Examiners' Report
June 2023

GCE Chemistry 9CH0 03

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Introduction

This paper is designed to be synoptic in nature and so draws on topics from the whole of the GCE specification and how these different topic areas relate or connect with each other. There is indirect assessment of practical skills and candidates are expected to draw on their experience of the Core Practicals as well as additional experiments that they have seen or taken part in.

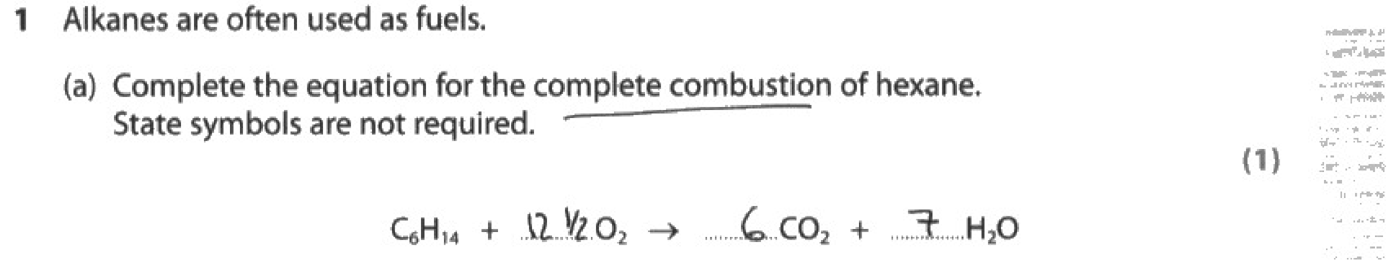
Many examiners reported that the layout of calculations in particular was especially challenging as it was difficult to understand exactly what a candidate was doing. Hence candidates are encouraged to work on making clear each mathematical step with appropriate labelling and units. It is worth reminding also that rounding should not be done during a calculation but only at the end.

It was pleasing to see that some candidates were extremely well-prepared for the rigor and demand of this paper. The quality of some of the answers and the reasoning or justification provided was very encouraging, especially with some of the more novel question settings.

There was no evidence that candidates ran out of time and it was very satisfying to see many good answers to the complex K_p calculation which was the penultimate question on the paper. Clearly candidates had not become too exhausted to answer these testing calculations at the end of the examination.

Question 1 (a)

The majority of candidates correctly balanced the combustion equation. It was acceptable to use decimals, fractions and improper fractions. Occasionally a candidate doubled the numbers to avoid the need for fractions or decimals and this was allowed.



1 Alkanes are often used as fuels.

(a) Complete the equation for the complete combustion of hexane.
State symbols are not required.

(1)

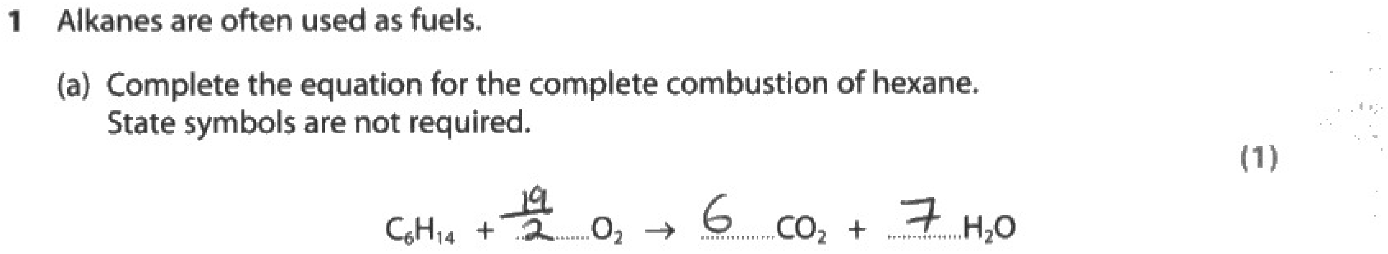
C_6H_{14} + 12 ½ O_2 → 6 CO_2 + 7 H_2O

ResultsPlus
Examiner Comments

An example of a response with an incorrect number of oxygen molecules. A reminder to check the balancing for all the elements in an equation and it can be especially helpful with questions at the start of the paper when an over-eagerness or a tendency to rush may be more easily felt.

ResultsPlus
Examiner Tip

Check for the balancing of **all** elements either side of the equation.



1 Alkanes are often used as fuels.

(a) Complete the equation for the complete combustion of hexane.
State symbols are not required.

(1)

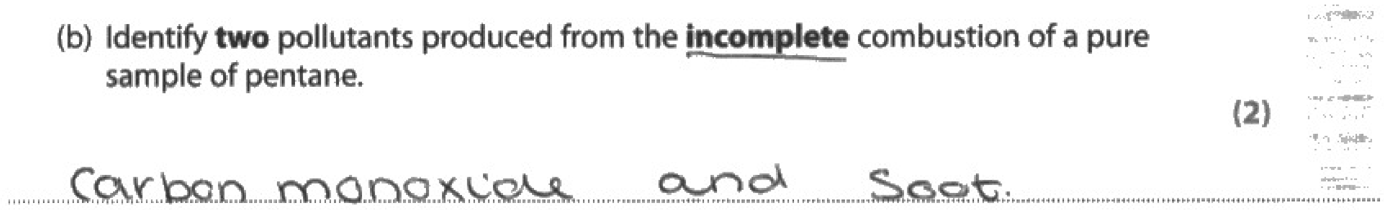
C_6H_{14} + $\frac{19}{2}$ O_2 → 6 CO_2 + 7 H_2O

ResultsPlus
Examiner Comments

Here is a response which used an improper fraction and scored the mark.

Question 1 (b)

Well-answered with most scoring 2 marks, usually with carbon monoxide and carbon or soot. Other acceptable answers such as nitrogen oxides and the unburnt pentane were seen, but rarely. Since carbon dioxide is a product of complete combustion, this was ignored.



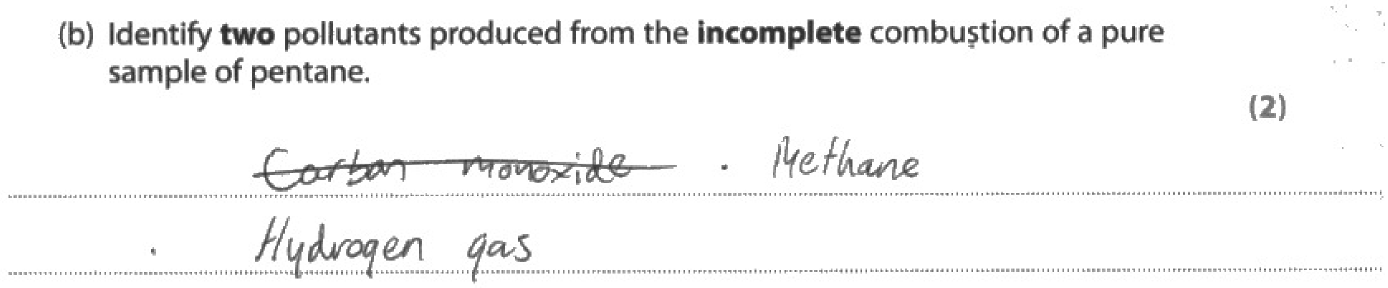
(b) Identify **two** pollutants produced from the **incomplete** combustion of a pure sample of pentane.

(2)

Carbon monoxide and Soot.

ResultsPlus
Examiner Comments

The reference to the production of 'soot' was allowed for carbon particulates and so, with the other correct pollutant, this response scored both marks.



(b) Identify **two** pollutants produced from the **incomplete** combustion of a pure sample of pentane.

(2)

~~Carbon monoxide~~ · Methane

· Hydrogen gas

ResultsPlus
Examiner Comments

Neither methane nor hydrogen are produced from the incomplete combustion of pentane. The reference to carbon monoxide is crossed out and replaced, so this does not score.

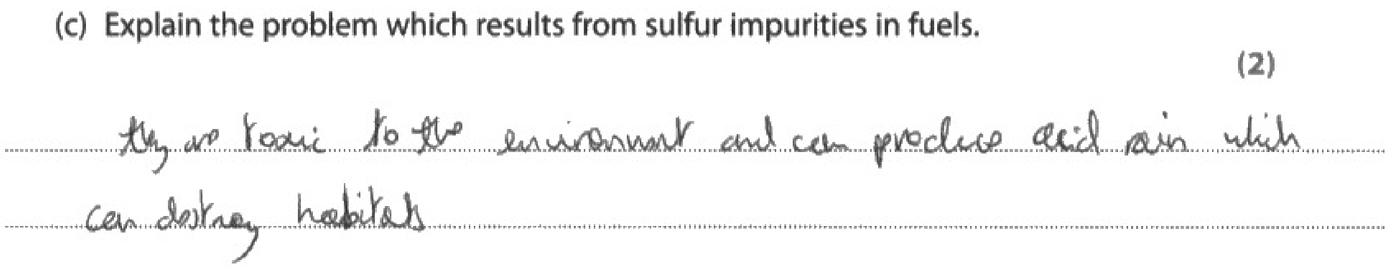
ResultsPlus
Examiner Tip

Hydrogen always combines with oxygen in combustion to produce water. The carbon-based fuel is always secondary to hydrogen in bonding to any limited oxygen present.

Question 1 (c)

Most candidates correctly identified the issue and many good explanations of the cause were seen.

Sulfur oxides are not greenhouse gases and so do not contribute to global warming which was occasionally seen. Responses which referred to the formation of sulfuric acid were allowed because this is the chemical responsible for the acidity of the rain from sulfur oxides.



(c) Explain the problem which results from sulfur impurities in fuels.

(2)

they are toxic to the environment and can produce acid rain which can destroy habitats

ResultsPlus
Examiner Comments

1 mark was awarded for the reference to acid rain but there is no explanation of how this is the result of sulfur oxides, so no second mark.

ResultsPlus
Examiner Tip

Make sure that the response makes at least the number of points corresponding to the number of marks for the question.

(c) Explain the problem which results from sulfur impurities in fuels.

(2)

- Sulfur monoxide released which can lead to acid rain

ResultsPlus
Examiner Comments

Reference to sulfur oxides was accepted but if a specific compound was mentioned, then it had to be correct. Sulfur monoxide does not exist and so, in this response, it did not score but the mark was awarded for the reference to acid rain.

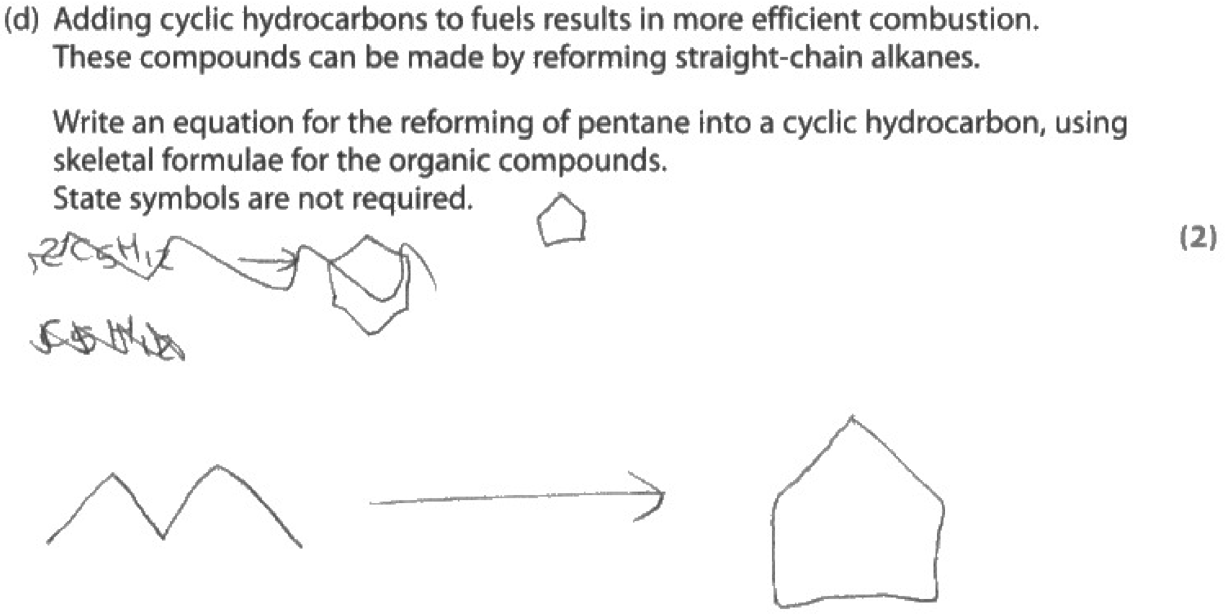
ResultsPlus
Examiner Tip

Stick with the names of compounds which are well-known.

Question 1 (d)

The mark scheme has many possible cyclic possibilities added but cyclopentane was by far the most frequently seen. This equation was given 2 marks because the use of skeletal formulae in the equation needed to be balanced by a hydrogen molecule as a product. Hence this proved an effective discriminator.

Occasionally the pentane reactant was given an extra carbon to form cyclohexane and so there is a real need to check the number of carbon atoms when drawing skeletal formulae.



(d) Adding cyclic hydrocarbons to fuels results in more efficient combustion.
These compounds can be made by reforming straight-chain alkanes.

Write an equation for the reforming of pentane into a cyclic hydrocarbon, using skeletal formulae for the organic compounds.
State symbols are not required.

(2)

ResultsPlus
Examiner Comments

The scribbled-out work was ignored and so this response scores 1 mark for the correct skeletal formulae. The second mark for the balancing with a hydrogen molecule was missed.

ResultsPlus
Examiner Tip

When writing skeletal formula, it can be helpful to write out the molecular formula in an appropriate space to the side. In this way, it can become evident that extra balancing is required.

Question 2 (a)(i)

This straightforward equation with state symbols was correctly given by the majority of candidates. Multiples were acceptable. Most of the errors could have been resolved by checking or by considering what candidates had likely experienced in class.

2 This question is about some reactions of the elements of Group 1 and Group 2 of the Periodic Table and their compounds.

(a) Group 2 metals react vigorously with oxygen when heated.

(i) Write the equation for the reaction between magnesium and oxygen. Include state symbols.

(1)

$Mg(s) + O_2(g) \longrightarrow MgO_2(s)$

ResultsPlus
Examiner Comments

The equation is balanced and all the state symbols are given, but note that the formula of magnesium oxide is incorrect. Hence no mark awarded.

ResultsPlus
Examiner Tip

Check the formula of each compound in an equation. Ask 'Does this look right'?

2 This question is about some reactions of the elements of Group 1 and Group 2 of the Periodic Table and their compounds.

(a) Group 2 metals react vigorously with oxygen when heated.

(i) Write the equation for the reaction between magnesium and oxygen. Include state symbols.

