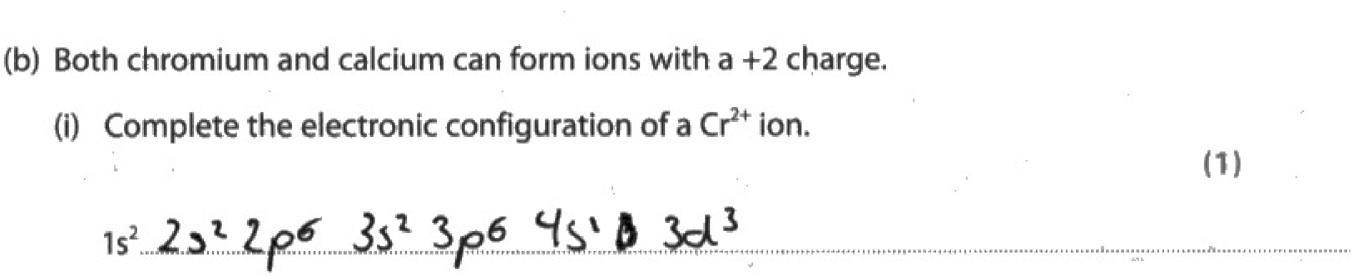
Examiner Tip

Revise what is meant by the term isotopes.

Question 7 (b)(i)

Many candidates gave the correct electronic configuration for a Cr^{2+} ion. However, many candidates did not realise that the 4s electrons are lost first. Some candidates did not use the atomic number of chromium from the periodic table to work out the number of electrons, so they gave an incorrect number of 3d electrons.



(b) Both chromium and calcium can form ions with a +2 charge.

(i) Complete the electronic configuration of a Cr^{2+} ion.

(1)

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^3$

ResultsPlus
Examiner Comments

This response scored 0.

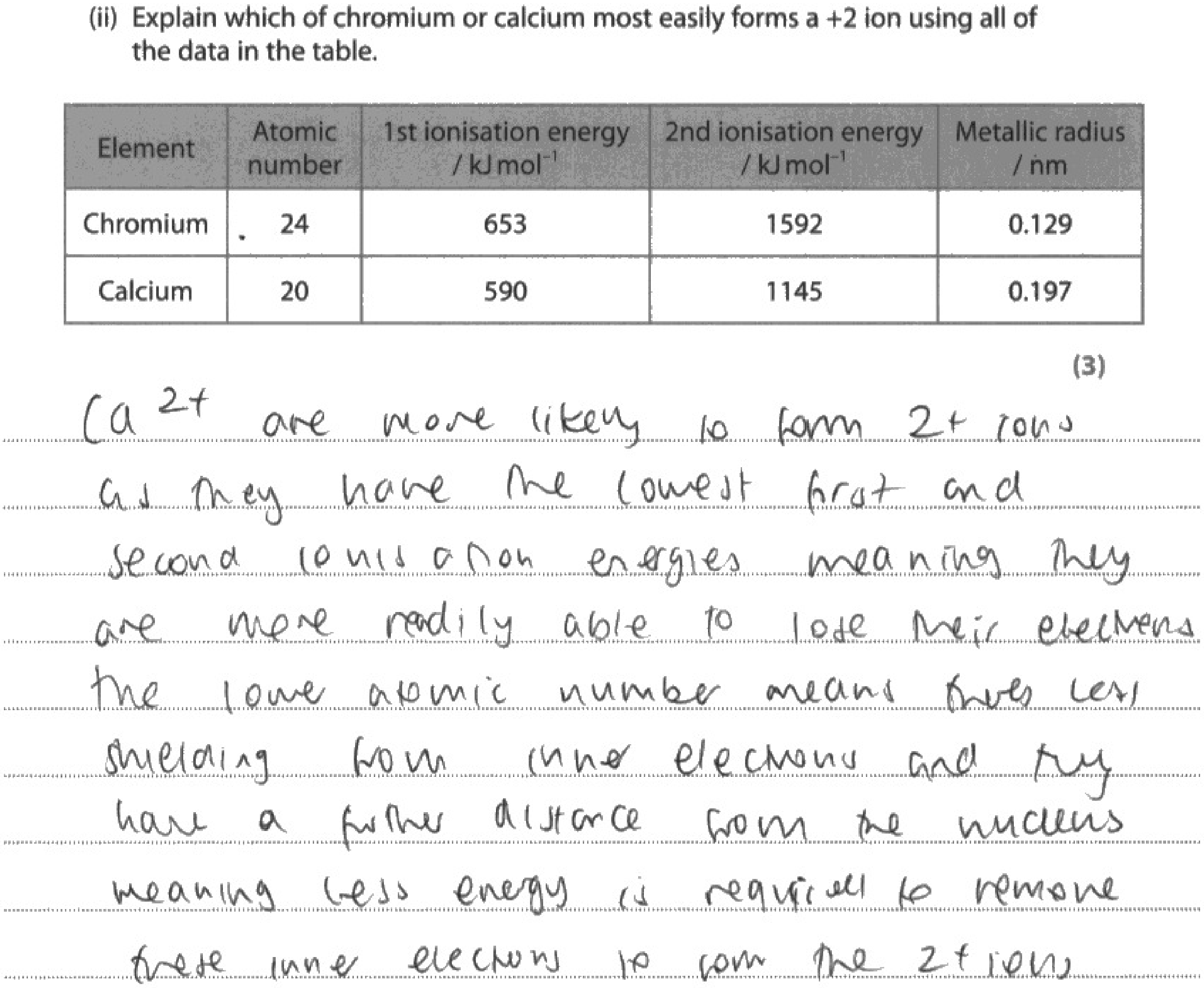
There are no 4s electrons in the ions.

ResultsPlus
Examiner Tip

Remember that transition metals form ions by losing their 4s electrons first.

Question 7 (b)(ii)

Some candidates gave excellent answers to this question as they used all the data given. A few candidates just referred to the second ionisation energy and omitted the first. Some candidates stated the difference in the metallic radius but did not expand on this to state that the outer electrons are further from the nucleus. Some candidates did not state that it is the outer electrons that are being lost and others did not refer to the attraction of the nucleus.



(ii) Explain which of chromium or calcium most easily forms a +2 ion using all of the data in the table.

Element	Atomic number	1st ionisation energy / kJ mol^{-1}	2nd ionisation energy / kJ mol^{-1}	Metallic radius / nm
Chromium	24	653	1592	0.129
Calcium	20	590	1145	0.197

(3)

Ca^{2+} are more likely to form 2+ ions as they have the lowest first and second ionisation energies meaning they are more readily able to lose their electrons the lower atomic number means theres less shielding from inner electrons and they have a further distance from the nucleus meaning less energy is required to remove these inner electrons to form the 2+ ions

ResultsPlus
Examiner Comments

This response scored 1 mark for calcium having lower first and second ionisation energies.

