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June 2025

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. This was the fourth series of Chemistry A Level papers in the June examination series that had been sat by candidates since 2019 due to the impact of the Coronavirus pandemic.

The paper proved accessible to all candidates and there was no evidence that any were hindered by not having sufficient time to complete their answers. A number of the questions were found to be demanding and it was pleasing to note that many candidates rose to the challenge and demonstrated their knowledge and understanding of A Level Chemistry.

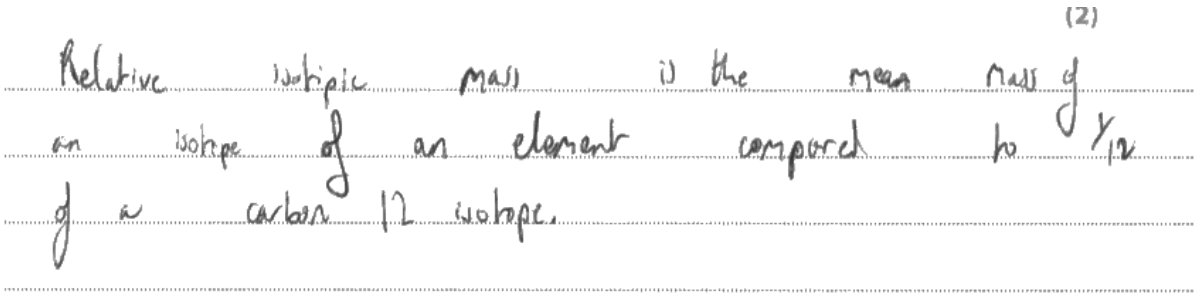
There were common errors of exam technique such as failing to double check answers, giving answers to the wrong number of significant figures, use of the correct terminology (ions vs atoms) and not reading the question properly before giving an answer. However, it was clear that many candidates were well prepared and were able to overcome the challenges of the last few years. Nonetheless, there are some key lessons for centres and candidates to learn from the feedback illustrated in the following examples.

Question 1(a)

This was an introduction question regarding the definition of the relative isotopic mass of an element.

Many fully correct answers were seen.

Common errors were the use of weighted/ average and mean mass of the atom, or the atom missing entirely.



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Examiner Comments

This is an example of a fully correct answer and scores all two marks.

The average mass of an ~~atom~~ isotope relative to $\frac{1}{12}$ of an atom carbon - 12 (2)

ResultsPlus
Examiner Comments

This response scores one mark.

The candidate has used the term average mass of an isotope and missed out the isotope atom, however is it correctly compared to 1/12 th of an atom of Carbon 12.

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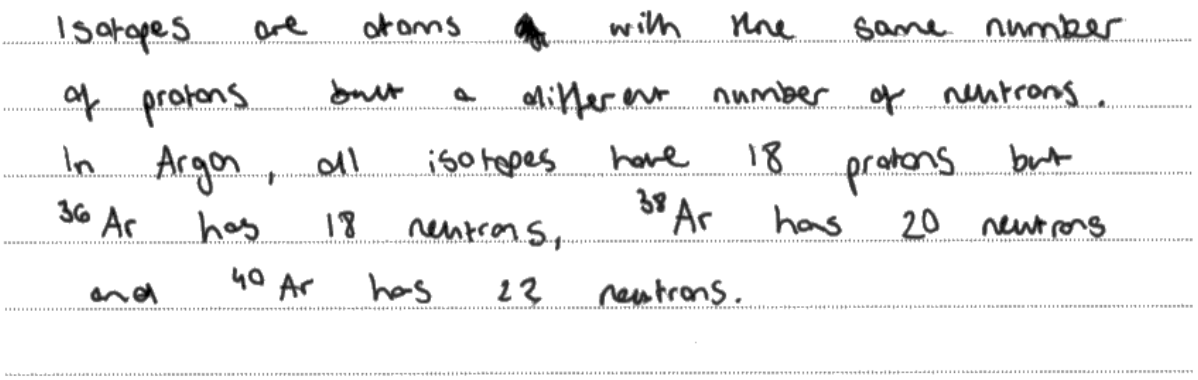
Examiner Tip

Always remember to specify Carbon 12.

Question 1(b)

This question required the candidates to explain what an isotope is with reference to Argon.

Many candidates could give the definition of an isotope but failed to refer to the three different isotopes of Argon given.



ResultsPlus
Examiner Comments

This is a fully correct example where the candidate has given the definition and included the number of protons and the number of neutrons for all three isotopes of Argon. This response scores two marks.

An isotope is a version of an atom of an element with the same number of protons but a different number of neutrons.

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Examiner Comments

This response just scores one mark for the basic description of an isotope.

Question 1(c)

This question required the candidates to calculate the relative atomic mass of Argon from the relative abundances of the different isotopic masses.

$$\frac{(35.97 \times 0.337) + (37.96 \times 0.063) + (39.96 \times 99.6)}{100} = \quad (2)$$

= 39.94529...

= 39.95 (2dp)

ResultsPlus
Examiner Comments

This is a fully correct answer scoring two marks.

$$R.A.M. = \frac{36 \times 0.337 + 38 \times 0.063 + 40 \times 99.600}{100}$$

$$R.A.M. = 39.99 \text{ to } 2dp$$

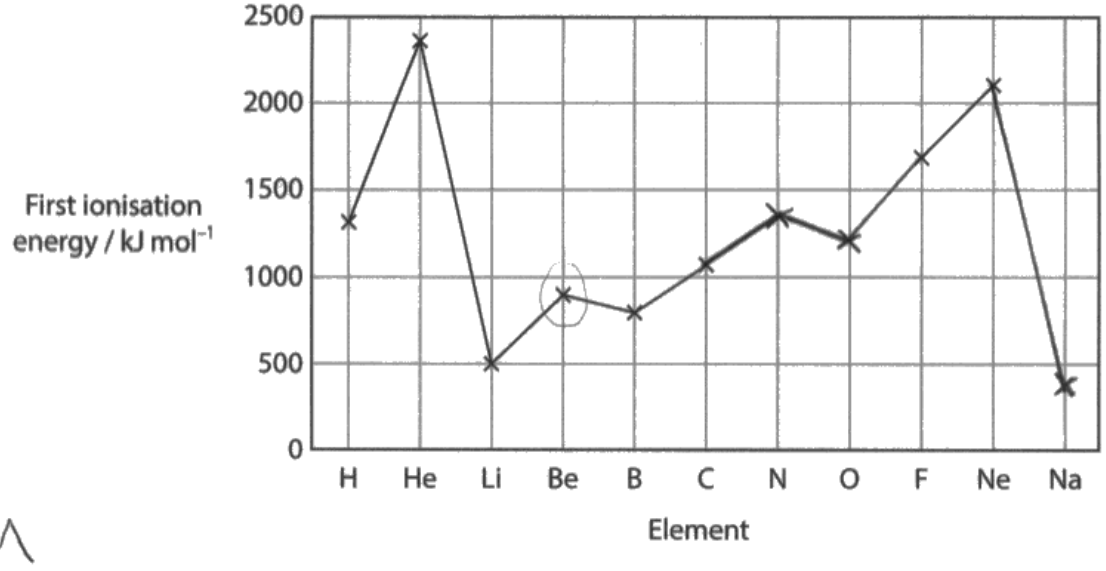
ResultsPlus
Examiner Comments

Here the candidate has incorrectly used the isotope number rather than the isotopic mass, so for 36 Ar they have used 36 rather than 35.97.

However the value has been correctly given to 2dp so the response scores one mark.

Question 2(a)

This question asked the candidates to fill in the missing first Ionisation Energies for the first 11 elements, by plotting points on a graph.



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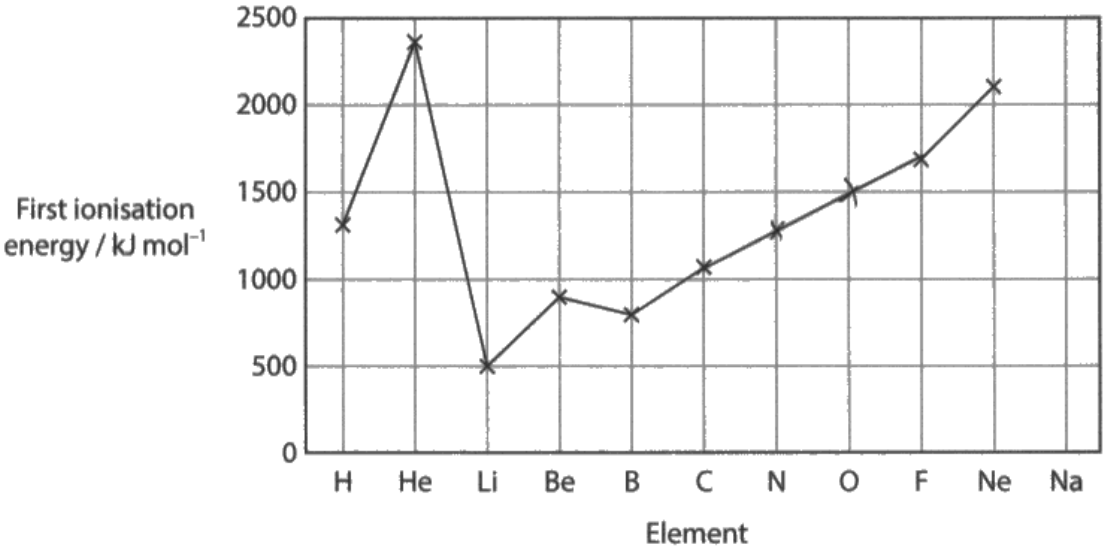
Examiner Comments

This response is a fully correct answer and scores three marks.