(1)

$2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(g)}$

ResultsPlus
Examiner Comments

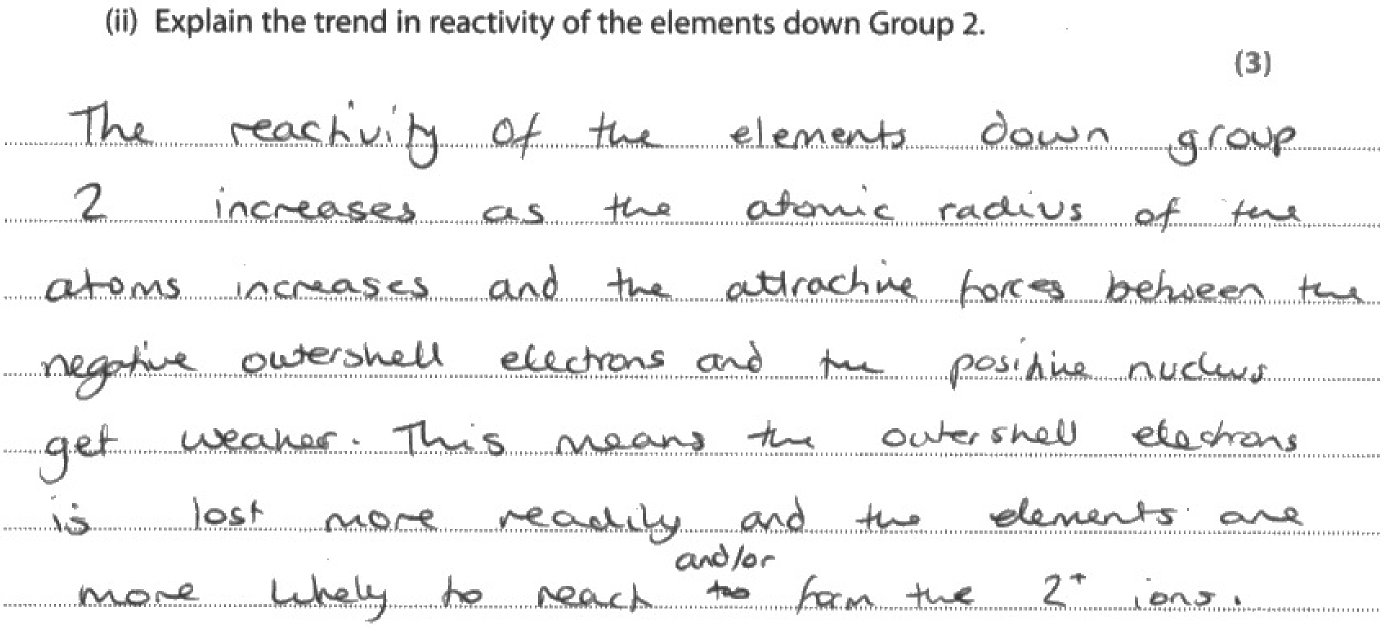
Magnesium oxide is used as a lining for furnaces because of it's very high melting and boiling temperatures. Hence this equation does not score because the product is not a gas.

ResultsPlus
Examiner Tip

The burning of magnesium in air is a very common experiment or demonstration. Try to recall such reactions because the white powder produced means that the product state symbol must be a solid.

Question 2 (a)(ii)

Many excellent responses were seen. This is a topic area which is well-understood by most candidates and generally marks were lost from a lack of accuracy or care in the answer. For example, it is not correct to refer to increasing 'ionic' radius because it is the atoms which are losing electrons. Hence the use of this term resulted in a loss of marking point two.



(ii) Explain the trend in reactivity of the elements down Group 2.

(3)

The reactivity of the elements down group 2 increases as the atomic radius of the atoms increases and the attractive forces between the negative outershell electrons and the positive nucleus get weaker. This means the outer shell electrons is lost more readily and the elements are more likely to react ~~to~~ and/or form the 2^+ ions.

ResultsPlus Examiner Comments

This is an answer which makes two points very well, but is lacking reference to the increased shielding experienced down the Group.

ResultsPlus Examiner Tip

Remember to make at least three points for a question worth three marks.

(ii) Explain the trend in reactivity of the elements down Group 2.

(3)

The ~~eleme~~ element are more reactive down the group in group 2. because there are more sheilding's between the outer electrons and the nucleus. Making the element reactwith electrophiles easier.

ResultsPlus
Examiner Comments

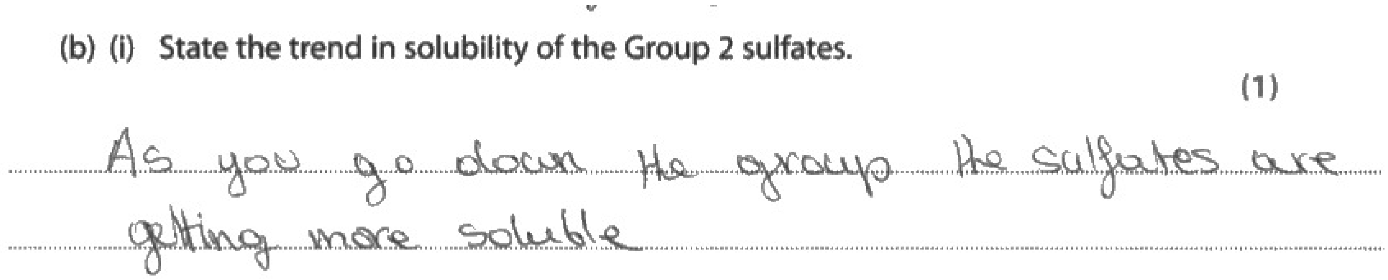
This response does state that reactivity increases down Group 2, but does not link this with decreasing ionisation energies nor the reduced attraction between the nucleus and the outermost electron(s). The reference to 'more shielding' does gain 1 mark, but there is nothing else creditworthy. The use of "electrophiles" at the end of the answer is understandable in the sense that atoms in Group 2 lose two electrons, but this term is used in organic chemistry and is not appropriate here.

ResultsPlus
Examiner Tip

Think carefully when using specialist terms because they should only be used in the correct context.

Question 2 (b)(i)

The majority of candidates knew that the trend down Group 2 sulfates is of decreasing solubility.



(b) (i) State the trend in solubility of the Group 2 sulfates.

(1)

As you go down the group the sulfates are getting more soluble

ResultsPlus
Examiner Comments

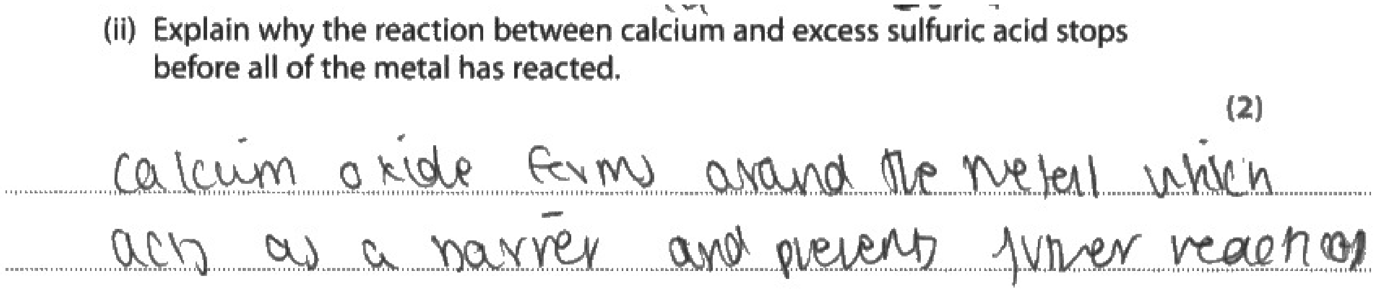
This response is stating that solubility is increasing down the group which is not correct.

ResultsPlus
Examiner Tip

Simple expressions save precious exam time and often avoid contradictions.

Question 2 (b)(ii)

This was one of the more challenging questions on the paper. It is worth reminding centres and their candidates that the rubric of the paper can provide some guidance. For example, parts (a), (b), (c) and so on are on the same general topic, but do not necessarily follow on. By contrast, sub-parts (i), (ii), (iii) and so on do often follow on from each other. Hence the answer of decreasing solubility in (i) provided some help or direction in answering this part (ii). The decreased solubility of the calcium sulfate formed a solid coating or layer on the metal which served as a physical barrier to further reaction.



(ii) Explain why the reaction between calcium and excess sulfuric acid stops before all of the metal has reacted.

(2)

calcium oxide forms around the metal which acts as a barrer and prevents further reaction

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Examiner Comments

This is an example of a response which gives the wrong product and so loses one mark, but the explanation is correct so still gains the second.

Recall that calcium oxide is a base and so would not be made in the presence of an acid.

ResultsPlus
Examiner Tip

Think about the compounds stated and whether the answer given makes sense. Pause and reflect.

(ii) Explain why the reaction between calcium and excess sulfuric acid stops before all of the metal has reacted.

(2)

- Calcium forms a precipitate that is white and this prevents

$Ca + H_2SO_4 \rightarrow Ca(SO_4)_2 + H_2$ it from further

reacting.

ResultsPlus
Examiner Comments

The first mark could have been awarded for the reference to the formation of a precipitate and the equation showing calcium sulfate being produced, but the formula given is incorrect. This is a shame and it is likely that a quick check of the equation would have easily identified the error.

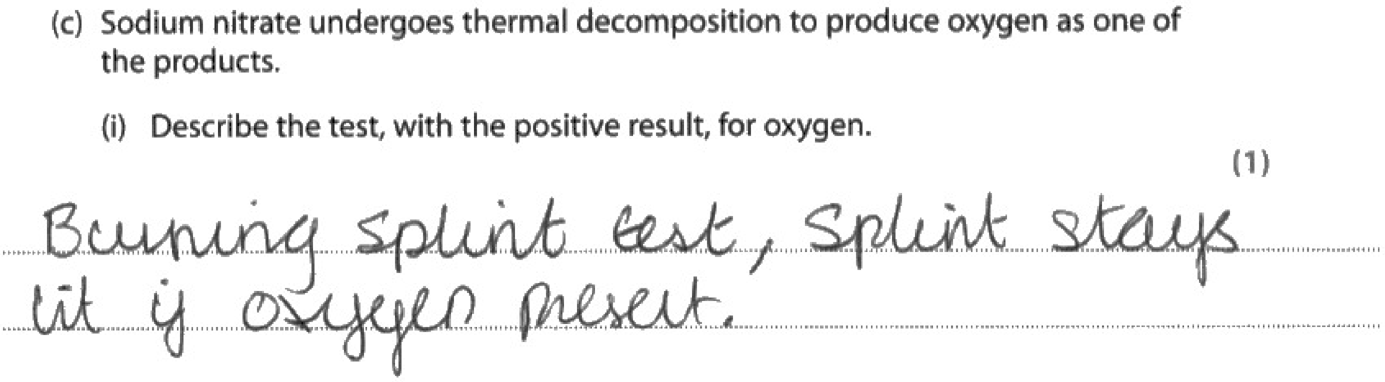
There is no reason given as to why the precipitate prevents further reaction and so the second mark is not awarded.

ResultsPlus
Examiner Tip

Make time to double check equations so that they are balanced for both atoms and charge.

Question 2 (c)(i)

Most of the candidates knew the test for oxygen very well. The main issues arose from poor expressions and a minority confusing the test for oxygen with that for hydrogen.



(c) Sodium nitrate undergoes thermal decomposition to produce oxygen as one of the products.

(i) Describe the test, with the positive result, for oxygen.

(1)

Burning splint test, Splint stays lit if oxygen present.

ResultsPlus Examiner Comments

This is an example of where poor expression let the answer down. In this test, the splint is relit and is not lit to begin with. Hence this response did not score.

ResultsPlus Examiner Tip

Some candidates correctly described what they had clearly done in class. This was more lengthy, but correct and is worth considering.

(c) Sodium nitrate undergoes thermal decomposition to produce oxygen as one of the products.

(i) Describe the test, with the positive result, for oxygen.

(1)

o the burning splint, place ~~it~~ the lit splint into a test tube containing the product ay

O_2 and the split burns brightly for a moment.

o Squeaky pop test in ~~the~~

ResultsPlus
Examiner Comments

The response ends with reference to the squeaky pop test, which is for hydrogen and not oxygen, which negates anything correct that comes before it.

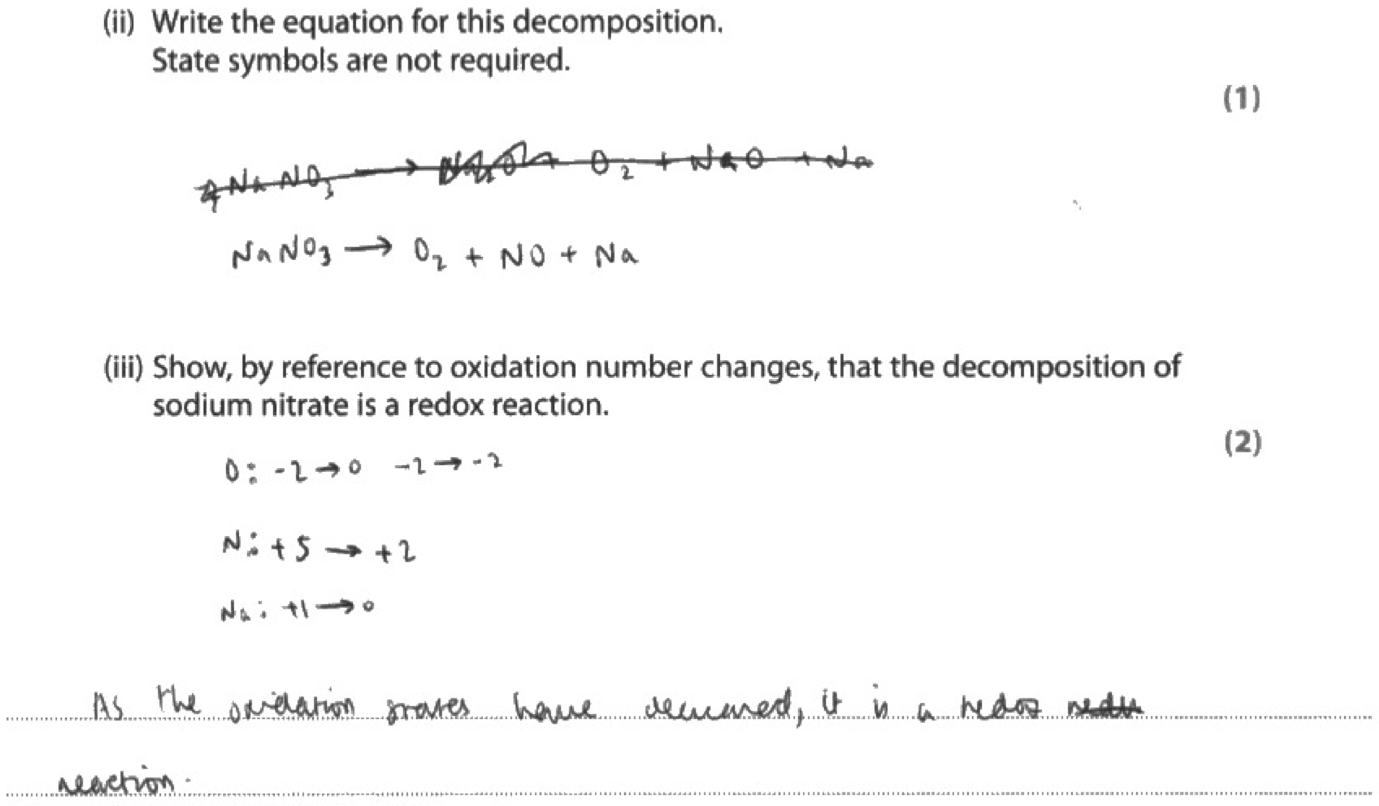
ResultsPlus
Examiner Tip

Never give two different answers to the same question.