The answer then becomes confused as the candidate thinks that the inner electrons are removed instead of the outer electrons.

ResultsPlus
Examiner Tip

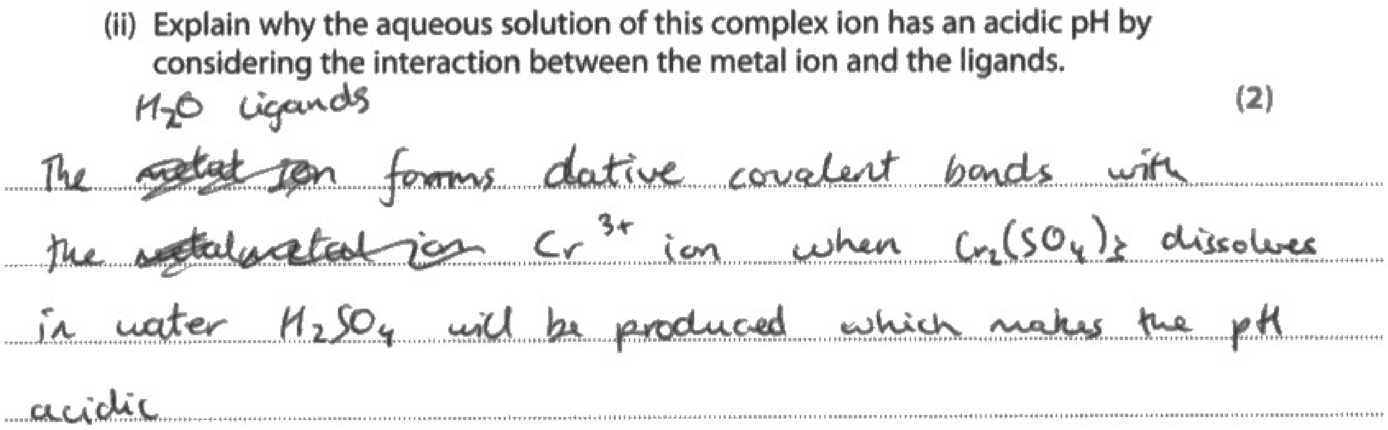
Read your answer carefully to make sure you have not made a slip like this.

Question 7 (c)(i)

The majority of candidates knew that the complex ion would be green or violet.

Question 7 (c)(ii)

The majority of candidates scored a mark for realising that the water ligands release H^+ ions that make the solution acidic. Very few candidates realised that it is the small, highly charged Cr^{3+} ion that weakens the O-H bonds in the water ligands that allows this to happen. Some candidates thought that OH^- ions deprotonated the water ligands. A few candidates thought that a precipitate of chromium(III) hydroxide would form and some referred to ligand exchange.



(ii) Explain why the aqueous solution of this complex ion has an acidic pH by considering the interaction between the metal ion and the ligands.

(2)

H_2O ligands

The ~~metal ion~~ forms dative covalent bonds with the ~~metal metal ion~~ Cr^{3+} ion when $Cr_2(SO_4)_3$ dissolves in water H_2SO_4 will be produced which makes the pH acidic

ResultsPlus
Examiner Comments

It is true that the water ligands form dative covalent bonds with the Cr^{3+} ion. However, these bonds are present in all complex ions and the majority of candidates did not realise that the small, highly charged metal ion would weaken the O-H bonds. This would then result in the loss of a proton.

This response scored 0.