Complete the graph by including the points for nitrogen, oxygen, and sodium.

(3)



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Examiner Comments

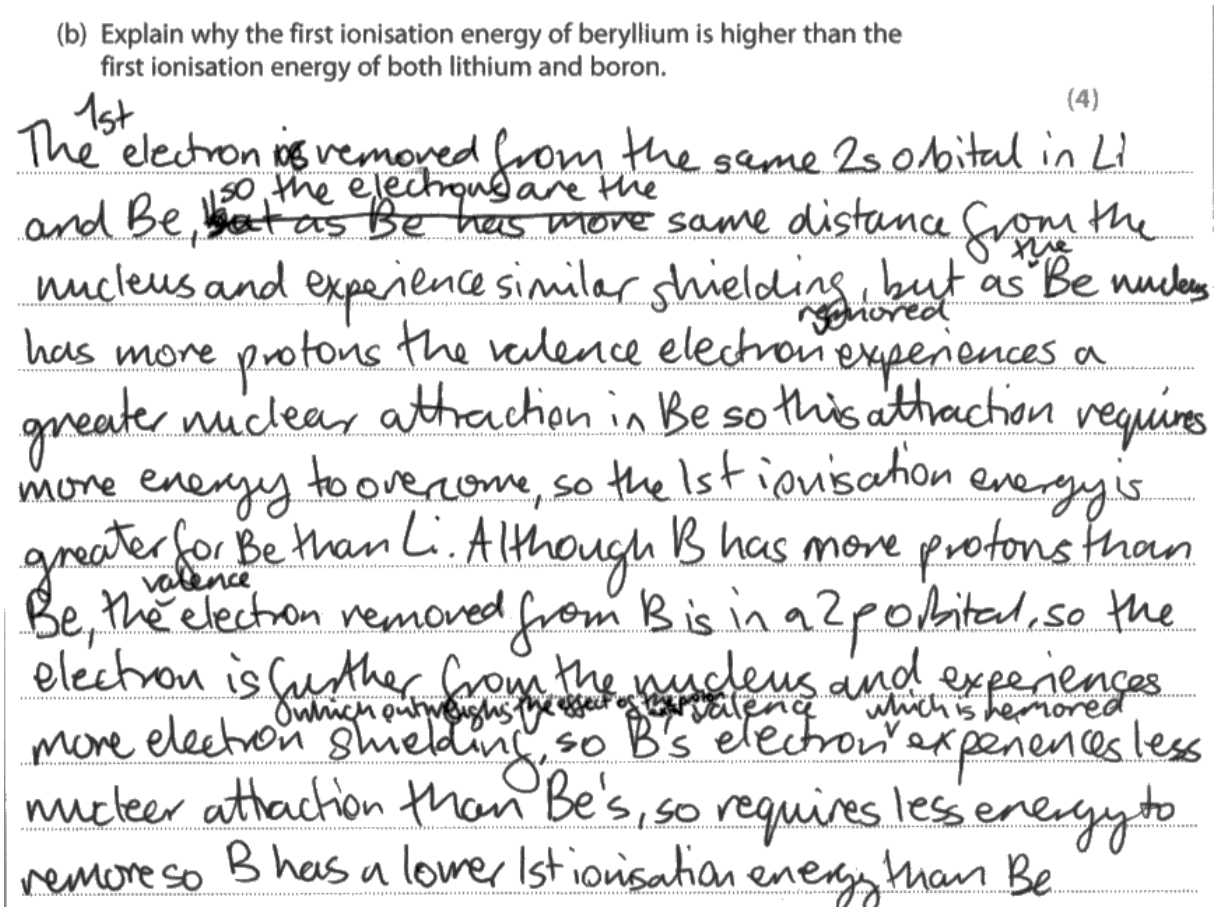
This response scored zero.

This candidate has failed to plot Na, and they have missed the step change between N and O at the point where the p orbital gains the 4th electron.

Question 2(b)

The question required the candidates to explain why the first Ionisation Energy of Beryllium was higher than both Lithium and Boron. It was looking for the candidate to show the relationship between the proton number and the effect on the outer electron of the nuclear attraction and repulsion from other electrons.

This proved challenging for a proportion of the candidates, some of whom ignored the effect of the nucleus entirely.



(b) Explain why the first ionisation energy of beryllium is higher than the first ionisation energy of both lithium and boron.

(4)

The 1st electron is removed from the same 2s orbital in Li and Be, so the electrons are the same distance from the nucleus and experience similar shielding, but as the Be nucleus has more protons the valence electron experiences a greater nuclear attraction in Be so this attraction requires more energy to overcome, so the 1st ionisation energy is greater for Be than Li. Although B has more protons than Be, the valence electron removed from B is in a 2p orbital, so the electron is further from the nucleus and experiences more electron shielding, so B's valence electron which is removed experiences less nuclear attraction than Be's, so requires less energy to remove so B has a lower 1st ionisation energy than Be

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Examiner Comments

This response is fully correct and scores four marks.

The first two marks are for the comparison of Lithium and Beryllium with their valence electrons in the same 2s orbital so same shielding and the extra proton in Beryllium meaning there is greater nuclear attraction.

The second two marks are scored for the statement that although Boron has more protons its valence electron is in the 2p orbital so experiences more shielding and less nuclear attraction so easier to remove.

ResultsPlus
Examiner Tip

Be careful on being accurate in your description of the electron, outer or valence.

Beryllium ~~in~~ ~~a~~ ~~a~~ first ionisation energy is higher than lithium because it has more electrons than lithium therefore it ~~has~~ is a bigger atom than lithium so the energy required to remove one electron is greater because of the stronger london forces.
Beryllium first ionisation energy is greater than boron because is a non-metal

ResultsPlus
Examiner Comments

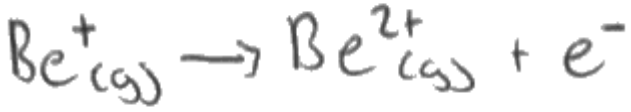
This response scores zero.

The fact that Beryllium has more electrons and is a bigger atom is too vague to score any mark.

Question 2(c)

This question asked the candidates to give the equation for the second ionisation energy for Beryllium.

This required them to recognise two things, that Beryllium was already Be+ and that the required state for IE is gaseous.



ResultsPlus
Examiner Comments

Fully correct answer which scored one mark.

(c) Write the equation for the **second** ionisation energy of beryllium.
Include state symbols.

(1)

$Be + 2e^- \rightarrow Be^{2-}$

This answer scores zero.

There are three errors: starts with Be not Be + , adds electrons and the states are missing.

Question 2(f)

This proved to be a challenging question for many candidates. They were required to explain the trend in boiling temperatures for H_2O, HF, HCl and HI in terms of the intermolecular forces between the compounds.

Permanent dipole - dipole interactions were often missed or if mentioned there was no indication if they were stronger or weaker than hydrogen bonding. There was also some confusion around the halogen hydrides in terms of covalency vs ionic, and quite which bonds are broken when a substance boils.

All four compounds contain London forces. London forces are greatest in ~~the~~ HI because it has the most electrons. All four compounds contain permanent dipole-dipole forces, only H_2O and HF form hydrogen bonds, which are stronger than London forces and permanent dipole-dipole forces which is why they have the two highest boiling temperatures. Water forms more hydrogen bonds per molecule than hydrogen fluoride ~~so~~ so more energy ~~the bonds~~ and forces required to overcome bonding in water than in hydrogen fluoride hence, why it has a higher boiling temperature (despite both containing H bonds). HI has a higher boiling temperature than HCl because there are more electrons so stronger London forces and the greater London forces outweigh the higher electronegativity difference in HCl (HCl = 0.9, HI = 0.4) so more energy required to overcome forces in HF than in HCl.

ResultsPlus
Examiner Comments

This response is neatly laid out and the points are clear and scores five marks from the six available as they have failed to be specific about the number of hydrogen bonds in water compared to hydrogen fluoride.

- Differences in boiling points are due to the differences of bonding of each compound.
- Water has the highest boiling point because it is made of hydrogen bonding which it has strong intermolecular forces between bonds. Lots of energy is needed to break bonds apart.
- HF, HCl and HI are all made up of ionic bonding. This is the strong electrostatic force between oppositely charged ions.
- HF has more london forces than / compared to the group 7 compounds.
- HCl has lowest boiling point because it has weaker intermolecular forces. It also has a larger ionic radius so has less nuclear attraction.
- Water has highest boiling because outer electron in subshell are closer to nucleus, so there is more attraction between molecules.
- In group 7 compounds shielding increases down the group.