Question 2 (c)(ii-iii)

In part (ii), it was disappointing that many candidates did not know the equation for the decomposition of sodium nitrate, but it was perhaps more worrying that in the answers given it was common to see elemental sodium being produced.

The oxidation number changes required in part (ii) were frequently given correctly for the equations written. However, if the equation was incorrect then only one mark for the reference to oxygen being oxidised from – 2 to 0 was awarded. There was one exception, if the equation given was the decomposition equation was that of lithium nitrate which mirrors Group 2 nitrates decomposition.



(ii) Write the equation for this decomposition.
State symbols are not required.

(1)

~~$4NaNO_3 \rightarrow Na_2O + O_2 + NaO + Na$~~

$NaNO_3 \rightarrow O_2 + NO + Na$

(iii) Show, by reference to oxidation number changes, that the decomposition of sodium nitrate is a redox reaction.

(2)

O: $-2 \rightarrow 0$ $-2 \rightarrow -2$

N: $+5 \rightarrow +2$

Na: $+1 \rightarrow 0$

As the oxidation states have decreased, it is a redox ~~redu~~ reaction.

ResultsPlus
Examiner Comments

In part (ii), there is an example of an incorrect decomposition equation.

Unfortunately, in part (ii) there is no mark for the oxygen oxidation number changes because this needed to be connected to the aim of the question, namely that it is a redox reaction. Hence it was essential to refer to the oxygen as being oxidised as well as justifying it by means of the oxidation number change.

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Examiner Tip

'Read The Question Twice' to make sure that the point is addressed.

(ii) Write the equation for this decomposition.
State symbols are not required.

(1)

~~Na_2NO_3~~ $\Rightarrow$ ~~Na~~

$2NaNO_3 \rightarrow Na_2O + 2NO_2 + \frac{1}{2}O_2$

(iii) Show, by reference to oxidation number changes, that the decomposition of sodium nitrate is a redox reaction.

(2)

the Nitrogen reduces from a 5+ charge to a 4+ charge, the oxygen oxidizes from a 2- charge to a 0 charge, as both oxidation and reduction occur this is a redox reaction

ResultsPlus
Examiner Comments

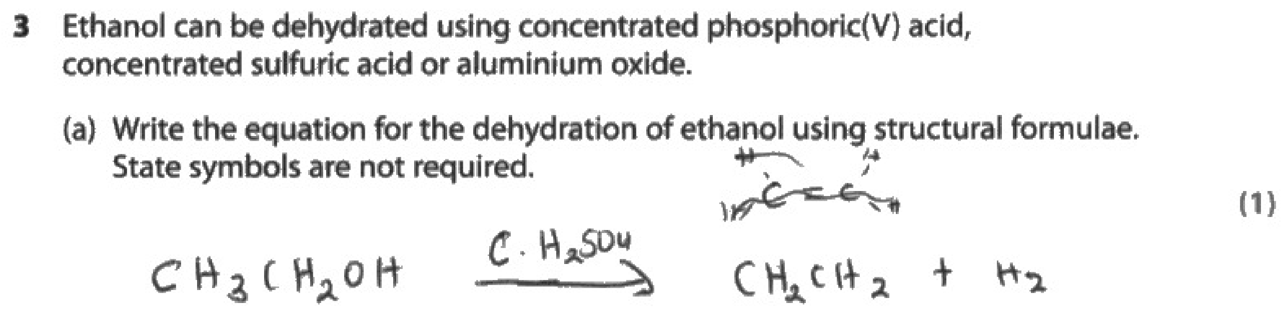
This is an example where the wrong decomposition equation is given, but since it is a 'near miss' being of lithium nitrate and not sodium nitrate then both marks were available in part (ii). In this response, the oxidation numbers given are all correct and there is reference to their showing that this is a redox reaction.

ResultsPlus
Examiner Tip

Transferred error often enhances marks that candidates achieve so it is always worth trying an answer and not leaving it blank.

Question 3 (a)

It was not expected that less than half of the candidates would not score this mark. Amongst the issues seen were: the inclusion of a catalyst in the equation, the production of ethene but omission of the water by-product, and incorrect ethene formulae.



3 Ethanol can be dehydrated using concentrated phosphoric(V) acid, concentrated sulfuric acid or aluminium oxide.

(a) Write the equation for the dehydration of ethanol using structural formulae. State symbols are not required.

(1)

$CH_3CH_2OH \xrightarrow{C.\ H_2SO_4} CH_2CH_2 + H_2$

ResultsPlus
Examiner Comments

It is acceptable to write the catalyst above the arrow as shown here but not that hydrogen and not water is made. It is likely that if a brief moment was spent to check the equation that the omission of the oxygen atom would have been spotted and corrected.

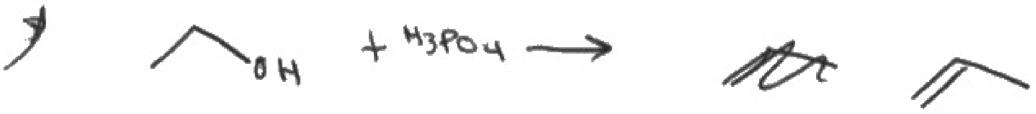
ResultsPlus
Examiner Tip

Make time to briefly check the balancing of equations.

3 Ethanol can be dehydrated using concentrated phosphoric(V) acid, H_3PO_4 concentrated sulfuric acid or aluminium oxide.

(a) Write the equation for the dehydration of ethanol using structural formulae. State symbols are not required.

(1)



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Examiner Comments

The question asks for structural formulae and not skeletal formulae. Skeletal formulae are extremely useful, but it can be very easy to add an extra carbon without meaning to. Note that the product here is actually propene instead of ethene. The catalyst is also incorrectly included in the equation and there is no water by-product.

ResultsPlus
Examiner Tip

Give your answer using the type of formulae required in the question.

Question 3 (b)

(b) Give the formula of phosphoric(V) acid.

(1)

$POCl_5$ or $H_2POCl_3^{2+}$ or $HPOCl_3$ or $POCl_3^{2-}$

ResultsPlus
Examiner Comments

Four possible formulae are given here. Unfortunately, none are correct but even if one had been correct, then the mark would have been negated by an incorrect formula.

ResultsPlus
Examiner Tip

Never give more than one answer to the same question

(b) Give the formula of phosphoric(V) acid.

(1)

HPO_3

ResultsPlus
Examiner Comments

This is an incorrect but reasonable attempt. The question gives the oxidation number of phosphorus as (v) or five and in this formula, the oxidation number for phosphorus does work out as such. However, this is called 'metaphosphoric acid' and is not the compound required in the question.

ResultsPlus
Examiner Tip

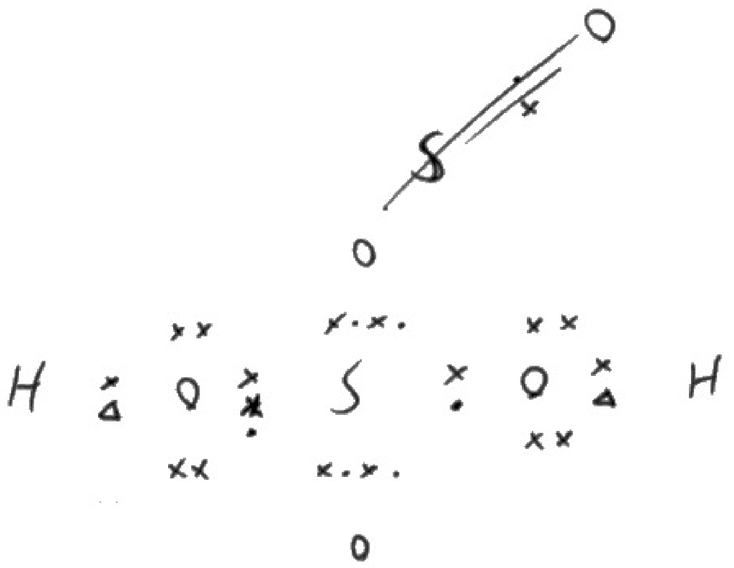
Learn the formulae of the reagents stated in the specification.

Question 3 (c)

Many scored one mark for the electron pairs around the sulfur, but the second mark for a completely correct diagram was seen less often.

(c) Draw the dot-and-cross diagram of sulfuric acid, H_2SO_4.
Clearly differentiate between sulfur, oxygen and hydrogen electrons.
Show outer shell electrons only.

(2)



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Examiner Comments

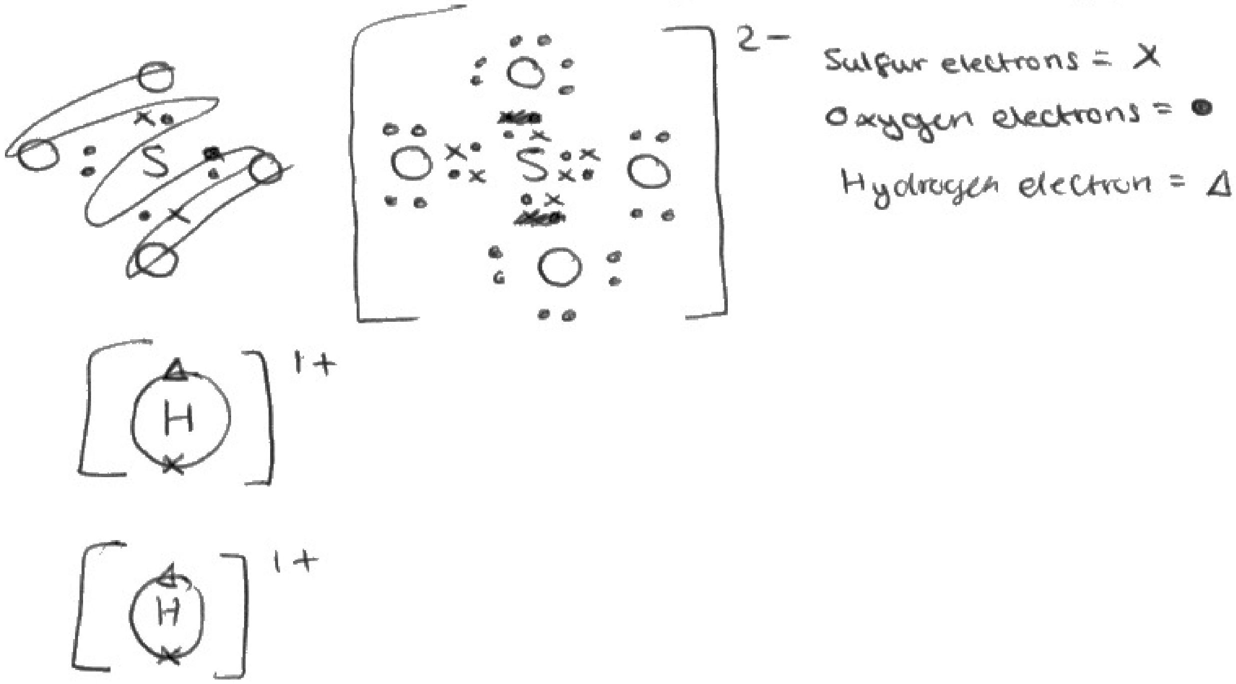
Benefit of the doubt was given to this candidate with respect to the electrons shown on the left-hand side of the central sulfur atom. It was assumed that one of the electrons was crossed out and so one mark was awarded. It was a shame that the second mark could not be awarded because this candidate does appreciate that the oxygen atoms have lone pairs of electrons as shown by the two atoms on either side. However, the two oxygen atoms at the top and bottom are missing their lone pairs.

ResultsPlus
Examiner Tip

Check to make sure that each and every atom has the correct number of electrons.

(c) Draw the dot-and-cross diagram of sulfuric acid, H_2SO_4.
Clearly differentiate between sulfur, oxygen and hydrogen electrons.
Show outer shell electrons only. ↖ 6e⁻ ↖ 6e⁻ ↑ 1e⁻

(2)



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Examiner Comments

This is an example of a response which was seen more than expected. The question asked for the diagram of sulfuric acid and not the sulfate ion with protons. However, one mark could have been awarded for correct diagrams but in this example the oxygen atoms at the top and bottom of the sulfate ion are drawn with seven electrons instead of six. In addition, the hydrogen ions are drawn with their electrons remaining rather than them donated to the oxygen atoms.

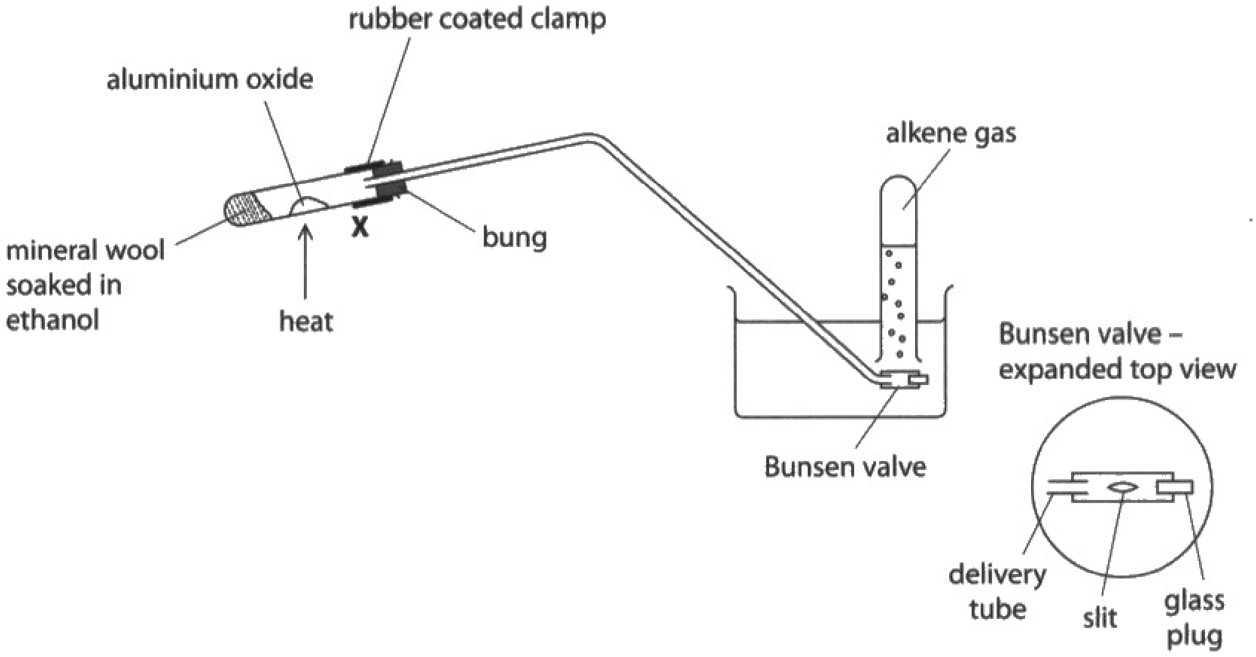
ResultsPlus
Examiner Tip

Another reminder to re-read the question to make sure that the answer matches the requirement of the question.