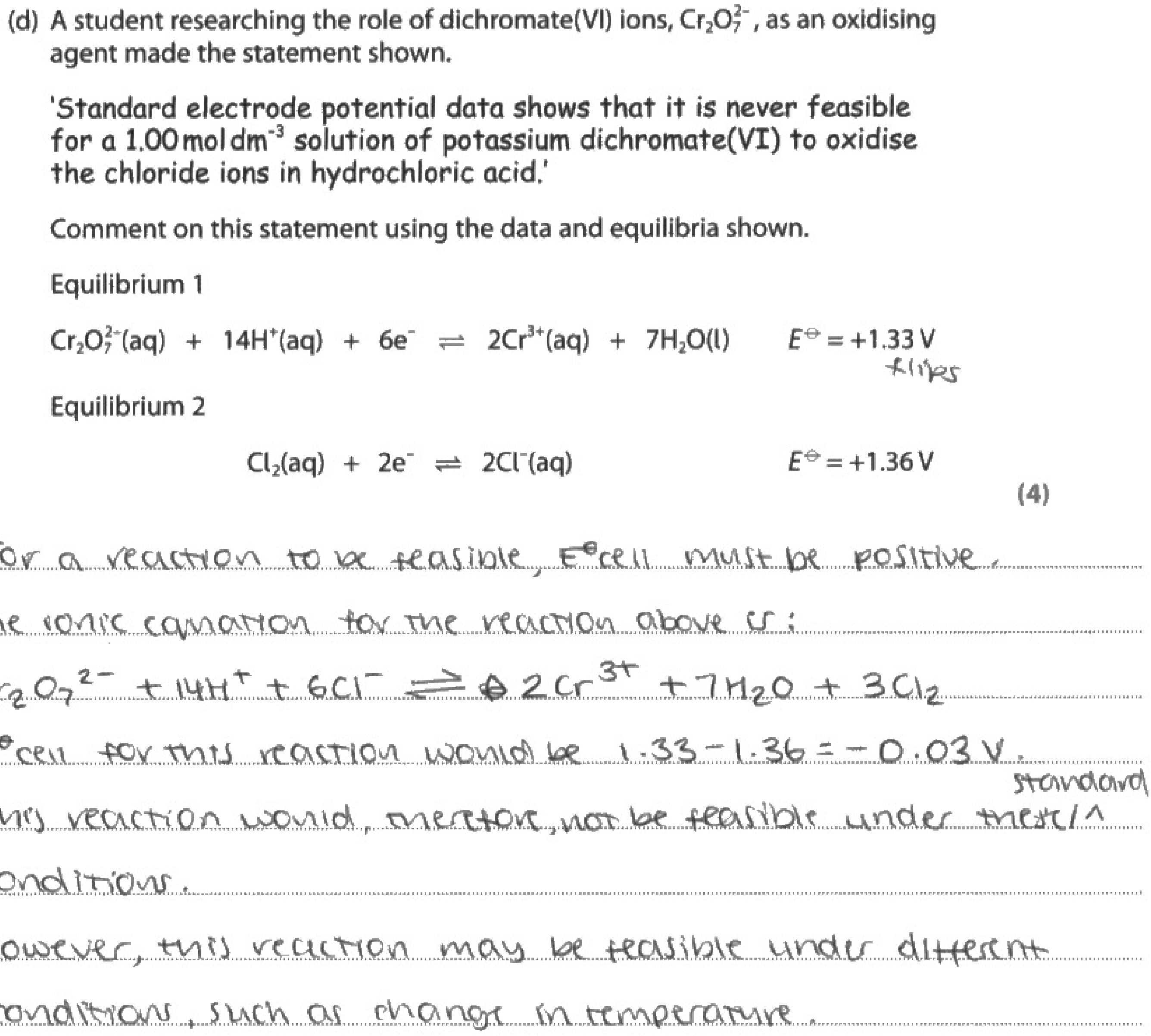
ResultsPlus
Examiner Tip

This question is about an acidic pH, so your answer should refer to the production of H^+ ions from the ligands.

Question 7 (d)

Questions that use the command word 'Comment on', and that are worth 4 marks, require detailed answers. A list of the meanings of all the command words used in question papers is given in the specification.

Some candidates just wrote one or two lines for their answers so would not be able to score high marks. Candidates were expected to calculate the E_{cell} value for the required reaction, but some were unable to do that correctly. They could then deduce that the negative value meant that the reaction is not feasible under standard conditions. However, the value is so small that changing the conditions may change the feasibility of the reaction. They could then explain the effect of changing the concentration of hydrochloric acid.



(d) A student researching the role of dichromate(VI) ions, $Cr_2O_7^{2-}$, as an oxidising agent made the statement shown.

'Standard electrode potential data shows that it is never feasible for a 1.00 mol dm^{-3} solution of potassium dichromate(VI) to oxidise the chloride ions in hydrochloric acid.'

Comment on this statement using the data and equilibria shown.

Equilibrium 1

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$ $E^\ominus = +1.33\,V$

flips

Equilibrium 2

$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$ $E^\ominus = +1.36\,V$

(4)

For a reaction to be feasible, $E^\ominus$cell must be positive.

The ionic equation for the reaction above is:

$Cr_2O_7^{2-} + 14H^+ + 6Cl^- \rightleftharpoons 2Cr^{3+} + 7H_2O + 3Cl_2$

$E^\ominus$cell for this reaction would be $1.33 - 1.36 = -0.03\,V$.

This reaction would, therefore, not be feasible under these standard conditions.

However, this reaction may be feasible under different conditions, such as change in temperature.

ResultsPlus
Examiner Comments

This response scored 2 marks.

The candidate has worked out the E_{cell} value for the required reaction and deduced that it is feasible. However, there is no comment on the small value of –0.03 V, so changing the conditions may change the feasibility of the reaction. They have also realised that if the temperature is changed, the reaction may become feasible.

ResultsPlus
Examiner Tip

Also consider other factors that affect the feasibility, such as changing the concentration of the hydrochloric acid. This contains H^+ and Cl^- ions so will affect both equilibria.

Question 8

Candidates who knew about different catalysts scored high marks on this question. The indicative point that was most frequently missing was reference to both catalysts providing an alternative mechanism with a lower activation energy. Some candidates were not so familiar with this topic and they used incorrect terminology, such as referring to homolytic and heterolytic catalysts instead of homogeneous and heterogeneous and absorption instead of adsorption. Some candidates did not explain that the reaction between ethanedioate ions and manganate(VII) ions starts slowly as both ions are negatively charged to repel each other.

***8** Transition metals and their compounds can act as catalysts in many reactions such as the ones shown:

- platinum, Pt, in the catalytic converters of vehicles
- manganese(II) ions, Mn^{2+}(aq), in the oxidation of ethanedioate ions, $C_2O_4^{2-}$(aq), by manganate(VII) ions, MnO_4^-(aq).

Compare and contrast the role of the catalysts in these reactions.

(6)

- in both these situations, the catalyst increases the rate of reaction

- in catalytic converters, hetereogenous catalysis occurs as the catalyst (a solid) is in a different state to the reactants (gases):

  - in a catalytic converter, the following reaction occurs : ~~$2CO + 2NO_2 \rightarrow N_2 + 2CO_2$~~

    $2CO_{(g)} + 2NO(g) \longrightarrow N_2(g) + 2CO_2(g)$

  - the CO and NO adsorb onto the surface of the platinum
  - the platinum weakens the C-O and N-O bonds causing CO_2 and N_2 to be produced
  - the CO_2 and N_2 then desorb from the catalyst's surface

- with the oxidation of $C_2O_4^{2-}$, autocatayisis occurs. The reaction produces Mn^{2+} ions which catalyse the reaction. Therefore, the reaction is initially slow as the $C_2O_4^{2-}$ and MnO_4^- ions repel each other but becomes faster as the Mn^{2+} ions produced catalyse the reaction as follows:

  overall: $MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + 8H^+(aq) \longrightarrow 10CO_2^{(g)} + Mn^{2+}_{(aq)} + 4H_2O_{(aq}$

intermediate:

$4Mn^{2+} + MnO_4^- + 8H^+ \rightarrow 5Mn^{3+} + 4H_2O$

$2Mn^{3+} + C_2O_4^{2-} \rightarrow 2Mn^{2+} + 2CO_2$

- the reaction is catalysed through the production of an intermediate.

ResultsPlus
Examiner Comments

IP1 is not awarded as there is no mention of both catalysts providing alternative mechanisms with lower activation energies.

IP2 is not awarded as both heterogeneous and homogeneous catalysts need to be specified.

IP3 and IP4 are awarded for the explanation of how platinum acts as a catalyst.

IP5 and IP6 are awarded for the explanation of how Mn^{2+} ions act as a catalyst.