ResultsPlus
Examiner Comments

This response fails to score. Whilst they do state water has hydrogen bonding they needed to state HF also has hydrogen bonding. The answer then becomes more confused as they start talking about ionic bonding and electrostatic forces of attraction. They then switch back to intermolecular forces, but have HF having more so clearly do not know how they form.

Question 3(a)

This question asked why it is not possible to directly measure the enthalpy change for the decomposition of $CaCO_3$.

We are looking for the idea of the difficulty in measuring a temperature change when heating a compound.

Heat change cannot be measured since the decomposition requires heating.

ResultsPlus
Examiner Comments

This response scores one mark.

because incomplete decomposition can take place producing CO which is toxic

ResultsPlus
Examiner Comments

This response fails to score, there is some merit to the incomplete decomposition but the production of CO is irrelevant as we are looking for measuring temperature change.

Question 3(b)

This question required the candidates to work though a calculation on enthalpy change for the decomposition of calcium carbonate.

The table was generally completed well. A few struggled with proving that the HCl was in excess. For the calculation most managed Q but then, rather than use the mol value of 0.41 given, they attempted to calculate moles from other values.

When it came to completing the cycle there were a number who were unsure what to put in the bottom box so put the elements rather than the formation of $CaCl_2(aq)$, $CO_2(g)$ and $H_2O(l)$. A few arrows went the wrong way too.

(b) The student placed a known mass of calcium carbonate in a polystyrene cup. generated from it
30.0 cm^3 of hydrochloric acid of concentration 3.00 mol dm^{-3} was added.
The mixture was stirred, and the highest temperature reached was recorded.

The equation for the reaction is shown.

Reaction **2**: $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

(i) Complete the missing data in the table for Reaction **2**.

(1)

Measurement	Value
Mass of weighing boat with calcium carbonate / g	4.30
Mass of weighing boat after emptying out calcium carbonate / g	0.20
Mass of calcium carbonate used / g	4.10
Temperature at the start / °C	19.0
Highest temperature / °C	25.4
Temperature change / °C	5.5

(ii) 0.041 mol of $CaCO_3(s)$ was used in the experiment.

Show, by calculation, that the hydrochloric acid is in excess for Reaction **2**.

(2)

$CaCO_3 = 100.1$

or

$\frac{30}{1000} \times 3 = 0.09$ mol

0.041 mol

$\times 2 = 0.082$

$CaCO_3$ HCl

$0.082 < 0.09$ mol

∴ the HCl is in excess

(iii) Calculate the enthalpy change, $\Delta_r H_2$, for Reaction **2** in kJ mol^{-1}.
Include a sign in your answer.

[Assume the specific heat capacity of the solution = 4.18 J g^{-1} °C^{-1}
and the mass of the solution = 30 g]

(3)

$q = mc\Delta T$

$30 \times 4.18 \times 5.5 = 689.7\ J$

$689.7 \div 1000 = 0.6897\ kJ$

mols = 0.041 g $CaCO_3$

$\frac{-0.6897}{0.041} = -16.8219\ldots$

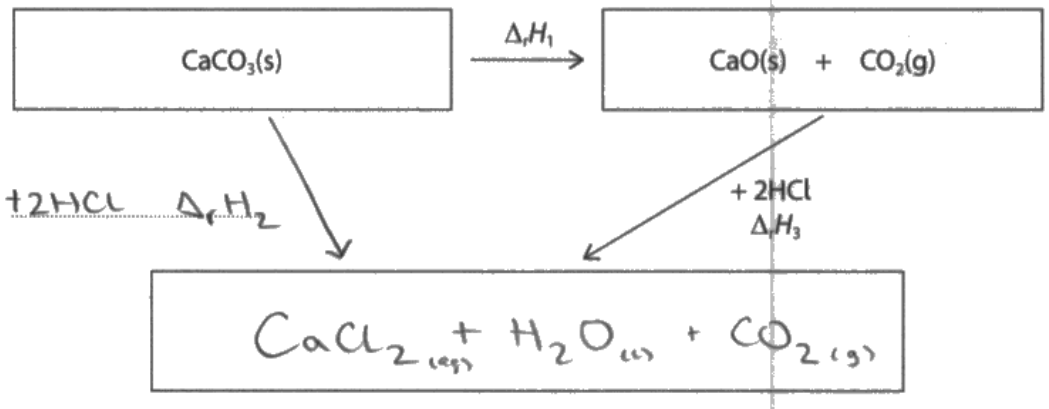
(3sf) : $-16.8\ kJ\ mol^{-1}$

(iv) The student carried out a similar procedure with calcium oxide.
The enthalpy change, $\Delta_r H_3$, calculated for Reaction **3** was −176.3 kJ mol^{-1}.

Reaction **3**: $CaO(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l)$

Complete the enthalpy cycle.
Include the correct substances with state symbols in the lower box.
Add an appropriately labelled arrow.

(2)



(v) Calculate a value for the enthalpy change $\Delta_r H_1$ for the thermal decomposition of calcium carbonate by using your cycle.

(1)

$-16.8 + 176.3 = 159.5\ kJ\ mol^{-1}$

ResultsPlus
Examiner Comments

This is a fully correct response, and scores nine marks.

(b) The student placed a known mass of calcium carbonate in a polystyrene cup. 30.0 cm^3 of hydrochloric acid of concentration 3.00 mol dm^{-3} was added. The mixture was stirred, and the highest temperature reached was recorded.

The equation for the reaction is shown.

Reaction **2**: $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

(i) Complete the missing data in the table for Reaction **2**.

(1)

Measurement	Value
Mass of weighing boat with calcium carbonate / g	4.30
Mass of weighing boat after emptying out calcium carbonate / g	0.20
Mass of calcium carbonate used / g	4.10
Temperature at the start / °C	19.0
Highest temperature / °C	24.5
Temperature change / °C	5.5

(ii) 0.041 mol of $CaCO_3(s)$ was used in the experiment.

Show, by calculation, that the hydrochloric acid is in excess for Reaction **2**.

(2)

$3 \times 0.03 = 0.09$ = moles of HCl

$0.09 > 0.041$

Hence HCl is in excess

(iii) Calculate the enthalpy change, $\Delta_r H_2$, for Reaction **2** in kJ mol^{-1}.
Include a sign in your answer.

[Assume the specific heat capacity of the solution = 4.18 J g^{-1} °C^{-1}
and the mass of the solution = 30 g]

(3)

$Q = mc\Delta T$

$30 \times 4.18 \times 5.5 = 689.7\text{J}$

moles = 0.041

$\frac{689.7}{0.041} = -16.8$ kJ/mol

(iv) The student carried out a similar procedure with calcium oxide.
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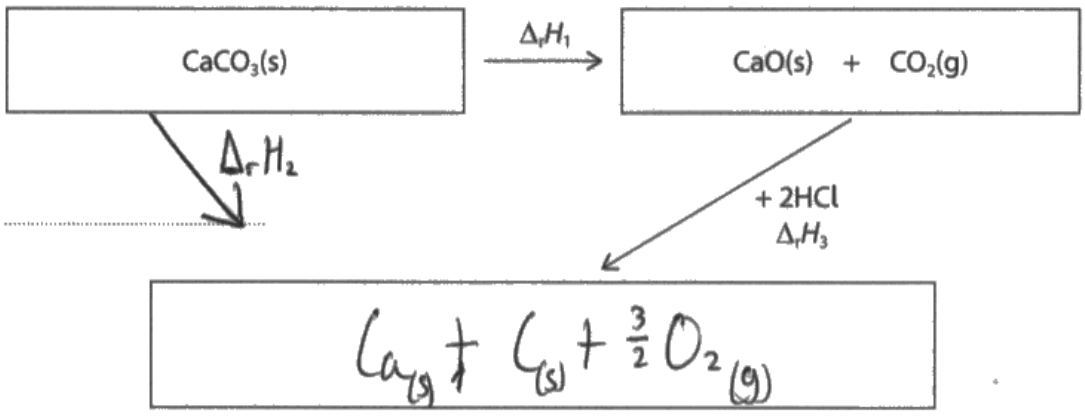

(v) Calculate a value for the enthalpy change $\Delta_r H_1$ for the thermal decomposition of calcium carbonate by using your cycle.

(1)

ResultsPlus
Examiner Comments

This response scores one for completion of the table.

They then score one for the correct calculation of mols of HCl. But they have not shown you need 0.082 mol to react with the $CaCO_3$.

The next part is fully correct scores three.

The cycle does not score, missing 2HCl on first arrow and the box is incorrect (elements).

Final part does not score due to not being attempted.

Question 3(c)

The question required the candidates to calculate the feasibility of the decomposition of calcium carbonate.

This could be done either by calculating Gibbs free energy or by the total entropy change and then commenting on the value as to whether or not it was feasible.

The second part of this question then asked them to use the entropy of the system to calculate the minimum temperature at which this would become feasible, and coverting to ^{o}C and giving an answer to 3SF.

(c) A data book value for the thermal decomposition of calcium carbonate, $\Delta_r H^{\ominus}$ (Reaction **1**), under standard conditions is +178.2 kJ mol^{-1}.

(i) Deduce the feasibility of the thermal decomposition of calcium carbonate at 298 K using the data in the table.