Question 3 (d)(i)

A seeming lack of practical experience was evident in this and the following questions. The rocksil wool soaked in ethanol does not retain the liquid very well and so the angle of the test tube was to prevent the ethanol from 'running down the tube'. This was rarely seen, but the idea was expressed by such answers that referred to the need to prevent the ethanol and the catalyst from mixing.

(d) Ethanol may be dehydrated using the catalyst aluminium oxide, Al_2O_3 .
The apparatus is shown.



(i) Give a possible reason for the boiling tube to be clamped at the angle shown.

(1)

To only heat the Al_2O_3 . ~~[illegible]~~

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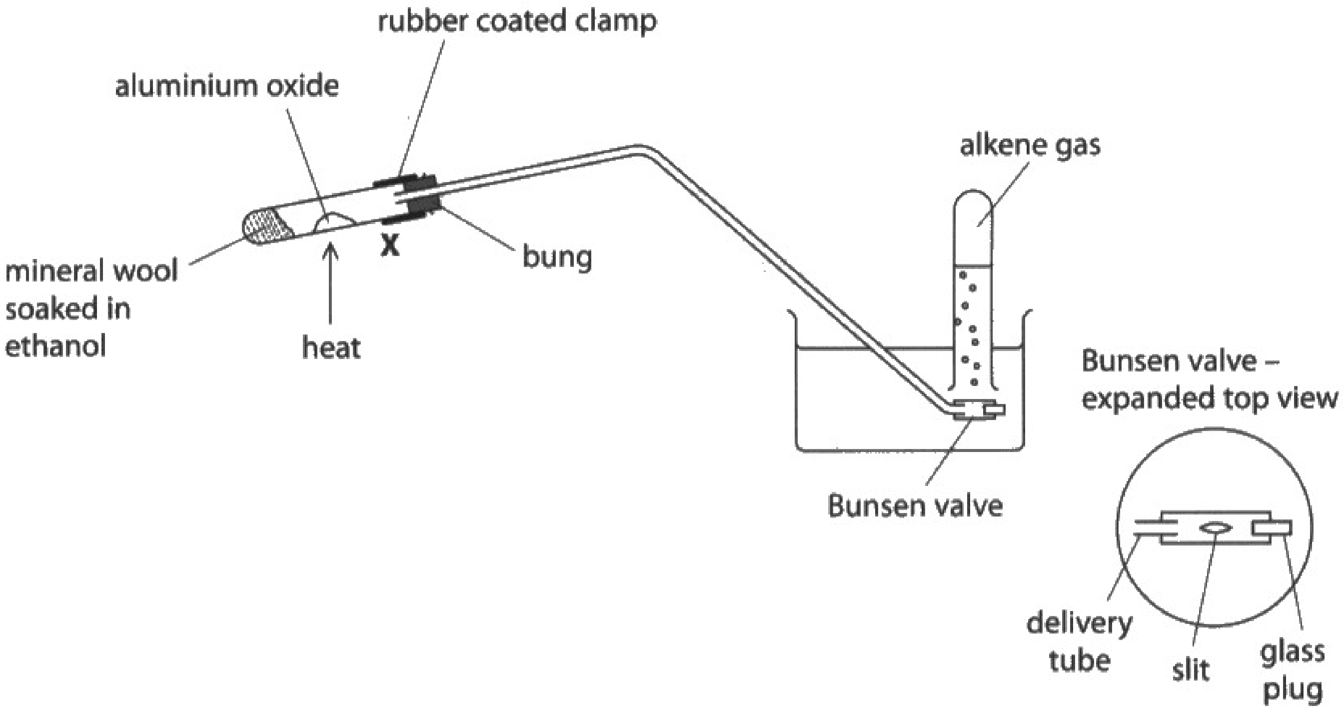
Examiner Comments

This was not an uncommon answer but focusses on the placement of the heat rather than the point of the question, which was the angle of the test tube.

ResultsPlus
Examiner Tip

Try to visualise the apparatus and what the issues might be.

(d) Ethanol may be dehydrated using the catalyst aluminium oxide, Al_2O_3.
The apparatus is shown.



(i) Give a possible reason for the boiling tube to be clamped at the angle shown. **(1)**

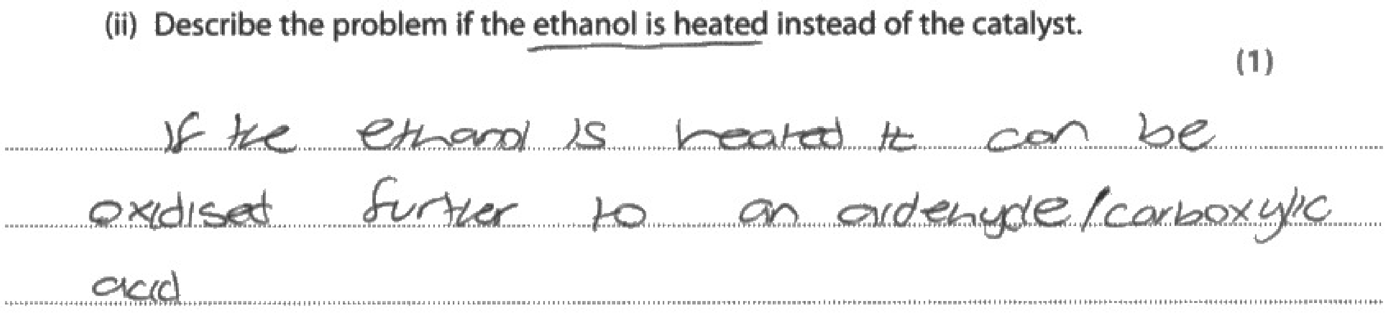
The boiling tube is clamped at an angle so the aluminium oxide or wool doesnt enter the delivery tube or only gas can rise and enter.

ResultsPlus
Examiner Comments

This is a better attempt at explaining the angle of the test tube. Unfortunately, the main issue is the movement of the liquid ethanol and not the solids so this did not score.

Question 3 (d)(ii)

The majority of responses seen mentioned the flammability of the ethanol and referred to ethanol undergoing combustion. Some candidates did refer to the evaporation of the ethanol, but unfortunately did not connect it with the fact that it would then pass over the catalyst without reaction.



(ii) Describe the problem if the ethanol is heated instead of the catalyst.

(1)

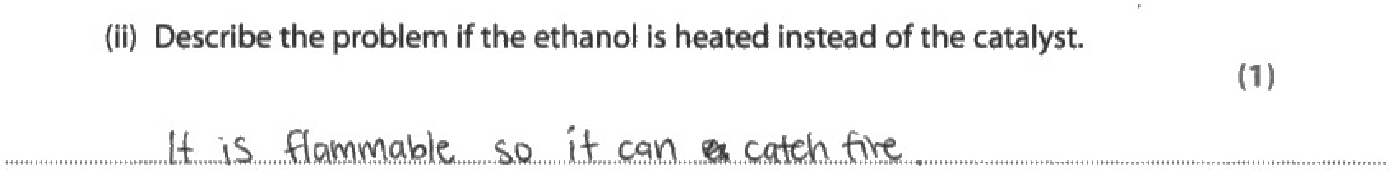
If the ethanol is heated it can be oxidised further to an aldehyde/carboxylic acid

ResultsPlus
Examiner Comments

This response misses the issue that the ethanol would evaporate and not undergo reaction. There would not be oxidation of the alcohol.

ResultsPlus
Examiner Tip

Remember that in class experiments, the oxidation of an alcohol requires acidified potassium or sodium dichromate(VI).



(ii) Describe the problem if the ethanol is heated instead of the catalyst.

(1)

It is flammable so it can ~~ex~~ catch fire.

ResultsPlus
Examiner Comments

An example of a common incorrect response. Ethanol is flammable but this would not be an issue by moving the heating position.

Question 3 (d)(iii)

This was one of the most accessible questions on the paper, perhaps because many candidates have experienced it in class. If the heat was moved to position X, then the vast majority knew that the rubber would melt or burn.

(iii) Identify a safety issue if the heat source was moved to the position labelled **X** on the diagram.

(1)

The rubber coated clamp could melt after ~~heat~~ heating, which would cause the tube to fall.

ResultsPlus
Examiner Comments

An example of a response which scored the mark. The reference to the melting of the clamp was sufficient to score. The mention of the tube falling was not necessary.

(iii) Identify a safety issue if the heat source was moved to the position labelled **X** on the diagram.

(1)

The bung might fly off due to the pressure which could cause injury.

ResultsPlus
Examiner Comments

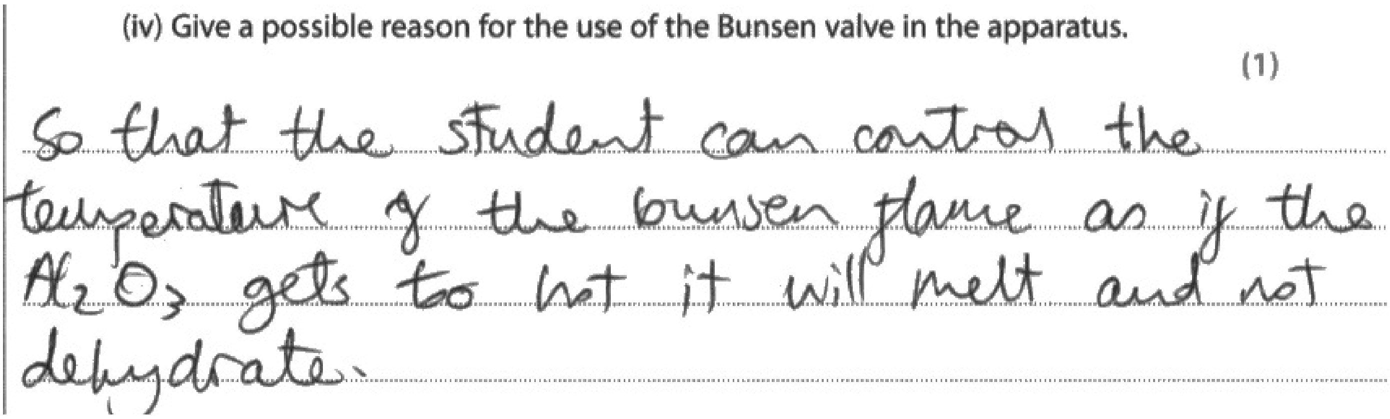
An example of a rare response which did not score. The movement of the position of heat would not lead to the bung flying off. Perhaps the candidate had experienced this in a different experiment and wondered if it happened here. It is good to consider past experiences, but care is also needed as to whether they apply elsewhere.

ResultsPlus
Examiner Tip

The wording used in the diagram labels often provides clues or hints to how to answer the question. In most previous occasions, the label has simply been 'clamp' on a diagram and so the inclusion of "rubber coated" in this instance was there to give candidates additional guidance.

Question 3 (d)(iv)

Another question where practical skills or experience was lacking. It was expected that a Bunsen valve would not have been used by many and so great care was taken to provide both a side view and a top view of the valve to illustrate how it would work. There are a number of experiments that candidates might have carried out where the 'suck-back' of water is an issue. This was the point here. This answer was rarely seen, but credit was also given for mentioning that the valve would prevent water from entering the delivery tube.



(iv) Give a possible reason for the use of the Bunsen valve in the apparatus.

(1)

So that the student can control the temperature of the bunsen flame as if the Al_2O_3 gets too hot it will melt and not dehydrate.

ResultsPlus
Examiner Comments

In this example, the term 'Bunsen valve' has been misunderstood because no note has been taken of the 'expanded top view'. Hence no mark awarded.

ResultsPlus
Examiner Tip

When something new or novel is incorporated into an exam question, then further or additional guidance will be provided. Do take note of this.

(iv) Give a possible reason for the use of the Bunsen valve in the apparatus.

(1)

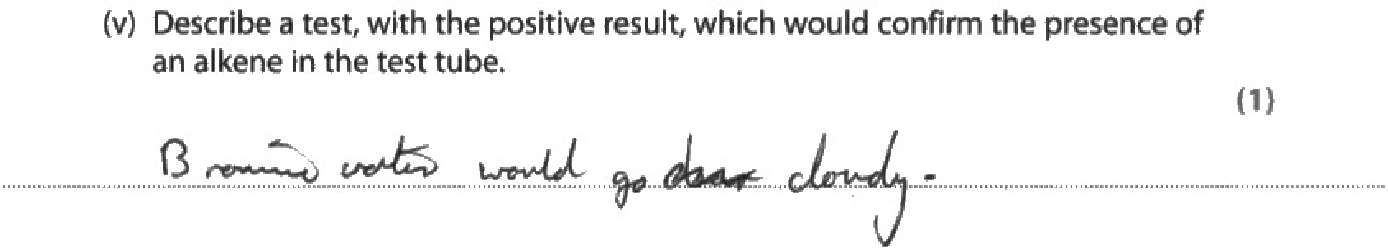
Allows gas to go straight to the inverted boiling tube /measuring cylinder, thus preventing gas from being absorbed by the water, ~~which~~ which would lead to a lower yield of alkene gas.

ResultsPlus
Examiner Comments

An example of a frequently seen response where the candidate mistakenly thinks that the Bunsen valve is to control the flow of the gas into the inverted tube. The side view of the diagram clearly shows the gas bubbling up through the trough of water and so there would have been no prevention of the gas dissolving in the water, should this have been possible.

Question 3 (d)(v)

The vast majority of candidates could clearly give the bromine test for alkenes which decolourise the halogen.



(v) Describe a test, with the positive result, which would confirm the presence of an alkene in the test tube.