4 Indicative points gives 3 marks and 1 mark is awarded for structure and lines of reasoning giving a total of 4 marks.

ResultsPlus
Examiner Tip

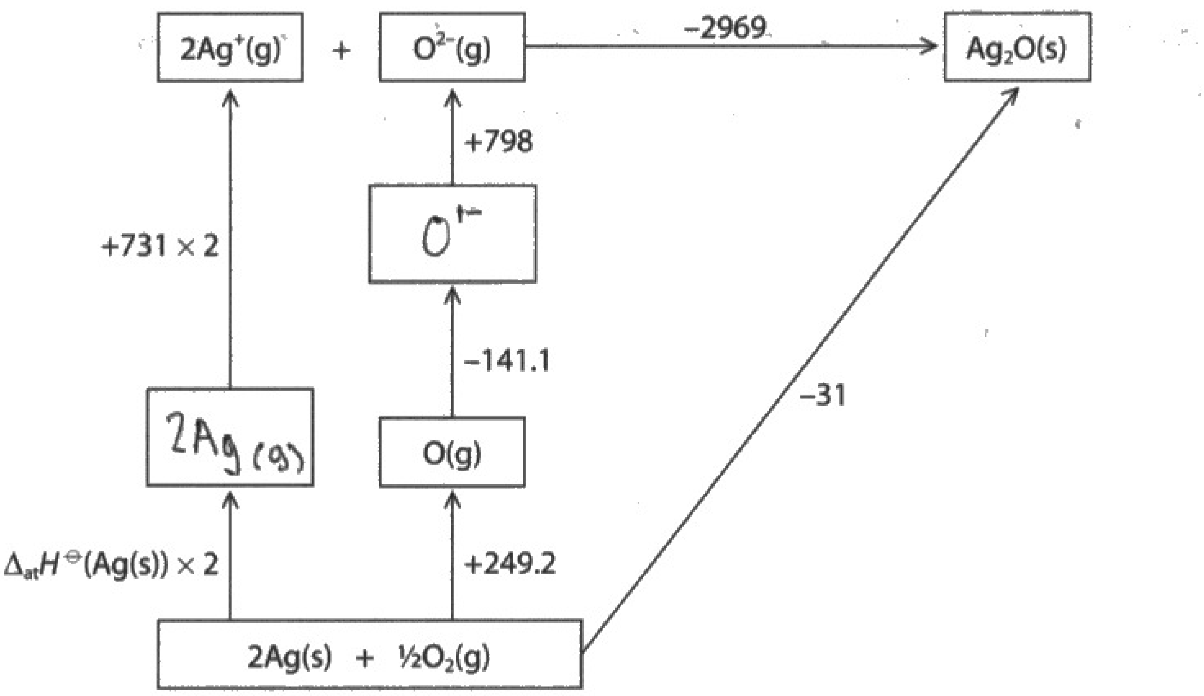
Try to give as much detail as possible in extended open response questions.

Question 9 (a)(i)

The majority of candidates scored 2 marks for this question. Common errors included: giving (s) as the state symbol for silver, omitting the 2 in front of Ag and adding an electron to the box with the O^-(g).

9 This question is about silver compounds.

(a) The diagram shows a Born–Haber cycle for the formation of silver(I) oxide, Ag_2O.
All quantities are measured in kJ mol^{-1}.



(i) Complete the diagram by adding appropriate species and state symbols to the empty boxes.

ResultsPlus
Examiner Comments

This response scored 1 mark for 2Ag(g).

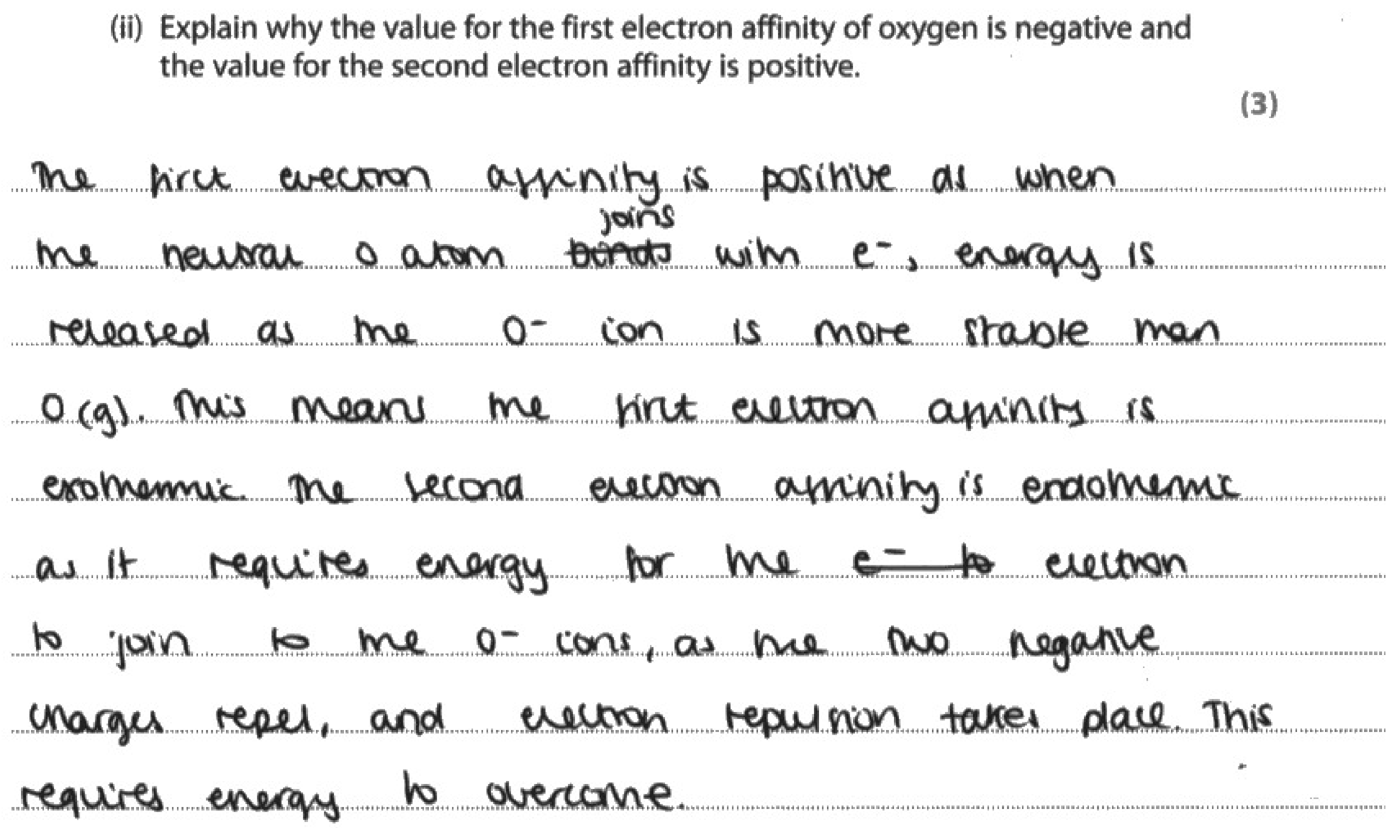
The second mark was not awarded as the candidate omitted the state symbol.

ResultsPlus
Examiner Tip

Read the question carefully and check to make sure that you have included all the required information.