(3)

	Compound	Entropy / J K^{-1} mol^{-1}
R	calcium carbonate, $CaCO_3(s)$	92.9
P	calcium oxide, $CaO(s)$	39.7
P	carbon dioxide, $CO_2(g)$	213.6

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

$= 178200 - (298 \times 160.4)$

$= +130400.8\ J\,mol^{-1}$

positive ΔG value ∴ not feasible

ΔS_{system} = Product − React

$= (39.7 + 213.6) - 92.9$

$= 160.4$

(ii) Calculate the **minimum** temperature, in **°C**, at which thermal decomposition would occur.
Give your answer to 3 significant figures.

(2)

$-273°C = 0K$

$25°C = 298K$

$-273K$

$-\frac{\Delta H}{\Delta S} = -T$ $\quad T = \frac{\Delta H}{\Delta S_{system}}$

$= \frac{178200}{160.4} = 1110.9725$

$-273 = 837.97$

$= 838°C$

Fully correct answer. It scores three marks for Q03(c)(i) and two marks for Q03(c)(ii).

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P	calcium carbonate, $CaCO_3(s)$	92.9
R	calcium oxide, $CaO(s)$	39.7
R	carbon dioxide, $CO_2(g)$	213.6

$39.7 + 213.6 = 253.3$

$253.3 - 92.9 = 160.4$

$-(178.2 \times 1000) = -597.98$

298

$160.4 + -597.98 = -437.59$

$-437.59 < 0$

∴ reaction is not feasible as ΔS total is less than 0

-437.6 kJ mol^{-1}

(ii) Calculate the **minimum** temperature, in **°C**, at which thermal decomposition would occur.
Give your answer to 3 significant figures.

(2)

$\Delta G = 0$

$0 = \Delta H - T\Delta S$

$0 = 178200 - 160.4T$

$-178200 = -160.4T$

$T = 1110.972569$ °K -273

$T = 837.97$ °C

$T = 838$ °C

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Examiner Comments

Fully correct answer using the delta S total route, it again scores three marks for Q03(c)(i) and two marks for Q03(c)(ii).

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(i) Deduce the feasibility of the thermal decomposition of calcium carbonate at 298 K using the data in the table.

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calcium carbonate, $CaCO_3(s)$	92.9
calcium oxide, $CaO(s)$	39.7
carbon dioxide, $CO_2(g)$	213.6

products − reactants

$CaCO_3 \rightarrow CaO + CO_2$

$39.7 + 213.6 = 253.3$

$253.3 - 92.9 = +160.4$ kJ^{-1}mol^{-}

is it feasible

(ii) Calculate the **minimum** temperature, in **°C**, at which thermal decomposition would occur.
Give your answer to 3 significant figures.

(2)

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

$+160.4 = -\frac{(178.2)}{T}$

$-\frac{178.2}{160.4} = -1.11$ + 298

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Examiner Comments

This answer scores one mark in the first part for the calculation of delta S of the system, but they have failed to complete the calculation, and just made a statement of it being feasible.

In the second part they fail to adjust for the difference in kJ and J so they end up with a small value added to which it is negative value for K so scores zero.

ResultsPlus
Examiner Tip

Remember that some values are given in J and some in kJ and convert so they are both in the same.

Also if you get a negative value for K you've got something wrong somewhere, check those negatives.

Question 3(d)

This question was about the comparison in thermal stability of two group 2 carbonates, Magnesium carbonate and Calcium carbonate. Many candidates scored two of the three available marks, many missing out on the first marking point by failing to reference the Magnesium or Calcium ions.

Mg^{2+} has the same charge as Ca^{2+}. However the size or ionic radius of Mg^{2+} is smaller. This means the charge density of Mg^{2+} is greater. Mg^{2+} has greater polarising power than Ca^{2+} so can distort the CO_3^{2-} electron cloud more. The C=O bond weakens more in $MgCO_3$ than $CaCO_3$ so more readily decomposes, i.e. decomposes at a lower temperature.

ResultsPlus
Examiner Comments

Fully correct answer, referencing the ions, and scores three marks.

ResultsPlus
Examiner Tip

This answer shows the importance of accuracy and detail. Reference to ions rather than the element and which bond is affected.

Magnesium and calcium both have a +2 charge however Mg^{2+} ion has a smaller ionic radius and a higher charge density. This means Mg^{2+} polarises the carbonate ion more than Ca^{2+} making the bond weaker and less stable so less energy is needed to break the bond.

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Examiner Comments

Here the candidate has referenced the ions but failed to identify the bond weakened by the cation. This response scores two marks.

Magnesium and calcium both have the same nuclear charge and similar shielding
The atomic radii ~~decrease~~ increase down a group meaning calcium has a larger atomic nuclei
than magnesium. ~~This would mean there is less attraction to between the~~
~~positive nuclei and the outer electrons meaning they are more easily lost.~~
~~Smaller radii means easier for bo~~. Magnesium undergoes polarisation more easily
whereas calcium does not.

This candidate has gone down the wrong route and therefore scores zero.

Question 4(a)

This question asked the candidates to calculate the K_p for a reaction, including both the expression and the units. Those who did best in this question laid out the calculation in table form.

A common error was the first step in the calculation ending up with the wrong number of moles at equilibrium.

Another less common error was the presence of square brackets in the expression.

4 Ethanol is made industrially by the reaction of ethene and steam.
The equation is shown.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -45.0\,kJ\,mol^{-1}$$

The catalyst used is phosphoric acid, H_3PO_4, which is bound to a solid silicon dioxide support.

90.0 mol of ethene and 54.0 mol of steam are mixed in a sealed reactor at 500 K. At equilibrium, the total pressure is 60.0 atm and 5% of the ethene has been converted into ethanol.

(a) Calculate the value of K_p at this temperature.
Include the expression for K_p and units as appropriate.

(5)

	C_2H_4	H_2O	C_2H_5OH
I	90	54	0
C	−4.5	−4.5	+4.5
E	85.5	49.5	4.5
Mol/	$\frac{85.5}{139.5}$	$\frac{49.5}{139.5}$	$\frac{4.5}{139.5}$
P	0.613×60	0.355×60	0.0323×60

$$K_p = \frac{P(C_2H_5OH)}{P(C_2H_4)\ P(H_2O)} \qquad K_p = \frac{P(0.0323\times60)}{P(0.613\times60) \times P(0.355\times60)}$$

$$= 2.47 \times 10^{-3}\ atm^{-1}$$

ResultsPlus
Examiner Comments

This is a clearly laid out and fully correct answer scoring five marks.

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The equation is shown.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \quad \Delta H = -45.0\,kJ\,mol^{-1}$$

The catalyst used is phosphoric acid, H_3PO_4, which is bound to a solid silicon dioxide support.

90.0 mol of ethene and 54.0 mol of steam are mixed in a sealed reactor at 500 K. At equilibrium, the total pressure is 60.0 atm and 5% of the ethene has been converted into ethanol.

(a) Calculate the value of K_p at this temperature.
Include the expression for K_p and units as appropriate.

(5)

$K_p = \dfrac{(p\,C_2H_5OH)}{(p\,C_2H_4)(p\,H_2O)}$

5% of 90.0 = 4.5

	C_2H_4	H_2O	C_2H_5OH
I	90	54	0
C	4.5	4.5	
E	85.5	54	4.5
	144	144	144

$= 0.59375$ | 0.375 | 0.03125

$\times 60$ | $\times 60$ | $\times 60$

$35.625 \times 22.5 \;/\; 1.875 = \dfrac{0.002339}{-45.0}$ $mol^{-1}dm^3$

$= -5.19777778 \times 10^{-5}$ $mol^{-1}dm^3$

$\dfrac{mol\,dm^{-3}}{mol\,dm^{-3}}\; mol\,dm^3 = mol^{-1}dm^3$

ResultsPlus Examiner Comments

This example of the calculation shows the initial error in the number of moles at equilibrium, they have unfortunately forgotten to change the moles of water. M2 and M3 are scored by TE, M4 is for the correct expression, but they lose M5 for incorrect units.

4 Ethanol is made industrially by the reaction of ethene and steam.
The equation is shown.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -45.0\,kJ\,mol^{-1}$$

90 54

The catalyst used is phosphoric acid, H_3PO_4, which is bound to a solid silicon dioxide support.

90.0 mol of ethene and 54.0 mol of steam are mixed in a sealed reactor at 500 K.
At equilibrium, the total pressure is 60.0 atm and 5% of the ethene has been converted into ethanol.

(a) Calculate the value of K_p at this temperature.
Include the expression for K_p and units as appropriate.

(5)

R	1	1	1
1	90	54	0
C	-4.5	-4.5	+4.5
E	85.5	49.5	4.5

$\therefore$ 90 - 5% = 4.5 mol.

$$K_p = \frac{[C_2H_5OH]}{[C_2H_4][H_2O]}$$

$$\frac{[mol\,dm^{-3}]}{[mol\,dm^{-3}][mol\,dm^{-3}]}$$

$$= mol^{-1}\,dm^{3}$$

ResultsPlus
Examiner Comments

This response scores one mark for the correct equilibrium moles.