(1)

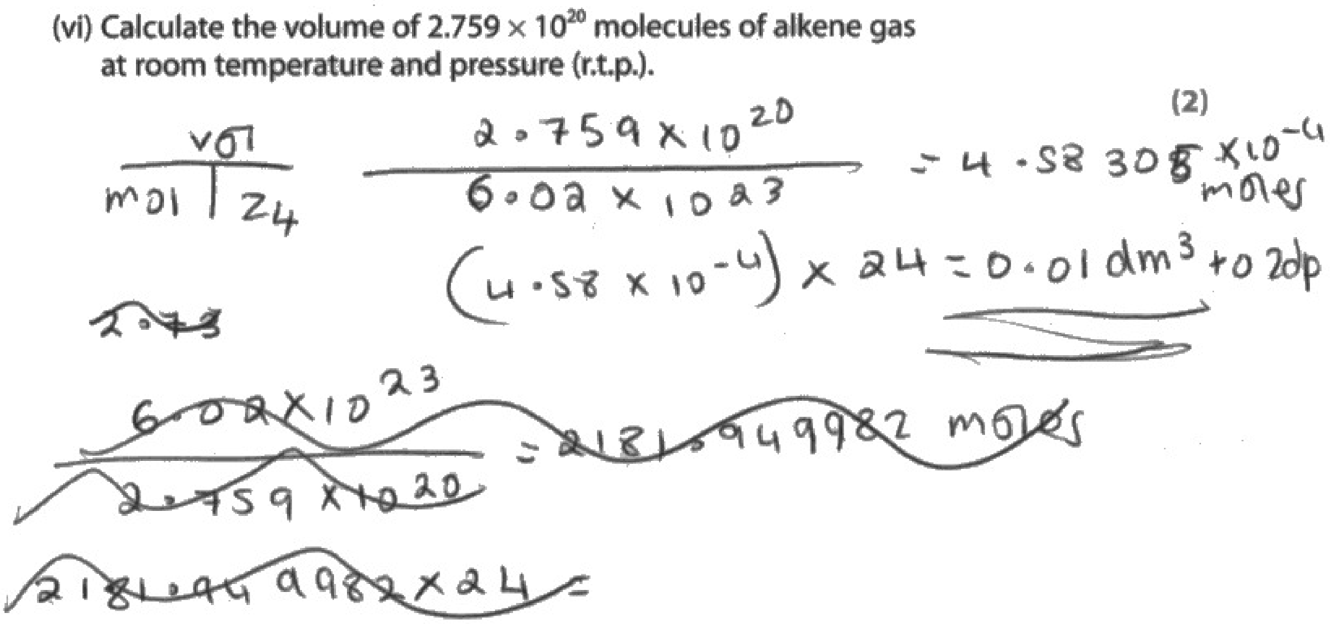
Bromine water would go ~~clear~~ cloudy.

ResultsPlus
Examiner Comments

One of the few answers which did not score because the bromine goes colourless and not cloudy.

Question 3 (d)(vi)

The greater number of candidates scored both marks here. Occasionally there was a rounding error or an answer was given to only one significant figure, and a small minority divided by 24 or 24000 instead of multiplying. The question did not specify the units that the volume was required in and so allowed for use of either 24 dm^3 or 24000 cm^3 as the molar gas volume. A small minority of candidates used $pV=nRT$ which was fine, as was an answer in cubic meters. It is worth candidates noting that calculations involving the use of the ideal gas law are generally worth at least three if not four marks. Reference to the volume a room temperature and pressure involve the mola gas volume and carry a smaller tariff.



(vi) Calculate the volume of 2.759×10^{20} molecules of alkene gas at room temperature and pressure (r.t.p.).

(2)

$\frac{\text{vol}}{\text{mol} \mid 24}$

$\frac{2.759 \times 10^{20}}{6.02 \times 10^{23}} = 4.58308 \times 10^{-4}$ moles

$(4.58 \times 10^{-4}) \times 24 = 0.01\ \text{dm}^3$ to 2dp

~~2.73~~

~~$\frac{6.02 \times 10^{23}}{2.759 \times 10^{20}} = 2181.949982$ moles~~

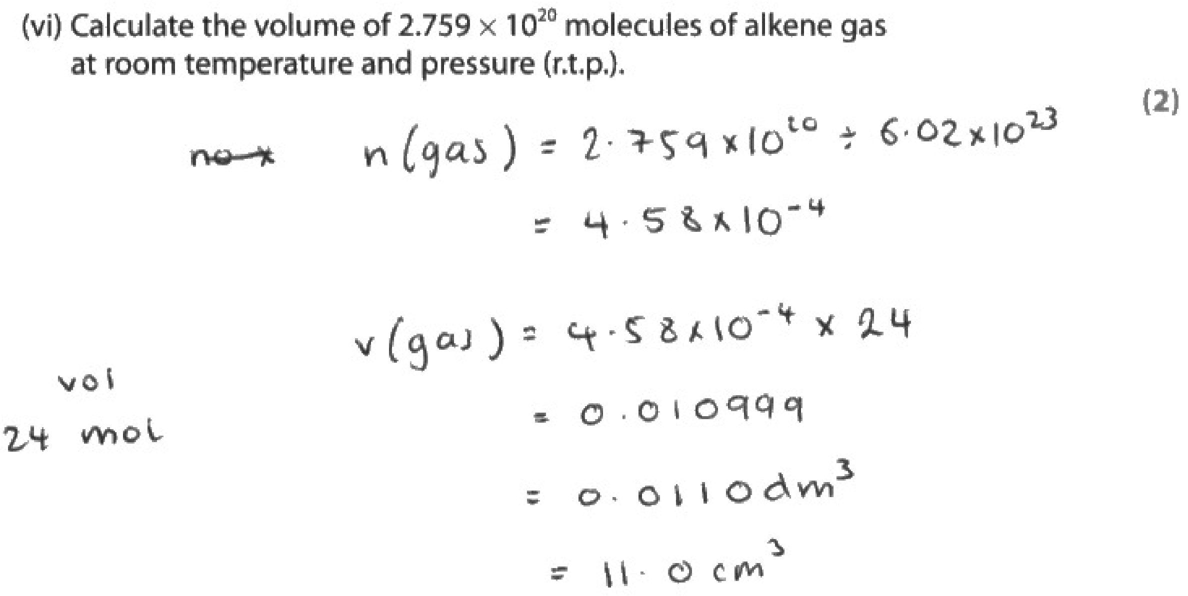
~~$2181.949982 \times 24 =$~~

ResultsPlus
Examiner Comments

This response only scored one mark. The final answer is to one significant figure which is generally more important than decimal place unless the question indicates otherwise.

ResultsPlus
Examiner Tip

Rarely are answers to one significant figure acceptable. If in doubt, then always given your answer to three significant figures.



(vi) Calculate the volume of 2.759×10^{20} molecules of alkene gas at room temperature and pressure (r.t.p.).

(2)

~~no~~

$n(\text{gas}) = 2.759 \times 10^{20} \div 6.02 \times 10^{23}$

$= 4.58 \times 10^{-4}$

$v(\text{gas}) = 4.58 \times 10^{-4} \times 24$

$= 0.010999$

$= 0.0110\,\text{dm}^3$

$= 11.0\,\text{cm}^3$

vol

24 mol

ResultsPlus

Examiner Comments

Both marks awarded here, but the giving of two answers is not to be recommended. Fortunately, the value in cubic decimetres and the value in cubic centimetres are both correct. The value has also been rounded correctly to three significant figures.

ResultsPlus

Examiner Tip

If the question does not state that units are required, then use of any appropriate unit is fine. There is no need to convert from one unit to another.

Question 4 (a)

There were some excellent well-structured responses here from candidates who had clearly understood the process and seemed to have had a good practical experience in their studies. The most common error from those who described the correct type of experiment was that they added the water to the salt. Doing it this way round would mean that the initial temperature of the solid would have to be measured and this is very difficult, nigh impossible to do. However, only one mark was lost. The second most common error or omission in this situation was that there was a mark for reference to stirring the mixture and this was often missing.

Large numbers of candidates, including those who scored all six marks, described the method of calculation despite the question clearly stating that this was not required. From the amount of writing that was seen, this would have taken a significant amount of time which could have been spent on other question parts and may have gained extra credit.

However, there was also a significant number of candidates who showed their misunderstanding by describing a thermal decomposition experiment. Either a crucible was heated to remove the water of crystallisation or the salt was heated in a polystyrene cup.

4 This question is about hydrated magnesium sulfate, $MgSO_4 \cdot 7H_2O$.

*(a) Devise an experimental procedure to determine the enthalpy change of solution for hydrated magnesium sulfate.

$$MgSO_4 \cdot 7H_2O(s) + aq \rightarrow MgSO_4(aq)$$

Details of the method of calculation are not required.

(6)

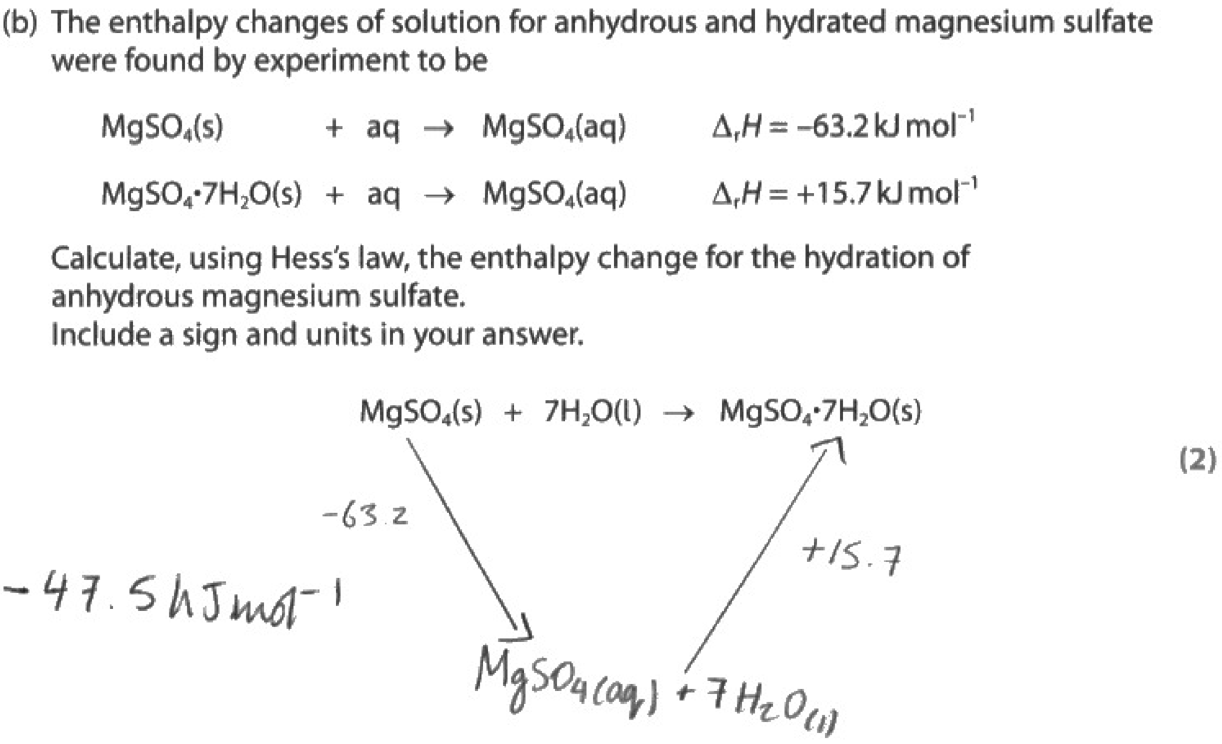
Add 5g of magnesium sulfate to a polystyrene cup inside a glass beaker. The polystyrene cup is used ~~to~~ as it is an insulator of heat energy. Add water (100cm³) to the magnesium sulfate and add a thermometer ~~and a lid to~~ to record temperature and a lid to prevent heat escaping. Record the initial temperature of the mixture using the thermometer. Then allow the magnesium ~~an~~ sulfate to dissolve while stirring and allow the temperature to rise until the temperature remains constant as this shows that all the magnesium sulfate has dissolved. Then record the temperature again and the temperature rise. Repeat the experiment and find a mean temperature rise and use this to calculate a value of enthalpy change of solution.

ResultsPlus
Examiner Comments

This is an example of a response which describes the addition of the water to the salt. The response does state to record the initial temperature of the mixture, but this is not appropriate given that the dissolving of the salt will have already begun and so the temperature will be changing. In all other respects the response is fine and was awarded 5 marks.

Question 4 (b)

The most common mark was two out of two on this question. Many knew both how to draw the Hess cycle and how to use it to calculate the enthalpy change required. Centres and their candidates can feel pleased that their practice paid off.



(b) The enthalpy changes of solution for anhydrous and hydrated magnesium sulfate were found by experiment to be

$MgSO_4(s) + aq \rightarrow MgSO_4(aq) \quad \Delta_r H = -63.2\ kJ\ mol^{-1}$

$MgSO_4{\cdot}7H_2O(s) + aq \rightarrow MgSO_4(aq) \quad \Delta_r H = +15.7\ kJ\ mol^{-1}$

Calculate, using Hess's law, the enthalpy change for the hydration of anhydrous magnesium sulfate.
Include a sign and units in your answer.

$MgSO_4(s) + 7H_2O(l) \rightarrow MgSO_4{\cdot}7H_2O(s)$

(2)

-63.2

+15.7

$MgSO_{4(aq)} + 7H_2O_{(l)}$

-47.5 kJ mol^{-1}

ResultsPlus
Examiner Comments

The right-hand arrow is going up, but should be going down. This one error meant that this response scored 1 mark and not 2.

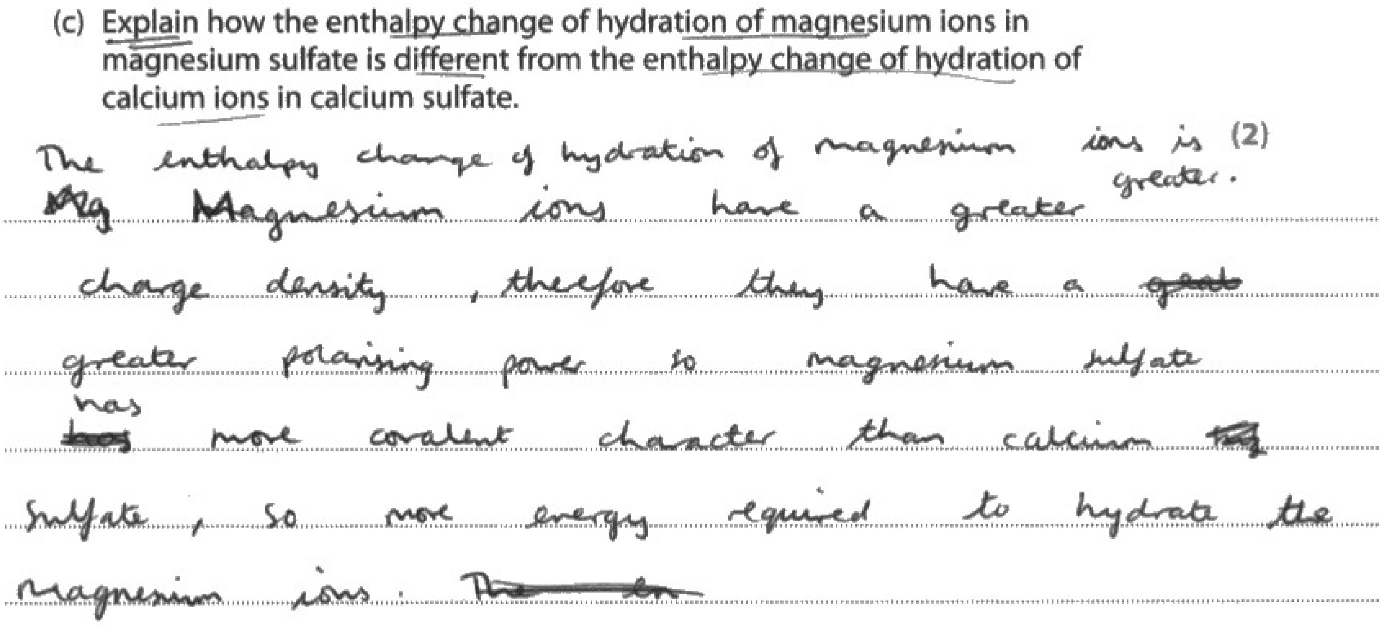
ResultsPlus
Examiner Tip

In a Hess cycle, check that the arrows go in the same direction as the arrows in the equations.