Question 9 (a)(ii)

This question showed that many candidates are confused between positive and negative enthalpy change values and whether the process is endothermic or exothermic. Only a small minority of candidates understood why the first electron affinity of oxygen (and other elements) is exothermic. The majority realised that the second electron affinity is endothermic due to repulsion but some just referred to electron-electron repulsion. Some candidates were confused and thought a negative value indicated an endothermic process and some thought that energy is needed to form bonds or attractions. Some candidates discussed removing electrons and scored 0 for this question.



(ii) Explain why the value for the first electron affinity of oxygen is negative and the value for the second electron affinity is positive.

(3)

The first electron affinity is positive as when the neutral O atom ~~bonds~~ joins with e^-, energy is released as the O^- ion is more stable than O (g). This means the first electron affinity is exothermic. The second electron affinity is endothermic as it requires energy for the ~~e^- to~~ electron to join to the O^- ions, as the two negative charges repel, and electron repulsion takes place. This requires energy to overcome.

ResultsPlus
Examiner Comments

This is an example of a common style of response where the candidate is unable to explain why the first electron affinity is negative, but they have a good understanding of why the second electron affinity is positive.

This response scored 2 marks.

Examiner Tip

The first electron affinity of an atom is always exothermic as there is an attraction between the positive nucleus in the neutral atom and the incoming electron.

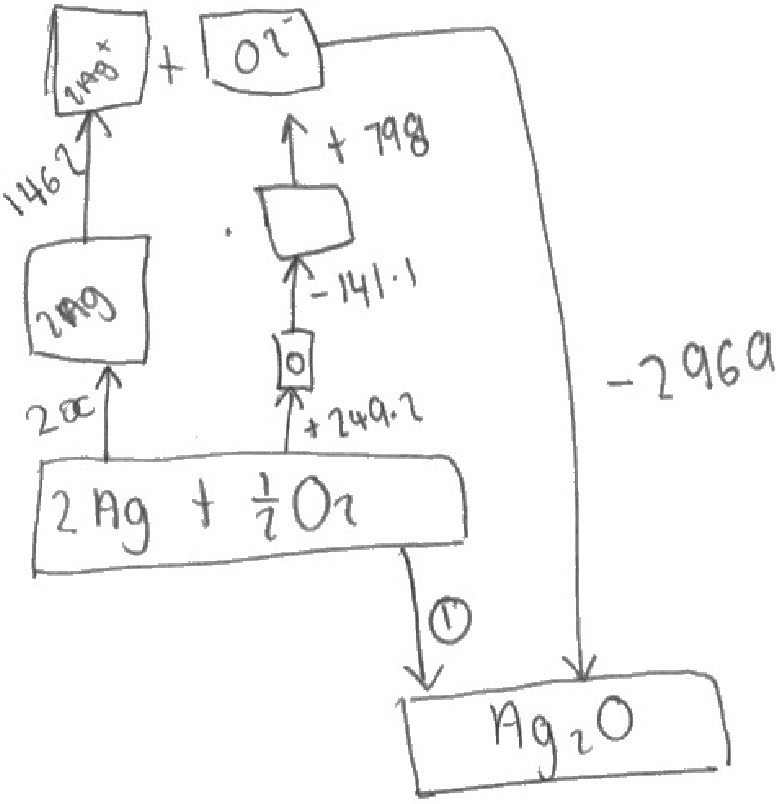
Question 9 (a)(iii)

Many candidates carried out a correct calculation using the Born-Haber cycle and scored full marks.

Some candidates were unable to use the cycle to calculate the standard enthalpy change of atomisation of silver and some omitted to divide by 2 as there are two silver atoms.

(iii) Calculate a value for the standard enthalpy change of atomisation of silver, $\Delta_{at}H^{\ominus}$, using the Born–Haber cycle.

(3)



$1 = 2 + 3 + 4 + 5 + 6 + 7$

$-31 = 2x + 249.2 + 1462 + (-141.1) + 798 + (-2969)$

$2x = -31 - 249.2 - 1462 - (-141.1) - 798 - (-2969)$

$2x = 569.9$

$x = \frac{569.9}{2}$

$x = 248.95$

$\Delta_{at}H^{\ominus}$ of silver $= 248.95$ Jkmol^{-1}

ResultsPlus
Examiner Comments

This answer has a correct cycle and working for the calculation.

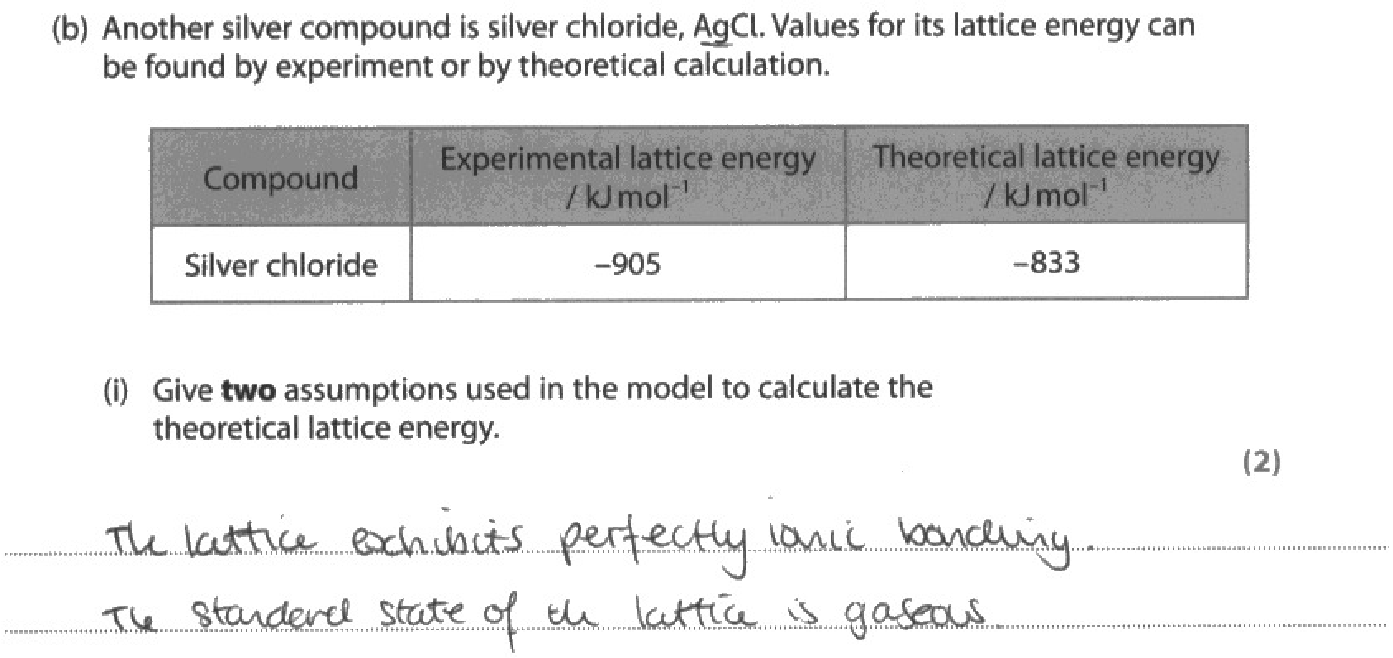
Unfortunately, the candidate has made an error when copying the final answer from their calculator and written 248.95 instead of 284.95 so scored 2 instead of 3 marks.