Unfortunately, although they have attempted to give the expression it has square brackets so does not score, they we obviously unsure where to go with the calculation but did attempt to work out the units but these too were wrong (probably as they had an expression for concentrations) although without a value M5 could still not have been awarded.

Question 4(b)(i)

This was a straightforward question on the effect of increasing the pressure on the reaction.

They needed to comment on the equilibrium shift and why, and the effect on the yield.

Increasing pressure would shift equilibrium to the right as there are less moles of products than reactants so yield of ethanol would increase

ResultsPlus
Examiner Comments

Fully correct answer scores both marks.

This would increase the yield as equilibrium would shift to the left.

ResultsPlus
Examiner Comments

The marks were stand alone fortunately as this response has the correct effect on yield but the candidate has clearly mixed their left and right.

Equilibrium will shift to the right and would increase the yield.

ResultsPlus
Examiner Comments

This response scores one mark for the yield but even though they have the equilibrium moving in the right direction they have not given a reason as to why, eg there are less gas moles on the RHS.

ResultsPlus
Examiner Tip

With Equilibrium questions it is important to give a reason as to why there is a change in the equilibrium position.

Question 5(b)

This question required the candidates to write an expression for the pH of a solution.

ResultsPlus
Examiner Comments

Fully correct answer.

This response scores zero. The absence of the minus sign means no score.

Question 6(a)(ii)

This was a straightforward question requiring the definition of a transition metal.

Chromium can form one or more stable ions with a partially-filled d subshell

ResultsPlus
Examiner Comments

Fully correct answer scores one mark.

Chromium is a transition metal as it forms more than one oxidation state

ResultsPlus
Examiner Comments

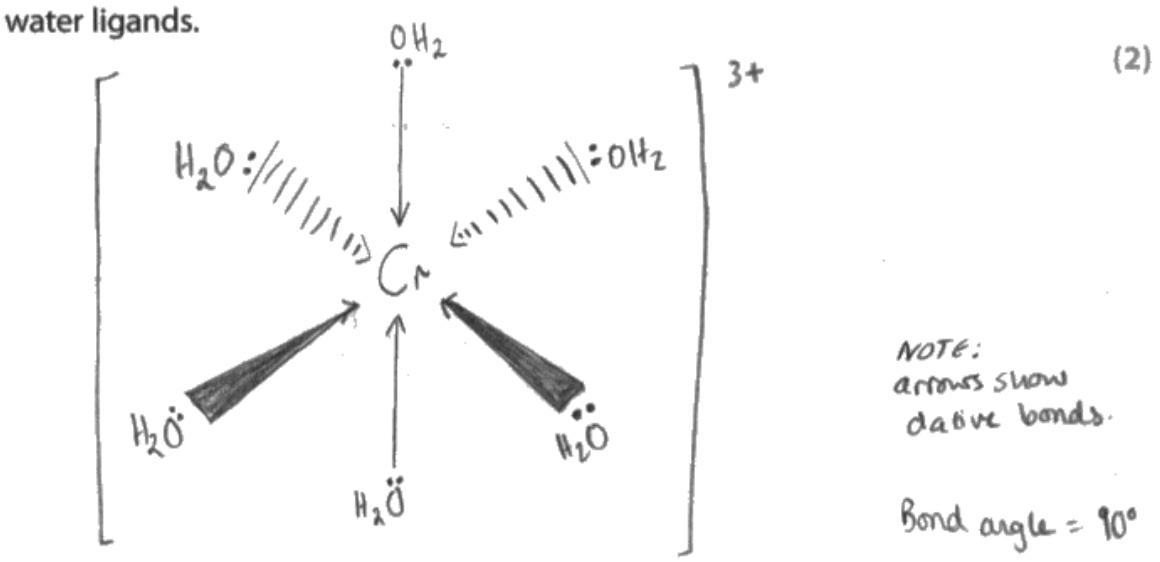
Whilst there is some merit in the answer it is not the definition and makes no reference to the incomplete d-orbitals or subshell.

This response scores zero.

Question 6(b)(i)

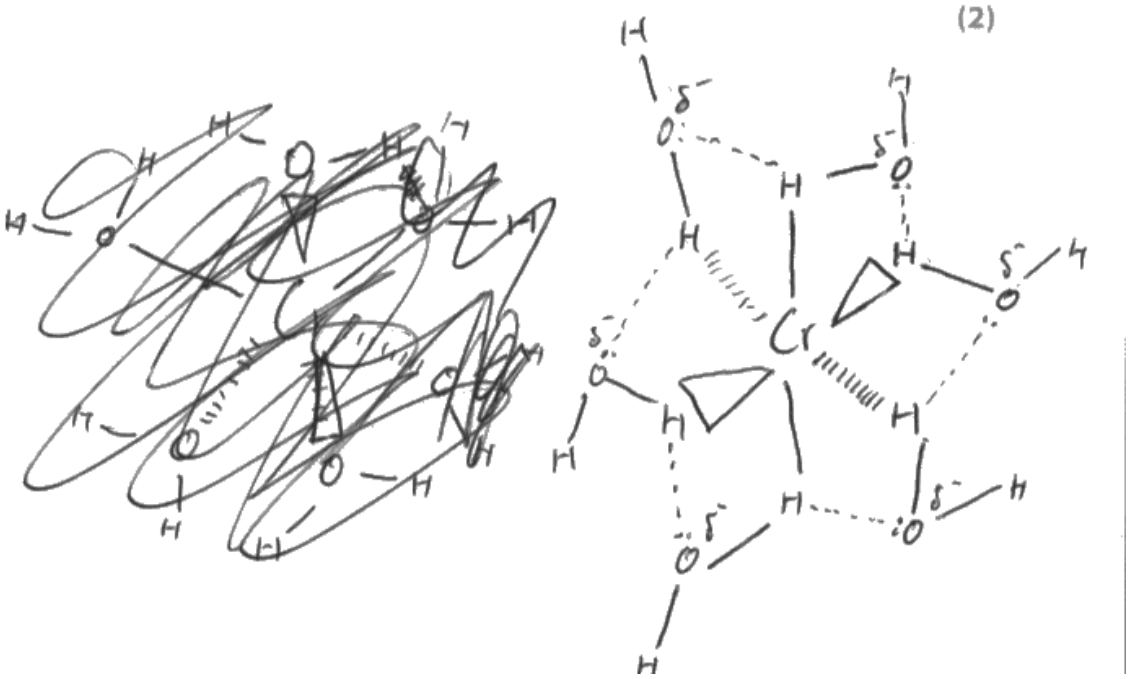
This question required the candidates to draw a 3d structure of the Cr^{3+} hexa aqua ion and proved more challenging than expected.

The errors ranged from not having the correct number of ligands, to incorrect connectivity and finally not being able to draw a 3D representation using two wedges, two dashes and two solid lines.



ResultsPlus
Examiner Comments

Fully correct answer which scores two marks.



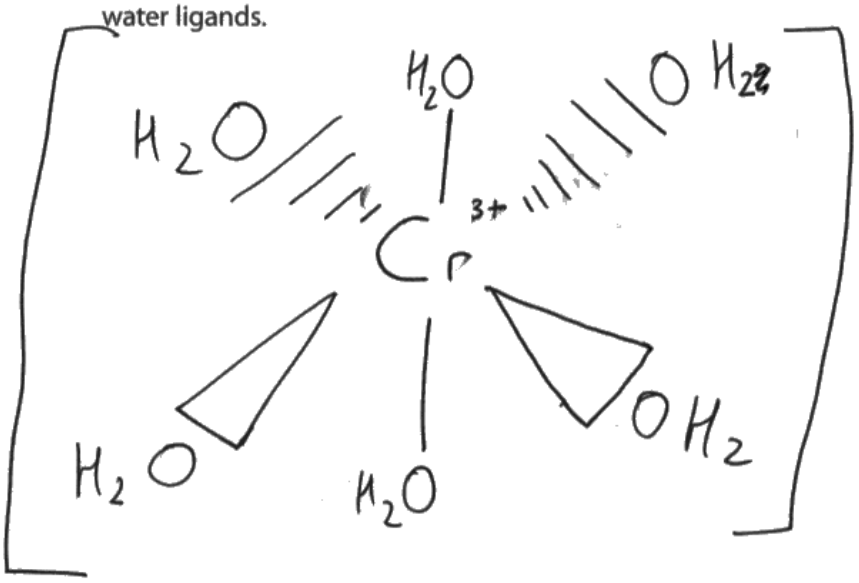
ResultsPlus
Examiner Comments

This response scores zero due to extra bonds (no M1) and incorrect connectivity (no M2).

The original diagram crossed though would have scored one mark.

(b) (i) Draw the structure of the complex ion, $[Cr(H_2O)_6]^{3+}(aq)$, showing clearly its 3-dimensional shape, and the bonds between the chromium ion and the water ligands.

(2)



ResultsPlus
Examiner Comments

This representation scores one - no arrows or lone pairs on the oxygens.

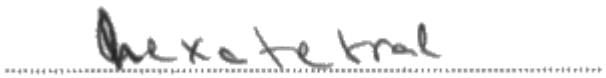
Question 6(b)(ii)

This question asked for a description of the shape of the Cr^{3+} hexa aqua ion.

octahedral, 6 coordinate bonds.