Question 4 (c)

Centres and their candidates are reminded that when exothermic enthalpy changes or those with a negative sign are being considered that a description of the value being bigger/larger/greater do not score. These terms are ambiguous when dealing with negative numbers.

A small minority of candidates did not focus on the Group 2 ions and referred to the hydration of the salt instead which did not score. At times, a correct reference to the magnesium ion hydration energy being more exothermic was then spoilt by then stating that more energy was "required".



(c) Explain how the enthalpy change of hydration of magnesium ions in magnesium sulfate is different from the enthalpy change of hydration of calcium ions in calcium sulfate.

(2)

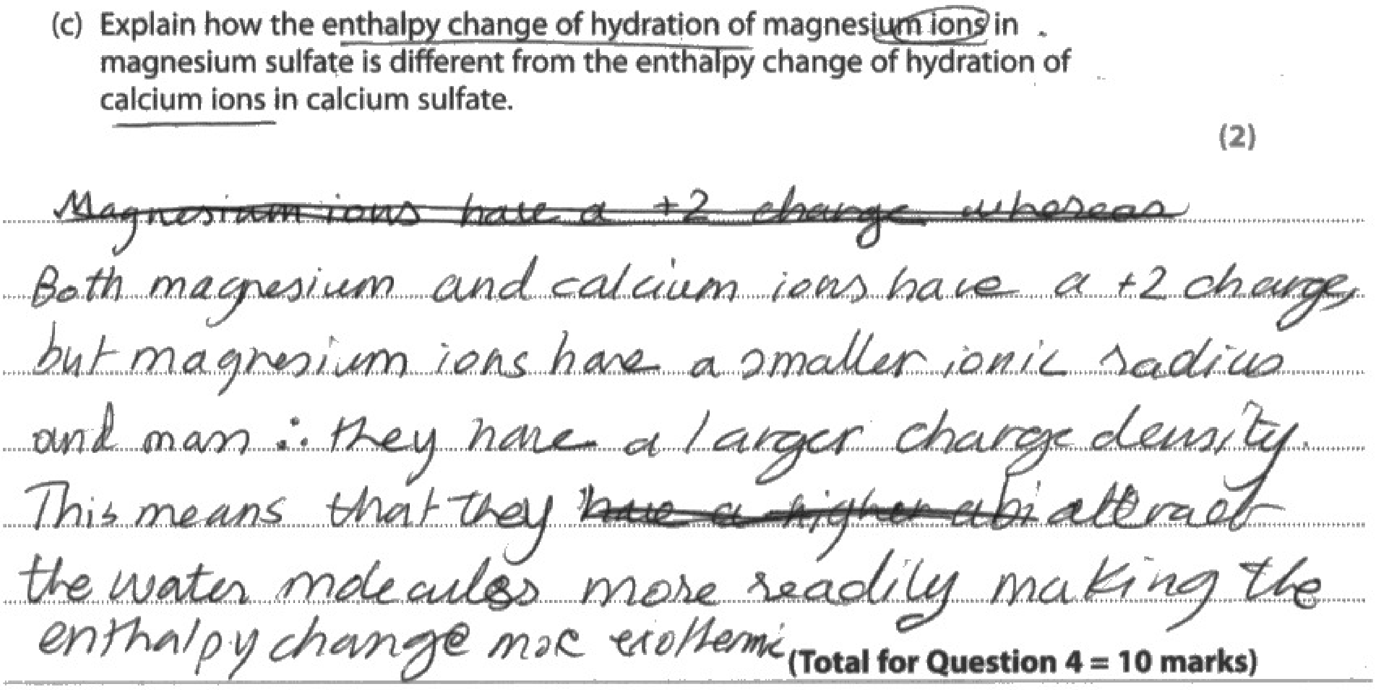
The enthalpy change of hydration of magnesium ions is greater. ~~Mg~~ Magnesium ions have a greater charge density, therefore they have a ~~great~~ greater polarising power so magnesium sulfate ~~has~~ has more covalent character than calcium ~~[illegible]~~ sulfate, so more energy required to hydrate the magnesium ions. ~~The ion~~

ResultsPlus
Examiner Comments

1 mark was awarded for reference to the greater charge density of the magnesium ions. There was no second mark because energy is released and not required when ions are hydrated.

ResultsPlus
Examiner Tip

Charge density is a very useful term because it includes reference to both charge and ionic radius.



(c) Explain how the enthalpy change of hydration of magnesium ions in magnesium sulfate is different from the enthalpy change of hydration of calcium ions in calcium sulfate.

(2)

~~Magnesium ions have a +2 charge whereas~~ Both magnesium and calcium ions have a +2 charge, but magnesium ions have a smaller ionic radius and mass ∴ they have a larger charge density. This means that they ~~have a higher abi~~ attract the water molecules more readily making the enthalpy change more exothermic

(Total for Question 4 = 10 marks)

ResultsPlus

Examiner Comments

Both marks awarded for this response. Reference is made to both the size and the charge on the Group 2 ions for one mark and the candidate has just squeezed in that the enthalpy change is more exothermic for the second mark.

Question 5 (a)

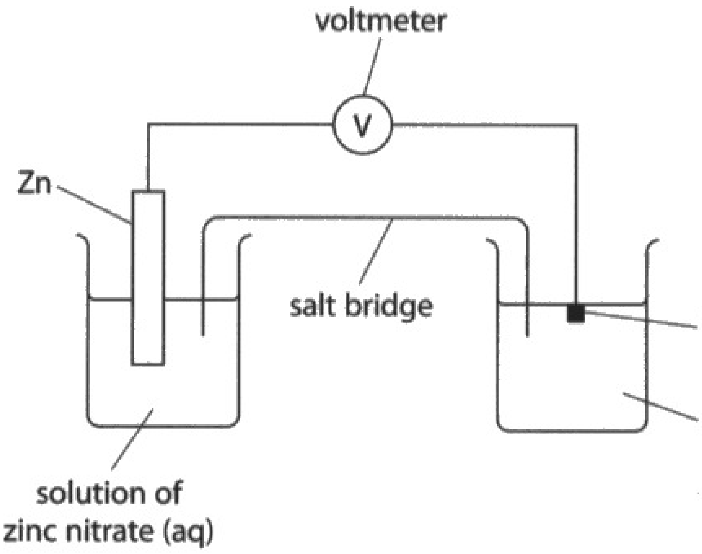
A large number of candidates scored one mark for the 'Y' label of the platinum electrode, although there was the occasional manganese electrode. The other two marks were rarely awarded. The question clearly requires "naming the substances needed" and so ions were insufficient. Both a suitable manganese(II) salt and potassium manganate(VII) were needed for the second mark. The third mark was for the naming of a suitable acid such as sulfuric acid, but this was only seen a few times.

5 This question is about electrochemical cells.

(a) A diagram is shown of the apparatus that is used to measure the emf of a cell with a zinc/zinc(II) electrode and an acidified manganese(II)/manganate(VII) electrode system.

Complete the labels **Y** and **Z** by naming the substances needed. Temperature and concentrations are not required.

(3)



Y platinum electrode

Z solution of manganese (II) sulfate and manganate (VII) sulfate

ResultsPlus Examiner Comments

This candidate has scored the mark for the 'Y' label and has given the names of substances for Z. Manganese(II) sulfate is acceptable as a source of Mn2+ ions but manganate(VII) sulfate does not exist, so the second mark is not awarded. There is no mention of acid, so no third mark.

ResultsPlus Examiner Tip

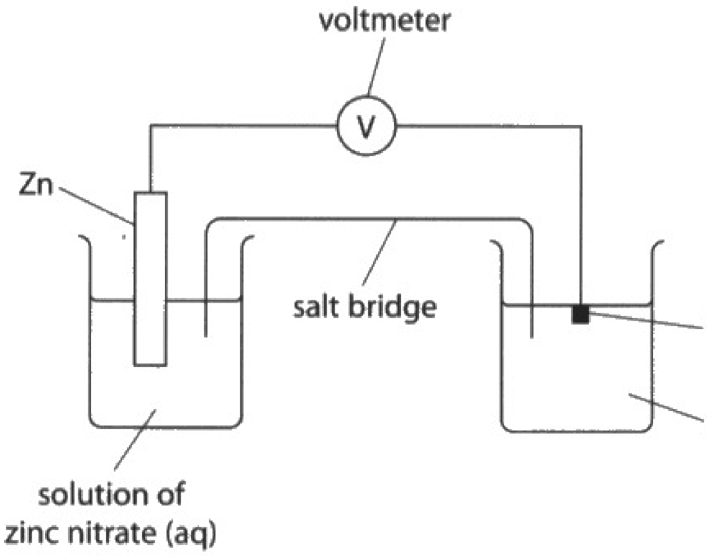
Candidates should stick to substances that they know exist. For example, potassium manganate(VII), KMnO4 is often used in redox titrations such as Core Practical 11.

5 This question is about electrochemical cells.

(a) A diagram is shown of the apparatus that is used to measure the emf of a cell with a zinc/zinc(II) electrode and an acidified manganese(II)/manganate(VII) electrode system.

Complete the labels **Y** and **Z** by naming the substances needed.
Temperature and concentrations are not required.

(3)



Y ~~Pta~~ Platinium electrode

Z [KMnO$_4$] solution [illegible]

[illegible] [illegible]

[MnCl$_2$] solution [illegible]

ResultsPlus
Examiner Comments

Another response which scores the first mark for the platinum electrode label.

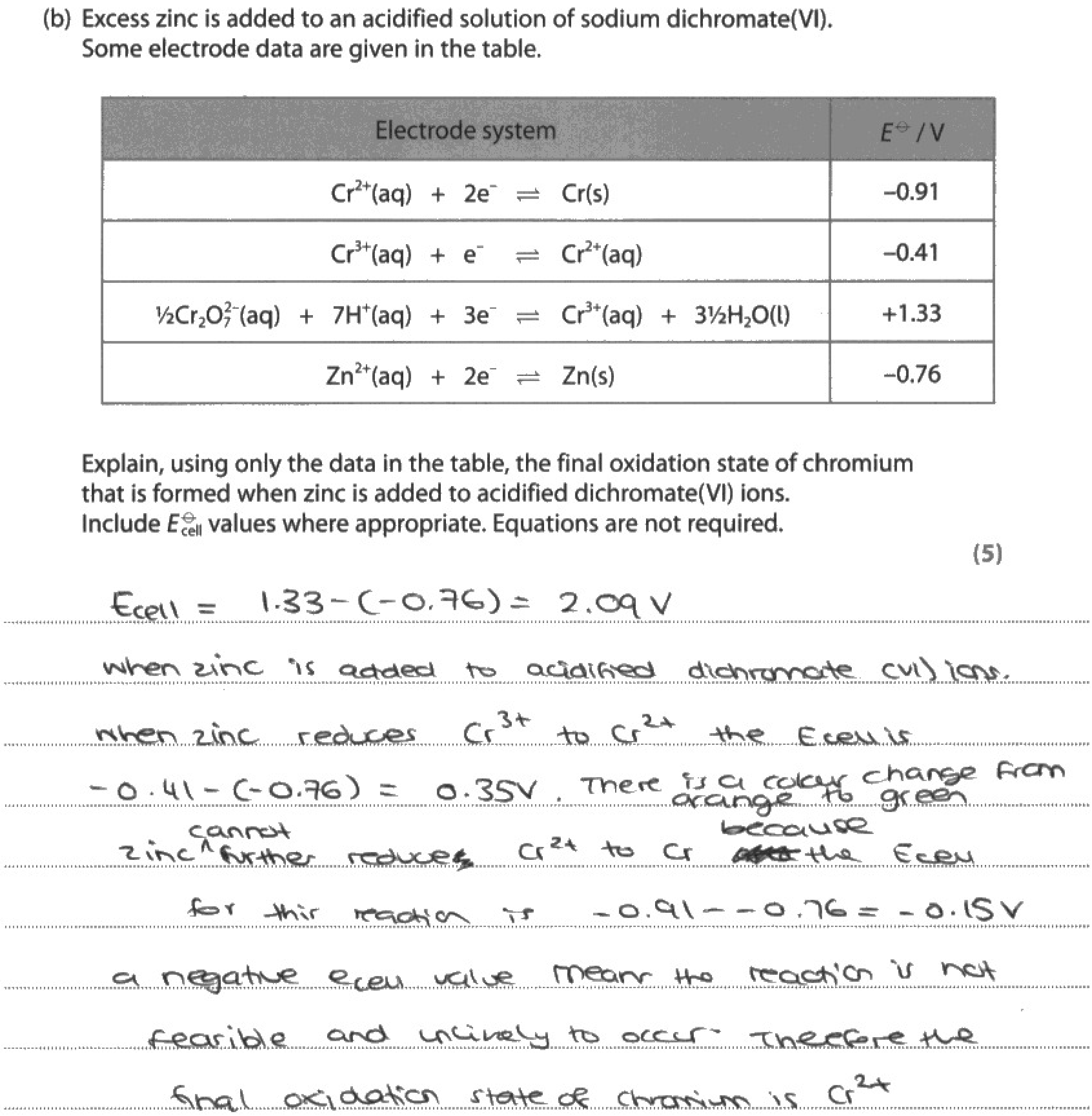
The two manganese compounds do exist and would provide the manganese ions required. However, the use of manganese(II) chloride was not allowed because the chloride ions would be oxidised by the manganate(VII) ions to chlorine. The label of the zinc nitrate salt in the other electrode was provided as a help, but not used.

ResultsPlus
Examiner Tip

All nitrates are soluble and so suitable for use in electrodes and in most situations they are unreactive so do not alter the desired reaction.

Question 5 (b)

This proved to be a high-scoring question with many candidates scoring all five marks. The only real issue was when a candidate hadn't read the question properly and didn't determine the E_{cell} values, but simply answered in terms of the difference in electrode potentials.



(b) Excess zinc is added to an acidified solution of sodium dichromate(VI).
Some electrode data are given in the table.

Electrode system	$E^\ominus$ / V
$Cr^{2+}(aq) + 2e^- \rightleftharpoons Cr(s)$	−0.91
$Cr^{3+}(aq) + e^- \rightleftharpoons Cr^{2+}(aq)$	−0.41
$\frac{1}{2}Cr_2O_7^{2-}(aq) + 7H^+(aq) + 3e^- \rightleftharpoons Cr^{3+}(aq) + 3\frac{1}{2}H_2O(l)$	+1.33
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	−0.76

Explain, using only the data in the table, the final oxidation state of chromium that is formed when zinc is added to acidified dichromate(VI) ions.
Include $E^\ominus_{cell}$ values where appropriate. Equations are not required.