ResultsPlus
Examiner Tip

Check your working and final answer carefully to make sure that you have not made an error.

Question 9 (b)(i)

Many candidates could give two of the assumptions used in the model to calculate the theoretical lattice energy. However, many gave some of the general assumptions made in enthalpy change calculations, such as no heat lost to the surroundings.



(b) Another silver compound is silver chloride, AgCl. Values for its lattice energy can be found by experiment or by theoretical calculation.

Compound	Experimental lattice energy / kJ mol^{-1}	Theoretical lattice energy / kJ mol^{-1}
Silver chloride	−905	−833

(i) Give **two** assumptions used in the model to calculate the theoretical lattice energy.

(2)

The lattice exhibits perfectly ionic bonding.

The standard state of the lattice is gaseous.

ResultsPlus
Examiner Comments

This response scored 1 mark for the idea of perfect ionic bonding. A crystal lattice is a solid, not a gas.

ResultsPlus
Examiner Tip

Learn the assumptions used in the model to calculate the theoretical lattice energy.

Question 9 (b)(ii)

The majority of candidates realised that the difference in the two values of lattice energy is due to some covalent character in silver chloride and that it is the small silver cation that polarises the larger chloride anion. Some candidates thought the silver ion is larger than the chloride ion or gave incorrect charges on the ions. Not many candidates stated that the experimental lattice energy is more exothermic than the theoretical lattice energy as the covalent character makes the bonding stronger.

(ii) Explain the difference in the two values for the lattice energy of silver chloride by considering the possible bonding models.

(3)

There is a little covalent character in silver chloride as there is a small difference in the experimental value and the theoretical value. It mostly has ionic characters as there is a small charge density on the Ag^+ as it is a large atom with 1+ charge and there is a small charge density on the Cl^- ion as it has −1 charge but it has a smaller ionic radius so is able to pull electrons from the Ag+.

ResultsPlus
Examiner Comments

This response scored 1 mark for the idea that there is a little covalent character in silver chloride. Unfortunately, the candidate has mixed up the ion sizes and which ion does the polarising so no further marks could be awarded.

ResultsPlus
Examiner Tip

Remember that it is cations (positive ions) that polarise anions (negative ions).

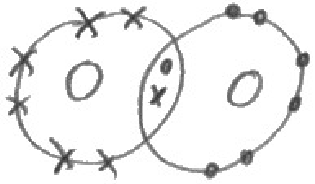
Question 10 (a)

The majority of candidates could draw a correct dot-and-cross diagram for an oxygen molecule. A small number of candidates did not include a double covalent bond and some showed three lone pairs of electrons on each oxygen.

10 Manganese compounds can be used to determine the amounts of dissolved molecular oxygen in water samples.

(a) Draw the dot-and-cross diagram for an oxygen molecule, O_2.
Show outer shell electrons only.

(1)



ResultsPlus
Examiner Comments

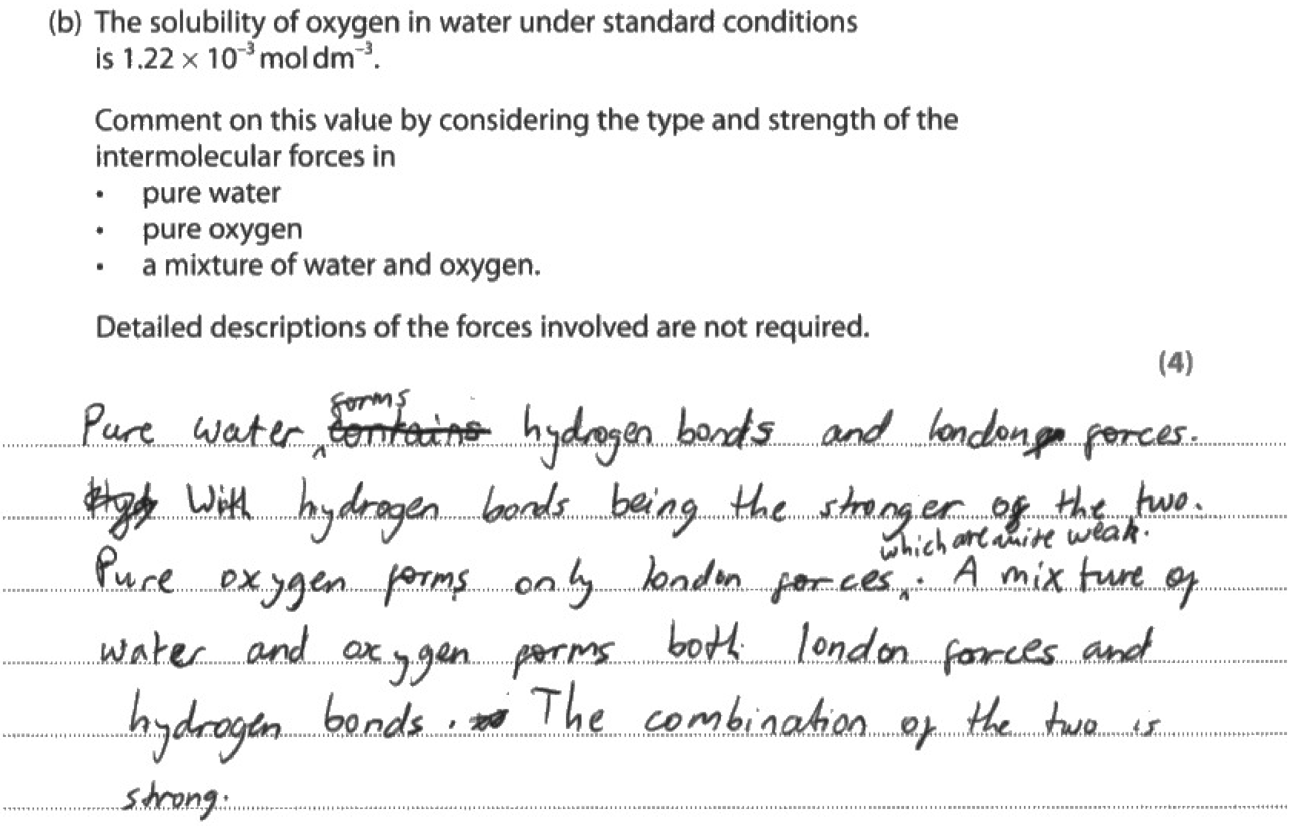
This dot-and-cross diagram on an oxygen molecule is incorrect so did not score a mark.