ResultsPlus
Examiner Comments

Fully correct answer which scores one mark.

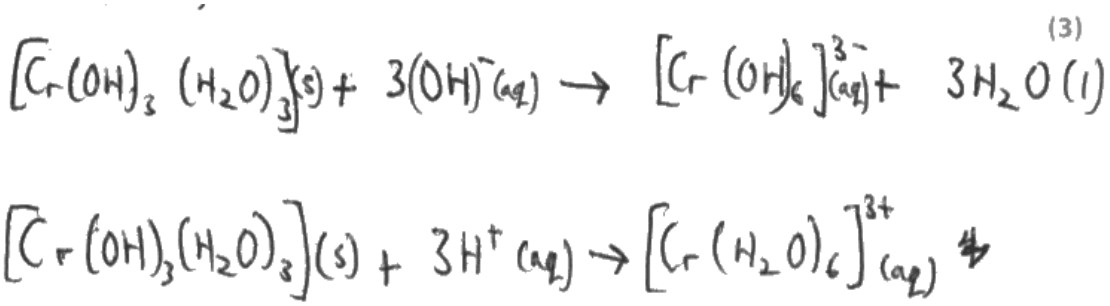


ResultsPlus
Examiner Comments

This is incorrect and scores zero.

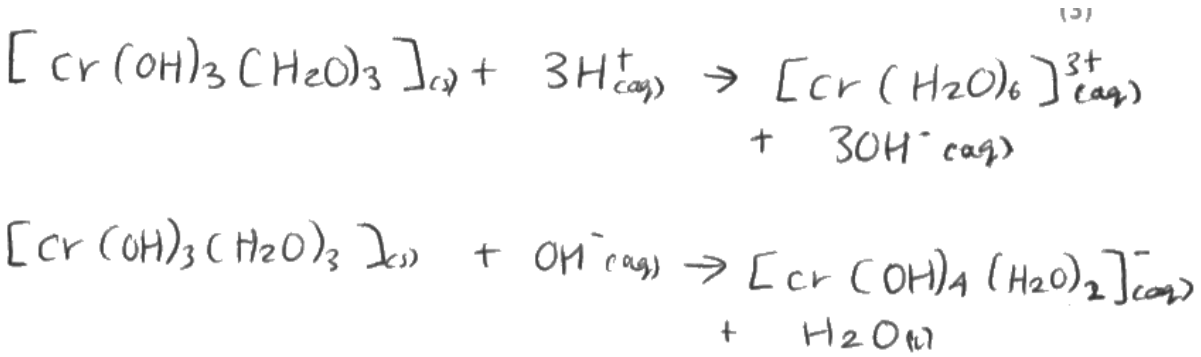
Question 6(c)

This was a challenging question for a large number of the candidates. It required them to write equations to show the amphoteric nature of the Chromium (III) hydroxide ion. This would involve writing two equations one adding OH^- and one adding H^+, they were also required to include the state symbols.



ResultsPlus
Examiner Comments

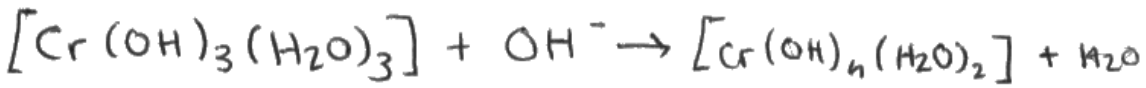
This answer is fully correct and scores all three points.



ResultsPlus
Examiner Comments

This response scores one mark.

The first equation is unbalanced. The second is correct for a mono substitution and scores M2. Both equations needed to be correct to score M3.



ResultsPlus
Examiner Comments

This response scores zero. First equation has missing charge. The second equation uses NH_3 and is incorrect. No M3.

Question 6(d)

This question was asking for the type of reaction that occurs when aqueous ammonia is added to the Chromium (III) hydroxide.

ligand exchange

ResultsPlus
Examiner Comments

This response is fully correct and scores one mark.

neutralisation reaction

This response scores zero.

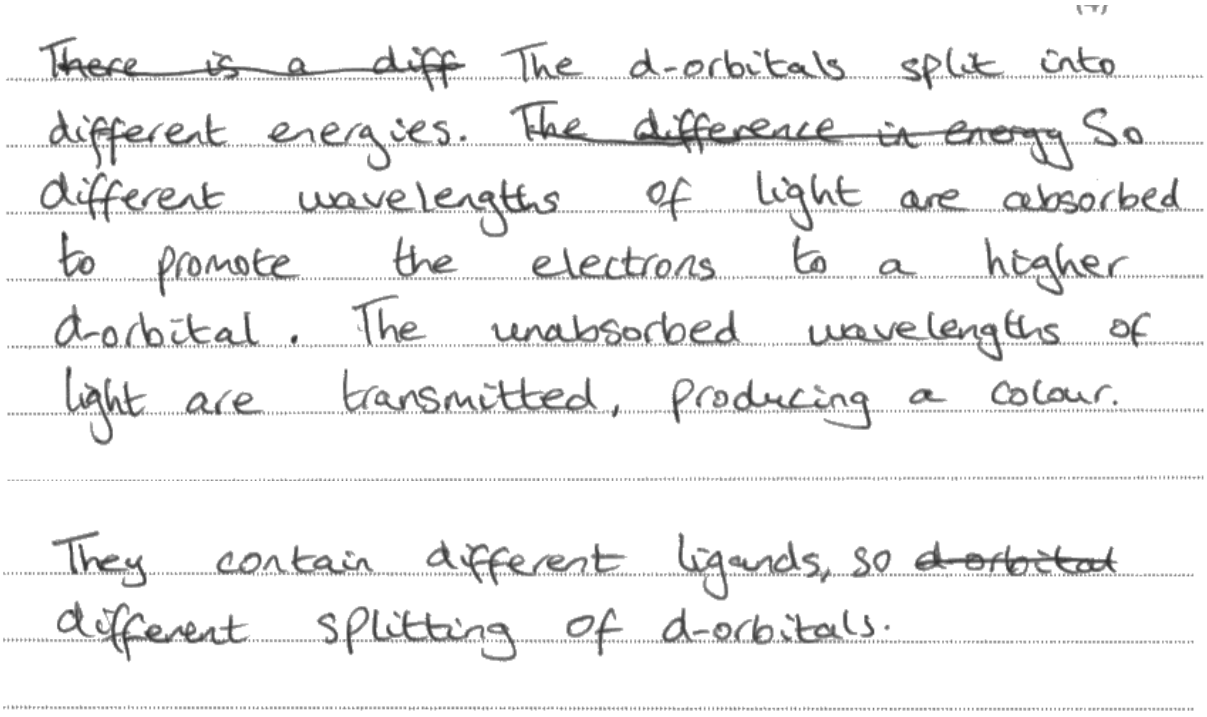
Question 6(e)

This question was looking at the reason why the Chromium (III) hexa aqua solution is coloured.

A general understanding of how the colour arises was shown, but candidates made some little errors which lost marks. A few candidates attributed the colour arising from the emission of light, this would be a flame test, rather than the transmission of the unabsorbed light.

There was the occasional careless use of subshells and d-orbital, rather than subshell and d-orbitals. This could lead to the loss of a mark.

In Q06(e)(ii), there was sometimes a lack of detail in the different ligand being added, and that was insufficient to gain the mark, the explanation of why was missing.



ResultsPlus
Examiner Comments

This is a fully correct answer, showing all 4 marking points in Q06(e)(i) and enough detail in Q06(e)(ii) to score the marking point.

Five marks in total.

wavelengths (4)

they are coloured as they produce wavelengths of light. The ~~in light~~ that ~~isn't~~ aren't emitted are absorbed, creating a coloured solutions. The wavelengths absorbed depends on the solution / transmitted.

different ions charges so different wavelengths emitted

ResultsPlus
Examiner Comments

This response scores zero.

In Q06(e)(i) they make no reference to d-orbitals splitting, so no M1.

There is no mention of electron promotion, no M2.

M3 and M4 cannot be awarded as the compound is described as producing light.