(5)

$E_{cell} = 1.33 - (-0.76) = 2.09$ V

when zinc is added to acidified dichromate (VI) ions.

when zinc reduces Cr^{3+} to Cr^{2+} the Ecell is

$-0.41 - (-0.76) = 0.35$V. There is a colour change from orange to green

zinc cannot further reduces Cr^{2+} to Cr because the Ecell

for this reaction is $-0.91 - -0.76 = -0.15$V

a negative ecell value means the reaction is not

feasible and unlikely to occur. Therefore the

final oxidation state of chromium is Cr^{2+}

ResultsPlus
Examiner Comments

This is an example of a clear and concise answer that scored all 5 marking points.

(b) Excess zinc is added to an acidified solution of sodium dichromate(VI).
Some electrode data are given in the table.

Electrode system	$E^{\ominus}$ / V
$Cr^{2+}(aq) + 2e^- \rightleftharpoons Cr(s)$	−0.91
$Cr^{3+}(aq) + e^- \rightleftharpoons Cr^{2+}(aq)$	−0.41
② $\frac{1}{2}Cr_2O_7^{2-}(aq) + 7H^+(aq) + 3e^- \rightleftharpoons Cr^{3+}(aq) + 3\frac{1}{2}H_2O(l)$	+1.33
③ $Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	−0.76

← +0.76

Explain, using only the data in the table, the final oxidation state of chromium that is formed when zinc is added to acidified dichromate(VI) ions.
Include $E^{\ominus}_{cell}$ values where appropriate. Equations are not required.

(5)

$Cr_2O_7^{2-}$ has a greater $E^{\ominus}$/V value of +1.33 so it will be reduced while Zn will be oxidised. ~~For every~~ So the oxidation state of ~~Cr in the~~ chromium will be +3 as it forms Cr^{3+} ions.

ResultsPlus
Examiner Comments

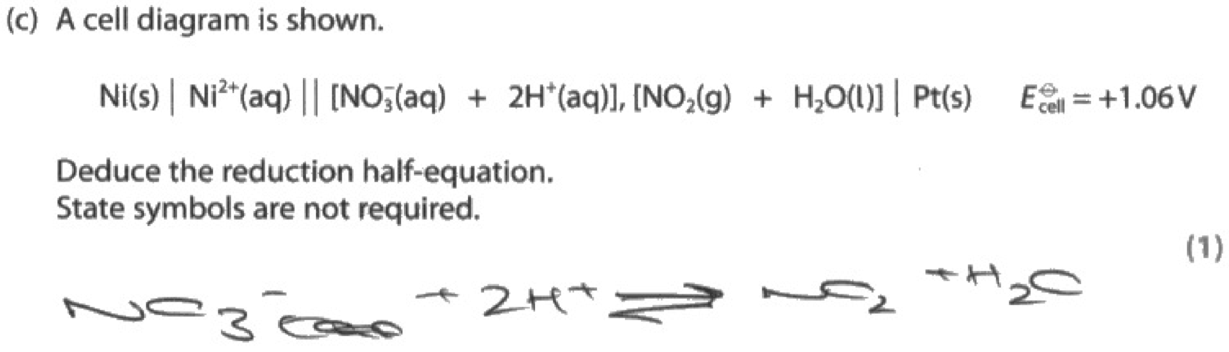
This candidate is correct in stating that the dichromate(VI) species will be reduced and that the zinc will be oxidised. However, no emf values are given. One mark was potentially available for such a qualitative consideration for the further reductions of the chromium, but this response doesn't go further and so no mark is awarded. The final oxidation state is chromium +2 and not +3 which means this response did not score any marks.

ResultsPlus
Examiner Tip

'Read The Question Twice' so that the answer matches what is required.

Question 5 (c)

It seemed that some candidates were familiar with the meaning of the cell diagram while others were not. It is worth centres and their candidates practising writing and interpreting these diagrams. Where candidates understood the meaning of the cell diagram, then this mark was confidently obtained.



(c) A cell diagram is shown.

$Ni(s) \mid Ni^{2+}(aq) \mid\mid [NO_3^-(aq) + 2H^+(aq)], [NO_2(g) + H_2O(l)] \mid Pt(s) \qquad E^{\ominus}_{cell} = +1.06\,V$

Deduce the reduction half-equation.
State symbols are not required.

(1)

$NO_3^- + 2H^+ \rightleftharpoons NO_2 + H_2O$

ResultsPlus
Examiner Comments

This is almost correct in that the equation is balanced for atoms but unfortunately, it is lacking the electrons which would both balance the charge and mean that it is a reduction half-equation.

ResultsPlus
Examiner Tip

Always check that an equation is balanced for charge.

A half-equation always includes electrons. Reduction is the gain of electrons.

(c) A cell diagram is shown.

−0.25 V   +0.80

$$\mathrm{Ni(s)\,|\,Ni^{2+}(aq)\,||\,[NO_3^-(aq) + 2H^+(aq)],\,[NO_2(g) + H_2O(l)]\,|\,Pt(s)} \qquad E^{\ominus}_{\mathrm{cell}} = +1.06\,\mathrm{V}$$

Deduce the reduction half-equation.
State symbols are not required.

(1)

$Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$

ResultsPlus
Examiner Comments

An example of an incorrect reduction equation that was often seen. The cell diagram has the nickel on the left which means that it is oxidised and not reduced. The order of the species in the cell diagram matches the order in the half-equation so solid nickel is oxidised to nickel(II) ions.

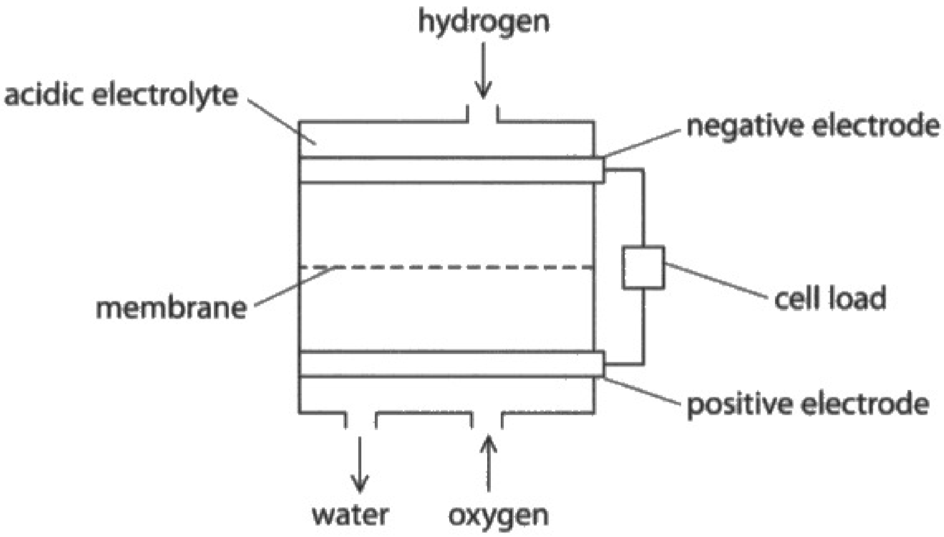
ResultsPlus
Examiner Tip

The term 'cell diagram' can be confusing given that it's not a diagram so learn what this term means and the conventions employed.

Question 5 (d)

Many candidates correctly stated the direction of electron flow for the first mark. A sizeable number of candidates mentioned the oxidation of hydrogen, but omitted the reduction of the oxygen and both were needed for the second mark. A small number of candidates referred to the reduction of the oxide ion O^{2-}, which is incorrect.

(d) State the direction of the electron flow in the hydrogen-oxygen fuel cell shown. Justify your answer by reference to the redox processes in the cell.



(2)

Across the membrane from the negative electrode to the positive electrode (from H_2 to O_2)

ResultsPlus
Examiner Comments

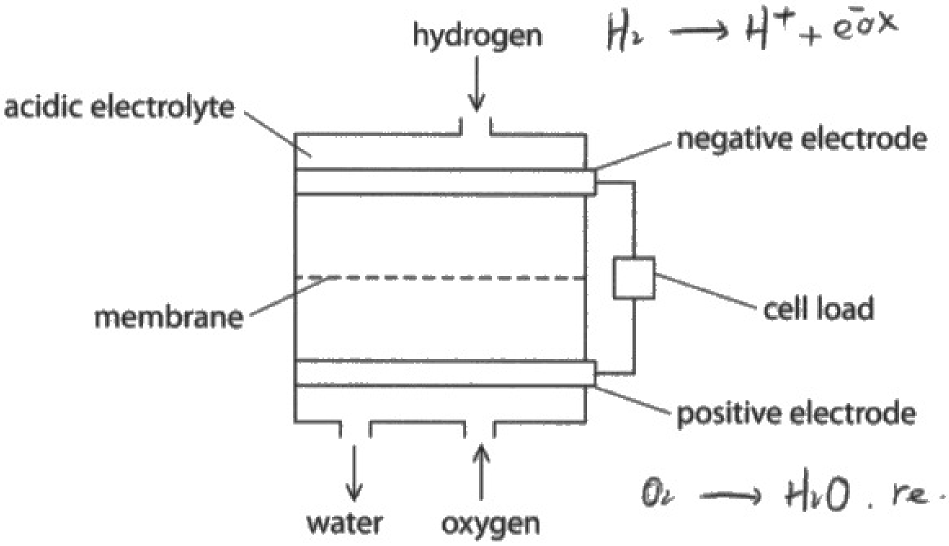
The movement of electrons is from the negative electrode to the positive electrode, but it is not through the membrane and so this comment negates the mark.

There is no justification with respect to the redox processes.

ResultsPlus
Examiner Tip

Sometimes 'less is more'.

(d) State the direction of the electron flow in the hydrogen-oxygen fuel cell shown. Justify your answer by reference to the redox processes in the cell.



$H_2 \longrightarrow H^+ + e^-$ ox

$O_2 \longrightarrow H_2O$. re .

(2)

Hydrogen is oxidized to H^+ ions by a loss of electrons, hence electrons flow from negative electrode to positive electrode.

ResultsPlus
Examiner Comments

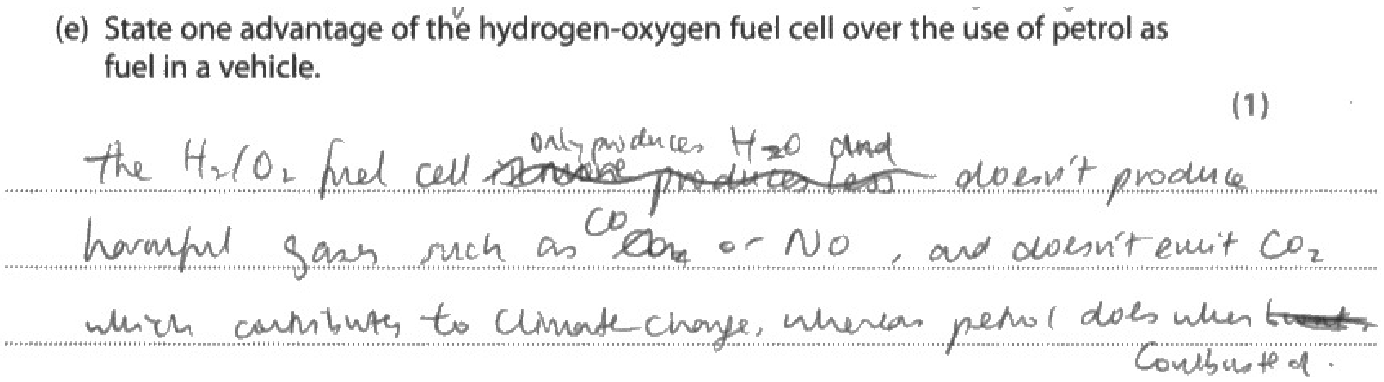
The correct movement of electrons is described for the first mark. Unfortunately, only the oxidation process is described so the second mark is not awarded. The brief note written just under the diagram is not quite enough because 're' is not necessarily reduction.

ResultsPlus
Examiner Tip

Annotations on or around diagrams can be credited, but best to answer in the space provided.

Question 5 (e)

A very well-scored question. The most common correct answers related either to water being the only/harmless product or that no greenhouse gases/CO_2 is produced.



(e) State one advantage of the hydrogen-oxygen fuel cell over the use of petrol as fuel in a vehicle.

(1)

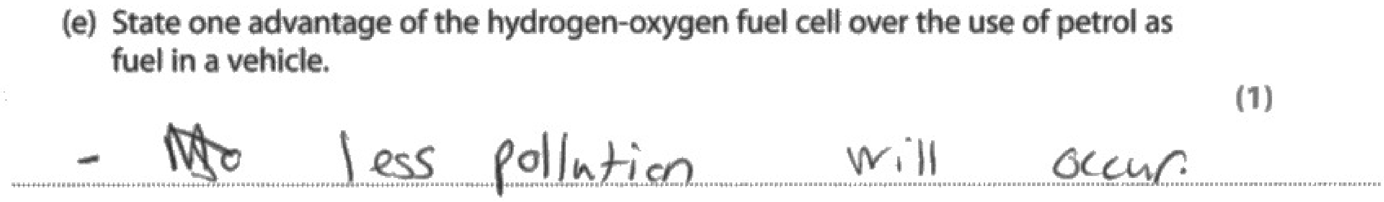
the H_2/O_2 fuel cell ~~[illegible]~~ only produces H_2O and ~~produces less~~ doesn't produce harmful gases such as CO ~~CO_2~~ or NO, and doesn't emit CO_2 which contributes to climate change, whereas petrol does when ~~[illegible]~~ combusted.

ResultsPlus
Examiner Comments

Everything that this candidate has written is correct and, in a sense, has scored the one mark several times. The request for "one advantage" seems to have been overlooked.

ResultsPlus
Examiner Tip

Avoid writing too much because it is possible to negate the correct answer.



(e) State one advantage of the hydrogen-oxygen fuel cell over the use of petrol as fuel in a vehicle.

(1)

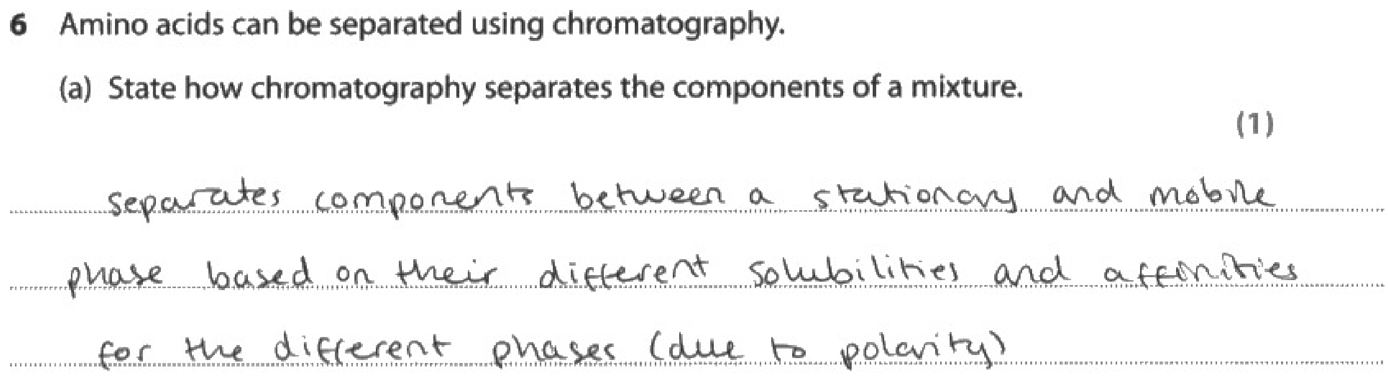
- ~~No~~ less pollution will occur.