ResultsPlus
Examiner Tip

The periodic table shows that the atomic number of oxygen atoms is 8 so there are 8 electrons and they are arranged 2.6. There needs to be a double covalent bond between the two atoms so they each have 8 electrons in their outer shell.

Question 10 (b)

Many candidates could identify the intermolecular forces present in pure water and in pure oxygen. Only a minority of candidates referred to the low solubility of oxygen in water and deduced that there must only be London forces between oxygen and water molecules. Some candidates thought that the value of 1.22×10^{-3} mol dm^{-3} indicates a high solubility.



(b) The solubility of oxygen in water under standard conditions is 1.22×10^{-3} mol dm^{-3}.

Comment on this value by considering the type and strength of the intermolecular forces in

- pure water
- pure oxygen
- a mixture of water and oxygen.

Detailed descriptions of the forces involved are not required.

(4)

Pure water ~~contains~~ forms hydrogen bonds and london~~g~~ forces. ~~Hyd~~ With hydrogen bonds being the stronger of the two. Pure oxygen forms only london forces which are quite weak. A mixture of water and oxygen porms both london forces and hydrogen bonds. ~~so~~ The combination of the two is strong.

ResultsPlus
Examiner Comments

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

The candidate has identified that there are hydrogen bonds between water molecules and only London forces between oxygen molecules. The candidate has not made use of the low value for the solubility of oxygen in water to complete their answer.

ResultsPlus
Examiner Tip

Use all the data given in the question. The very low solubility of oxygen in water shows that the oxygen molecules are unable to disrupt the hydrogen bonding in water.

(b) The solubility of oxygen in water under standard conditions is 1.22×10^{-3} mol dm^{-3}.

Comment on this value by considering the type and strength of the intermolecular forces in

- pure water
- pure oxygen
- a mixture of water and oxygen.

Detailed descriptions of the forces involved are not required.

(4)

Pure water has London forces, permanent dipole-dipole interactions and hydrogen bonding. Hydrogen bonding is the strongest intermolecular force which requires most energy to overcome.

Pure oxygen only has weak London forces which require little energy to overcome.

So oxygen ~~is~~ has a low solubility in water as oxygen cannot form hydrogen bonds with water as it is not a highly polar molecule, and can only form weak London forces with water.

ResultsPlus
Examiner Comments

This is an example of a clear answer that scored 4 marks.

ResultsPlus
Examiner Tip

Set out your answers in a clear, concise and logical way, as in this example.

Question 10 (c)(i-ii)

Many candidates were able to score 4 or 5 marks for the unstructured titration calculation in (i). Some candidates did not use the mole ratios given in the equations and some just worked out the concentration of oxygen in mol dm^{-3} instead of g dm^{-3}. A few used an incorrect M_r of oxygen as 16 or even 18.

Only a small minority of candidates could calculate the concentration of oxygen in ppm as most of them didn't notice that one piece of data was in g dm^{-3} and the other was in g cm^{-3}.

(c) The amount of dissolved oxygen in a sample of river water was found using the process outlined.

- excess alkaline manganese(II) sulfate, $MnSO_4$, was added to a 150 cm³ sample of river water
- the Mn^{2+} ions reacted with the dissolved oxygen forming a precipitate of manganese(IV) oxide hydroxide

$$2Mn^{2+}(aq) + O_2(aq) + 4OH^-(aq) \rightarrow 2MnO(OH)_2(s)$$

- the precipitate was then dissolved using excess sulfuric acid, forming $Mn^{4+}(aq)$ ions

$$MnO(OH)_2(s) + 4H^+(aq) \rightarrow Mn^{4+}(aq) + 3H_2O(l)$$

- excess potassium iodide solution was then added, forming iodine

$$Mn^{4+}(aq) + 2I^-(aq) \rightarrow Mn^{2+}(aq) + I_2(aq)$$

- the liberated iodine was then titrated with sodium thiosulfate solution, $Na_2S_2O_3(aq)$, of concentration 0.00518 mol dm⁻³

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

- the mean volume of the titre of $Na_2S_2O_3(aq)$ was 34.20 cm³.

(i) Calculate the concentration of dissolved oxygen in the sample of river water, in g dm⁻³.

(5)

mol ($S_2O_3^{2-}$) = 0.00518 × 0.0342 = 1.77156×10^{-4}

mol (I_2) = 8.8578×10^{-5}

mol (I_2) = mol (Mn^{2+}) = mol (Mn^{4+}) = mol ($MnO(OH)_2$)

in first step : mol ($MnO(OH)_2$) = 1.77156×10^{-4}

mol (O_2) = 8.8578×10^{-5}

conc of O_2 : $\frac{8.8578 \times 10^{-5}}{0.15} = 5.9052 \times 10^{-4}$ moldm⁻³

4 ~~[illegible]~~ $5.9052 \times 10^{-4} \times 32 = 0.01889664$

$= 0.019$ g dm⁻³

(ii) The concentration of oxygen in water is often expressed in parts per million (ppm), where 1 ppm equals 1 g of solute dissolved in 1 × 10^6 g of solvent.

Calculate the concentration of the oxygen in the sample of river water in ppm. Assume the density of the river water is 1.00 g cm^{-3}.

(1)

1ppm = 1×10^6 g

~~0.01889664 x 1x106 = 18896.64 = 19,000 ppm dm⁻³~~

$$\frac{0.01889664}{1 \times 106} = 1.889664 \times 10^{-8}$$

$$= 1.9 \times 10^{-8} \text{ ppm dm}^{-3}$$

ResultsPlus
Examiner Comments

(i) This calculation scored 4 marks.

The candidate has calculated the amounts of sodium thiosulfate and iodine correctly. However, they did not use the mole ratios given in the equations to calculate the amount of O_2 correctly. The candidate completed the calculation using the correct steps of working out the concentration of O_2 in mol dm^{-3} and g dm^{-3} so they could be awarded transferred error marks.

(ii) This answer is incorrect so did not score a mark.

The candidate has not realised that the density of water is given as 1.00 g cm^{-3} but the concentration of oxygen is in g dm^{-3}.