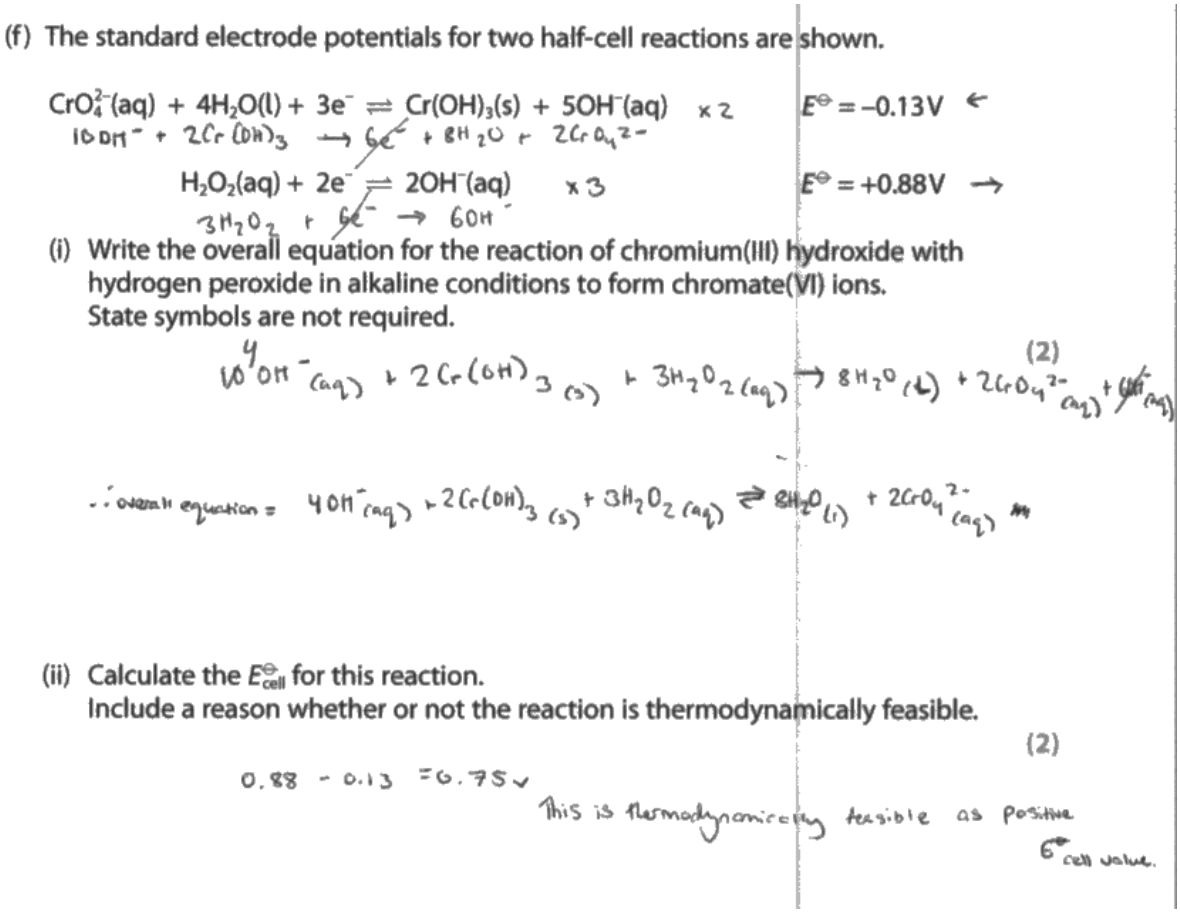
In Q06(e)(ii) they again refer to light emission so no mark.

Question 6(f)(i-ii)

This question was about the feasibility of a reaction with respect to the E^{θ}_{cell} calculation.

They had to combine two half equations together and then calculate the E^{θ}_{cell}. Most had a good attempt at combining the equations but slipped up on small things like cancelling the OH^- on both sides of the equation.

The calculation of E^{θ}_{cell} was generally done well.



(f) The standard electrode potentials for two half-cell reactions are shown.

$CrO_4^{2-}(aq) + 4H_2O(l) + 3e^- \rightleftharpoons Cr(OH)_3(s) + 5OH^-(aq)$ ×2 $E^{\ominus} = -0.13V$ ←

$10OH^- + 2Cr(OH)_3 \rightarrow 6e^- + 8H_2O + 2CrO_4^{2-}$

$H_2O_2(aq) + 2e^- \rightleftharpoons 2OH^-(aq)$ ×3 $E^{\ominus} = +0.88V$ →

$3H_2O_2 + 6e^- \rightarrow 6OH^-$

(i) Write the overall equation for the reaction of chromium(III) hydroxide with hydrogen peroxide in alkaline conditions to form chromate(VI) ions.
State symbols are not required.

(2)

$10^4 OH^-(aq) + 2Cr(OH)_3(s) + 3H_2O_2(aq) \rightarrow 8H_2O(l) + 2CrO_4^{2-}(aq) + \cancel{OH^-(aq)}$

∴ overall equation = $4OH^-(aq) + 2Cr(OH)_3(s) + 3H_2O_2(aq) \rightleftharpoons 8H_2O(l) + 2CrO_4^{2-}(aq)$

(ii) Calculate the $E^{\ominus}_{cell}$ for this reaction.
Include a reason whether or not the reaction is thermodynamically feasible.

(2)

$0.88 - 0.13 = 0.75$ ✓

This is thermodynamically feasible as positive $E^{\ominus}_{cell}$ value.

ResultsPlus
Examiner Comments

This response scored two for Q06(f)(i), fully correct. And it scored one for Q06(f)(ii). Correct answer should be 1.01 v, but they got M2 for the correct statement on feasibility.

(f) The standard electrode potentials for two half-cell reactions are shown.

$CrO_4^{2-}(aq) + 4H_2O(l) + 3e^- \rightleftharpoons Cr(OH)_3(s) + 5OH^-(aq)$ X2 $E^\ominus = -0.13V$

$H_2O_2(aq) + 2e^- \rightleftharpoons 2OH^-(aq)$ X3 $E^\ominus = +0.88V$

(i) Write the overall equation for the reaction of chromium(III) hydroxide with hydrogen peroxide in alkaline conditions to form chromate(VI) ions.
State symbols are not required.

(2)

$10OH^- + 2Cr(OH)_3 \rightleftharpoons 6OH^- + 2CrO_4^{2-} + 8H_2O$
$+ 3H_2O_2$

$4OH^- + 2Cr(OH)_3 \rightleftharpoons 2CrO_4^{2-} + 5H_2O$

(ii) Calculate the $E^\ominus_{cell}$ for this reaction.
Include a reason whether or not the reaction is thermodynamically feasible.

(2)

reduced − oxidised

0.88 − (−0.13)

= 1.01V

positive value so reaction is thermodynamically feasible.

ResultsPlus
Examiner Comments

This response scores M1 for the indication of which half equation is multiplied by 2 and which is by 3. They then incorrectly tried to combine them making an error in that the $3H_2O_2$ do not cancel out with $8H_2O$. In part Q06(f)(ii) they score two marks for a fully correct response.

Question 8

This question asked the candidates to compare the action of two catalysts. They were required to look at both similarities and differences. They were also required to give the equations for the reaction of both with sulfur compounds.

Many candidates understood that one catalyst was heterogeneous and one homogeneous (although we did see some other terms here). Many could describe the mechanisms although some referred to autocatalysis which was not the case for either. Equations were generally done well. However an area the candidates barely approached was the variable oxidation states which enable the catalysts to work.

- Both increase the rate of reaction by providing an alternate reaction pathway with a lower activation energy.

- $V_2O_{5\,(s)}$ is heterogenous whereas $Fe^{2+}_{(aq)}$ is homogenous

- The reaction between $S_2O_8^{2-}$ & I^- is slow as the negative ions repel each other, so Fe^{2+} increases the rate of reaction by reducing $S_2O_8^{2-}$ to SO_4^{2-}

$2Fe^{2+}_{(aq)} + S_2O_8^{2-}{}_{(aq)} \rightarrow 2SO_4^{2-}{}_{(aq)} + 2Fe^{3+}_{(aq)}$

The Fe^{3+} formed now reduces I^- to I_2

$2Fe^{3+}_{(aq)} + 2I^-_{(aq)} \rightarrow I_{2\,(aq)} + 2Fe^{2+}_{(aq)}$, reforming the Fe^{2+} catalyst.

$V_2O_{5\,(s)} + SO_{2\,(g)} \rightarrow SO_{3\,(s)} + V_2O_{4\,(s)}$

$V_2O_{4\,(s)} + \frac{1}{2}O_{2\,(g)} \rightarrow V_2O_{5\,(s)}$

V_2O_5 is reduced to V_2O_4 ~~4+~~ which is oxidised by O_2 back to V_2O_5.

~~V_2O_5 provides a surface from reactions to happen.~~

Reaction happens on V_2O_5 / V_2O_4 surface

Reactants adsorb onto catalyst, reaction occurs then products desorb (no desorption in reaction w/ O_2 as only solid V_2O_5 is formed).

Both metals change oxidation state (Fe from +2 → +3 and V from +5 to +4) in order to provide alternate reaction pathway.

ResultsPlus
Examiner Comments

This answer scores all six marks.

IP1 for the definition of a catalyst. IP4 for the hetero/ homogeneous catalysts. M3 for the description of the mechanism for the Fe^{2+} catalysed reaction. And part of IP2 is present as they describe the oxidation of the Fe^{2+} to Fe^{3+} and then its reduction back to Fe^{2+}. IP6 for the correct balanced equations. IP5 for the vanadium equations and finally the remainder of IP2 on the description of V_2O_5 reduced to V_2O_4 and then oxidised back to V_2O_5.