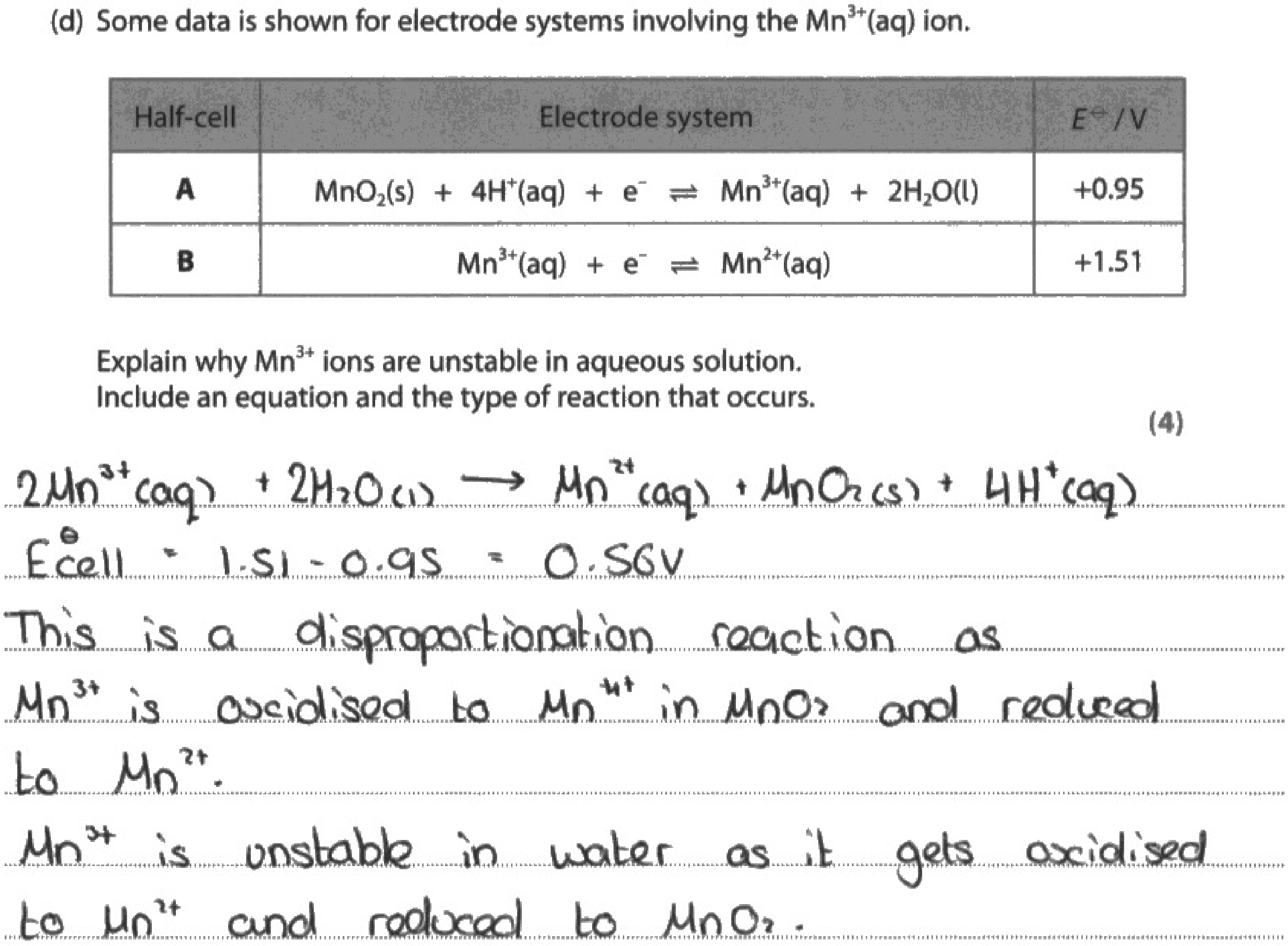
ResultsPlus
Examiner Tip

(i) Set out your working for calculations clearly and state what you are calculating in each step, as in this example. If you do make a mistake part the way through, the examiner can award transferred error marks if they can follow your working, so you are only penalised once for an error.

(ii) Look carefully at any units given in the question.

Question 10 (d)

Many candidates were able to show that Mn^{3+} ions are unstable in aqueous solution by writing the overall equation and calculating the positive E_{cell} value. A few candidates were unable to calculate a correct E_{cell} value as they added the separate standard electrode potential values. Many candidates knew this is a disproportionation reaction but not all of them explained that the Mn^{3+} ions are oxidised to MnO_2 and reduced to Mn^{2+}.



(d) Some data is shown for electrode systems involving the Mn^{3+}(aq) ion.

Half-cell	Electrode system	$E^{\ominus}$ / V
A	$MnO_2(s) + 4H^+(aq) + e^- \rightleftharpoons Mn^{3+}(aq) + 2H_2O(l)$	+0.95
B	$Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$	+1.51

Explain why Mn^{3+} ions are unstable in aqueous solution.
Include an equation and the type of reaction that occurs.

(4)

$2Mn^{3+}(aq) + 2H_2O(l) \longrightarrow Mn^{2+}(aq) + MnO_2(s) + 4H^+(aq)$

$E^{\ominus}_{cell} = 1.51 - 0.95 = 0.56V$

This is a disproportionation reaction as Mn^{3+} is oxidised to Mn^{4+} in MnO_2 and reduced to Mn^{2+}.

Mn^{3+} is unstable in water as it gets oxidised to Mn^{2+} and reduced to MnO_2.

ResultsPlus
Examiner Comments

This is an example of a clear answer that scored 4 marks.

The candidate has written the overall equation, calculated the E_{cell} value to show that it is feasible and explained why it is a disproportionation reaction.

ResultsPlus
Examiner Tip

Check your answers to make sure that you have included everything that has been asked for. When standard electrode potential values are given, you should use them to calculate E_{cell}.

Paper Summary

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

- Always read the question carefully and check that you have understood what is required, for example, do not write about ionisation energy when you are asked about melting temperature.
- After you have written your answer, re-read the question and your answer to ensure you have fully answered the question.
- Learn the meanings of as many of the key scientific words in each topic and practise using them in your answers to past papers.
- Explain all your working in unstructured calculations so that if you make an error, you have the opportunity to be awarded transferred error marks.
- Practise answering extended writing questions, so you understand how to improve your performance by giving more relevant details, or in some cases, by writing more concisely and not repeating points.
- Look at the command words in the specification and make sure that you understand what is required for each of them.

Grade boundaries

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