The first equation, famously known as the contact process, features a heterogenous catalyst – one of a different state to the relevant reactants. SO_2 gas is adsorbed by the surface of solid V_2O_5, where the following redox reactions occur:

* $SO_{2\,(g)} + V_2O_{5\,(s)} \longrightarrow SO_{3\,(g)} + V_2O_{4\,(s)}$
* $V_2O_{4\,(s)} + \frac{1}{2}O_{2\,(g)} \longrightarrow V_2O_{5\,(s)}$

This second equation shows V_2O_5 being reformed from O_2 in the air, so the net amount of catalyst present remains constant.
As the catalyst here isn't gaseous, the reaction quotient is independent of the mass of V_2O_5 initially added. The only relevant change is that the desired SO_3 yield is obtained in a shorter time.

The second equation features a homogenous catalyst – the reactants are in the same state as the catalyst. Fe^{2+} cations are helpful to reaction rate as the anions are attracted to it's positive charge; left to their own devices the anions' like charges would repel each other and reaction rate would be quite low. The relevant equations are as follows:

* $S_2O_8^{2-}{}_{(aq)} + 2Fe^{2+}{}_{(aq)} \longrightarrow 2SO_4^{2-}{}_{(aq)} + 2Fe^{3+}{}_{(aq)}$
* $2Fe^{3+}{}_{(aq)} + 2I^-{}_{(aq)} \longrightarrow 2Fe^{2+}{}_{(aq)} + I_{2\,(s)}$ [next page]

This second equation shows Fe^{2+} being reformed from I^- ions in the solution, so the net concentration of catalyst present remains constant.
The first step of this reaction is the rate-determining step, with the collision between $S_2O_8^{2-}$ and Fe^{2+} being depended upon. Thus the reaction quotient becomes dependent on $[Fe^{2+}]$, with more ions present resulting in more collisions in the same unit of time.

ResultsPlus
Examiner Comments

This answer scores four marks.

IP5 correct Vanadium equations. IP4 heterogeneous and homogeneous both referenced. IP3 mechanism details for te Fe2+ reaction. IP6 correct equations for Fe2+. IP1 is not commented on and the reforming of the catalysts is not quite enough for IP2 where the answer was looking for the oxidation and reduction/ change in oxidation numbers.

V_2O_5 (s) * is a heterogenous catalyst that provides an electron to sulfur causing the reaction to take place.

$V_2O_5 \cdot \longrightarrow V_2O_4^{+} + \frac{1}{2}O_2^{-}$

$SO_2 + \frac{1}{2}O_{2(aq)}^{-} + \frac{1}{2}O_{2(g)} \longrightarrow SO_3 + \frac{1}{2}O_2$

$\frac{1}{2}O_2 + V_2O_4^{+} \longrightarrow V_2O_5$

This is how the reaction takes place for the catalyst $V_2O_5 \cdot Fe^{2+}$ however is a ~~ff~~ homogenous catalyst that reduces the reactants giving products

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

$Fe^{3+} + 2I^{-} \longrightarrow Fe^{2+} + 2I$

This reaction takes place in 2 steps

ResultsPlus
Examiner Comments

This answer scores one mark for IP4 the heterogenous and homogenous catalysts.

Both sets of equations are wrong there is a spurious charge on the V_2O_4 and the Fe^{2+} equations are not balanced.

Question 9(a)(b)

These two parts of question 9 are to do with completing a titration table and calculating the mean titre.

Generally the table was done well. The main error on the mean titre was either not recognising which two titres were concordant or adding all four and dividing by four.

Titration number	1	2	3	4
Final burette reading / cm^3	15.90	24.00	15.30	25.00
Initial burette reading / cm^3	0.00	8.45	0.05	9.35
Titre / cm^3	15.90	15.55	15.25	15.65

(b) The mean titre was calculated to be 15.60 cm^3.

State how this value was determined.

(1)

Took the concordant results 15.55 cm^3 and 15.65 cm^3 as they are within 0.1 cm^3 of another and found the mean of them $\frac{15.55 + 15.65}{2} = 15.6\ cm^3$

ResultsPlus Examiner Comments

Fully correct answer scores two marks.

One mark for the table and one for the mean titre.

Titration number	1	2	3	4
Final burette reading / cm^3	15.90	24.00	15.30	25.00
Initial burette reading / cm^3	0.00	8.45	0.05	9.35
Titre / cm^3	15.90	15.55	15.25	15.65

(b) The mean titre was calculated to be 15.60 cm^3.

State how this value was determined.

(1)

All titre values were added and divided by 4 (total titration number) and rounded to 1 decimal place

ResultsPlus
Examiner Comments

This response scores one mark.

One mark for the table but no mark for the calculation of the mean.

Question 9(c)

This question asked for the colour change in the flask when the manganate was added. It seemed that some candidates misread this as there were a significant number of purple to colourless colour changes.

ResultsPlus
Examiner Comments

This response is fully correct and scores two marks.

From pink / purple to colourless

ResultsPlus
Examiner Comments

This response does not score. Zero marks.

Question 9(d)

This question required the candidates to work through a titration calculation. Most were able to do this in a logical fashion and thus gained most or all of the marks. A common error was missing a step, usually the determining moles in the sample scalling factor. Occasional slips on the M_r of the H_2O_2.

(d) Deduce by calculation whether the concentration of hydrogen peroxide in the hand sanitiser is within World Health Organization guidelines. (5)

8.2 g of sanitiser

$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$

$0.0156 \times 0.02 = \text{mol } MnO_4^- = 3.12 \times 10^{-4}$

$\text{mol } H_2O_2 = 7.8 \times 10^{-4}$

$7.8 \times 10^{-4} \times 10 = 7.8 \times 10^{-3} = \text{mol } H_2O_2 \text{ in } 250cm^3$

mass = Mr x moles

mass = 34 x 7.8×10^{-3} = 0.2652 g in $250cm^3$

8.2 grams of sanitiser in $250 cm^3$

$\frac{0.2652}{8.2} = 0.03234$ amount H_2O_2

= 3.23 % H_2O_2 in sanitiser.

It is within the range.

ResultsPlus Examiner Comments

This is a fully correct response and scores all five marks.

(d) Deduce by calculation whether the concentration of hydrogen peroxide in the hand sanitiser is within World Health Organization guidelines.

(5)

$n(KMnO_4^-) = 3.12 \times 10^{-4}$ in 25 cm^3

$n(H_2O_2) = 7.8 \times 10^{-4}$ in 250 in 25 $\rightarrow \times 10$

$n(H_2O_2)$ in 250 $cm^3 = 7.8 \times 10^{-3}$

in 10 $cm^3 = 3.12 \times 10^{-4}$

8.2 10 cm^3 $\times 0.82 = 8.2$ g

$3.12 \times 10^{-4} \times 34 = 0.010608$ g

$\frac{0.010608}{8.2} \times 100 = 0.129\%$ ∴ not

thus outside of range at 3% → 6%

hence not suitable for WHO guidance

ResultsPlus
Examiner Comments

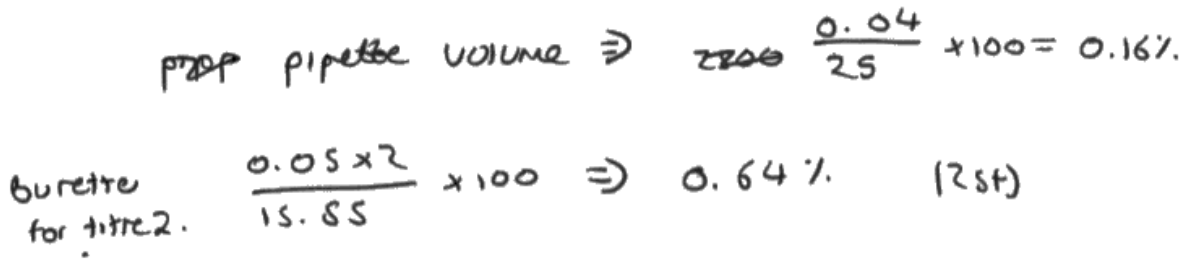
This response scores three marks.

The first step is correct, they then do a combination of steps and end up back at the original answer so M1. From following logically from the initial answer they get the TE and get M4 and then M5.

Question 9(e)

The final question was looking at the percentage uncertainty of apparatus used within a titration namely the pipette and the burette.

The most common error here was the failure to realise that the burette uncertainty involves x2 as there are two readings taken.



ResultsPlus
Examiner Comments

A fully correct response which scores two marks.

$$\frac{0.04}{25} \times 100 = 0.16\ \%$$

$$\frac{0.05}{15.55} \times 100 = 0.32\ \%$$

This response scores one mark.

This shows the common error for the percentage uncertainty of the burette.

Paper Summary

Based on their performance on this paper, candidates should:

- Ensure that they can explain differences in first ionisation energies by referencing changing nuclear charge and shielding.
- Know the difference between intermolecular bonding (eg hydrogen bonds) and covalent and ionic bonding.
- Be able to explain the trends in the thermal decomposition of Group 2 carbonates.
- Check all calculations and do not leave expressions unevaluated.
- The correct expressions and whether to use round brackets or square brackets in these expressions.
- Understand how to explain the reasons for colours in transition metal complexes, in terms of ligands causing d-orbitals to split and light energy.
- Correct balancing and states of compounds within equations.
- Ensure they are clear on units for entropy and Gibbs free energy.
- Set out working for multi-step calculations clearly.

Grade boundaries

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