ResultsPlus
Examiner Comments

Brief can be good but in this instance, there is no named pollutant and so this response does not score.

Question 6 (a)

Approximately half of the candidates correctly compared the different interactions between the amino acids and the stationary or mobile phases. A significant number of candidates referred to differences in solubility, but without relating it to chromatography.



6 Amino acids can be separated using chromatography.

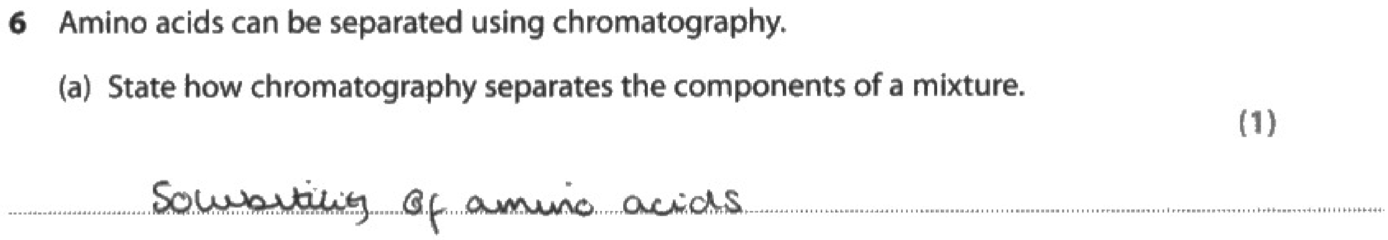
(a) State how chromatography separates the components of a mixture.

(1)

separates components between a stationary and mobile phase based on their different solubilities and affinities for the different phases (due to polarity)

ResultsPlus
Examiner Comments

Very clear answer which scored the mark.



6 Amino acids can be separated using chromatography.

(a) State how chromatography separates the components of a mixture.

(1)

Solubility of amino acids

ResultsPlus
Examiner Comments

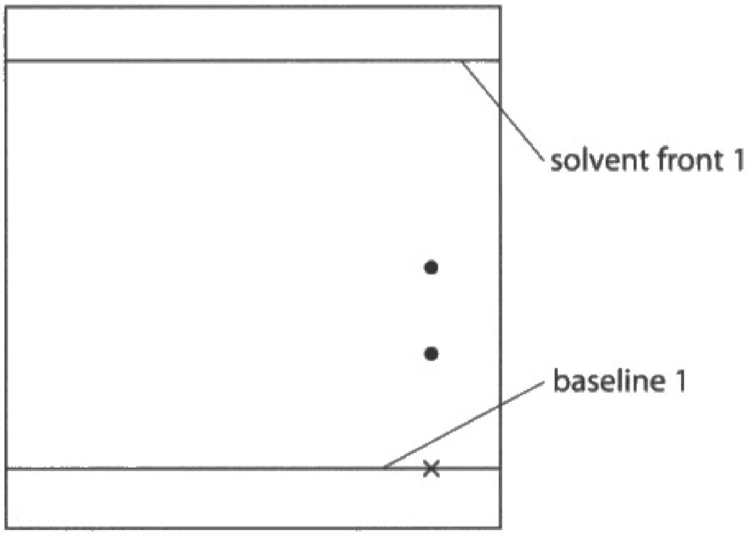
There is no comparison nor any reference to either the mobile or stationary phase.

Question 6 (b)(i)

A sizeable number of candidates missed key points given in the information in this question. There is no spot on the baseline of the chromatogram and so comments about the lack of movement of an amino acid due to poor solubility were not accepted. Also, the question clearly stated that answers "other than ....almost identical R_f values" were required and so it was disappointing that many responses gave this as an answer.

(b) A sample of a tripeptide was hydrolysed and then placed on an 'X' at the bottom right-hand corner of a piece of chromatography paper.

A simplified diagram of a developed chromatogram is shown.



(i) Give a possible reason for the presence of only two spots for the tripeptide other than two amino acids have almost identical R_f values.

(1)

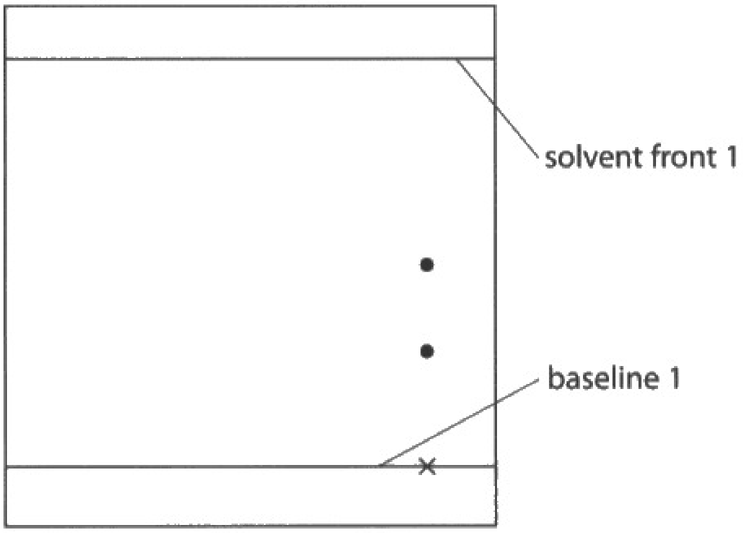
one amino acid is not soluble.

ResultsPlus
Examiner Comments

An example of a response which had missed the point that there was not spot on the baseline, so a lack of solubility was not a creditworthy response.

(b) A sample of a tripeptide was hydrolysed and then placed on an 'X' at the bottom right-hand corner of a piece of chromatography paper.

A simplified diagram of a developed chromatogram is shown.



(i) Give a possible reason for the presence of only two spots for the tripeptide other than two amino acids have almost identical R_f values.

(1)

Two of the tripeptides may have very similar attractions to the stationary phase + so travel up the chromatography paper the same amount.

ResultsPlus
Examiner Comments

Unfortunately, either this candidate has missed the point that the tripeptide has been hydrolysed or that there is a misunderstanding in the use of the term 'tripeptide'.

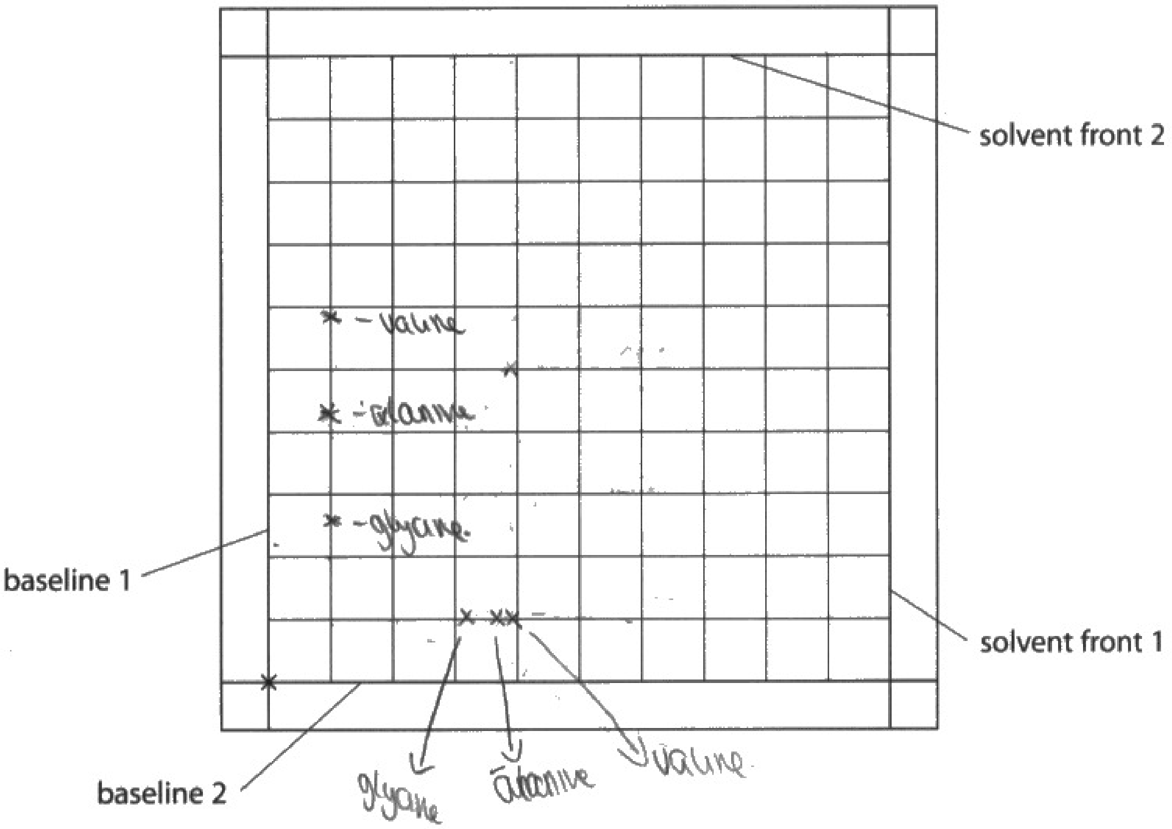
Question 6 (b)(ii)

A minority of candidates was able to draw a correct fully labelled chromatogram. It was clear that most candidates had not met this two solvent process before. There was also a significant number of candidates that didn't realise the three amino acids would occupy the same position at the beginning and instead started them from different positions on the baseline. Some candidates who understood the basic principle still lost credit through inaccurate placement of their spots.

(ii) Some amino acid mixtures cannot be effectively separated in one chromatography 'run'.
The chromatography paper from the first run is dried but not developed.
The chromatography paper is then rotated clockwise by 90° and placed in a different solvent.

Complete the simplified diagram of the developed chromatography paper after a second 'run' for a tripeptide of alanine, glycine and valine by adding **labelled** spots for each amino acid.

Amino acid	R_f in solvent 1	R_f in solvent 2
alanine	0.38	0.43
glycine	0.33	0.26
valine	0.39	0.58



ResultsPlus
Examiner Comments

This is an example of a response which illustrates some of the misunderstandings evidenced by some candidates. This candidate has drawn two 'sets' of three spots rather than just one. There is one set of spots which have moved the correct distance from baseline 1 and a second set of spots are shown as having moved from baseline 2. Neither sets of spots are starting from the spot on the baseline, but each set of spots has been measured from one square along each baseline from the original starting spot.

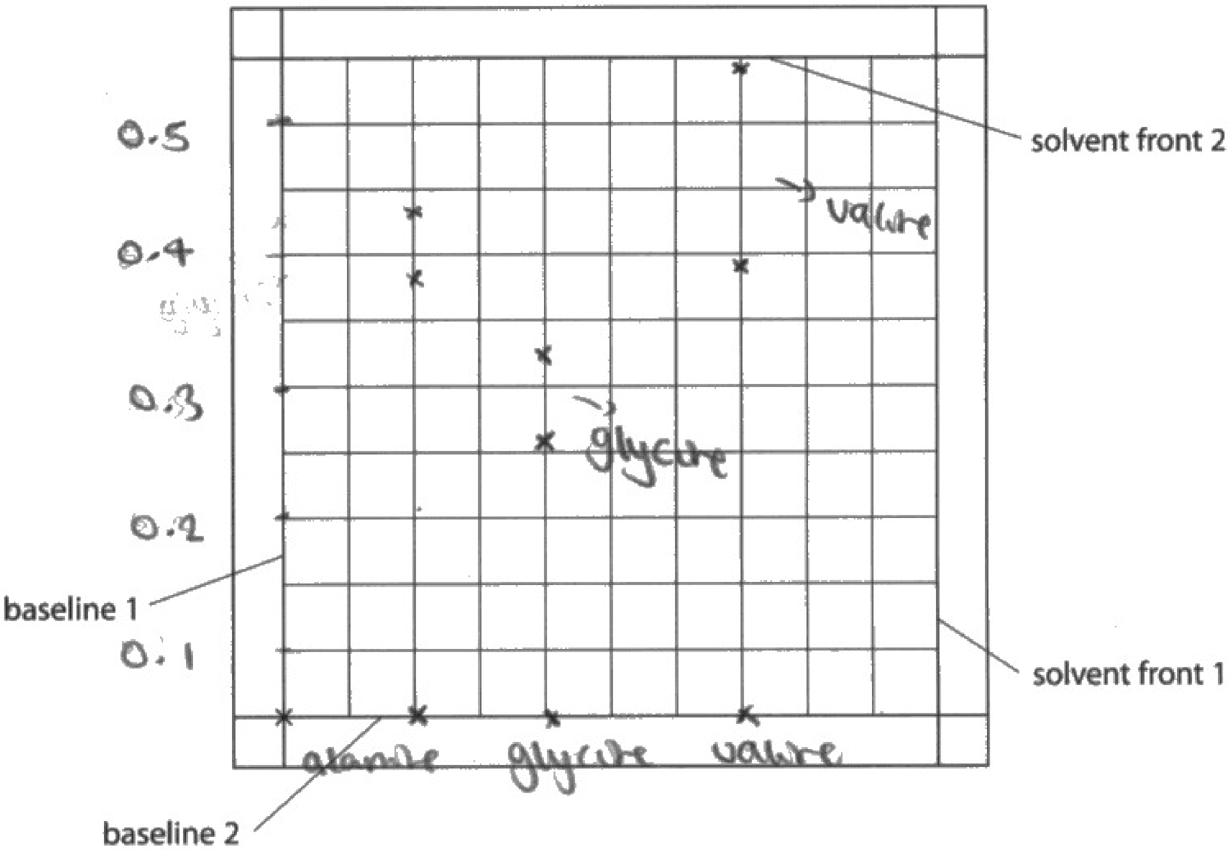
Responses of this type scored one mark only.

(ii) Some amino acid mixtures cannot be effectively separated in one chromatography 'run'.
The chromatography paper from the first run is dried but not developed.
The chromatography paper is then rotated clockwise by 90° and placed in a different solvent.

Complete the simplified diagram of the developed chromatography paper after a second 'run' for a tripeptide of alanine, glycine and valine by adding **labelled** spots for each amino acid.

Amino acid	R_f in solvent 1	R_f in solvent 2
alanine	0.38	0.43
glycine	0.33	0.26
valine	0.39	0.58

(3)



ResultsPlus
Examiner Comments

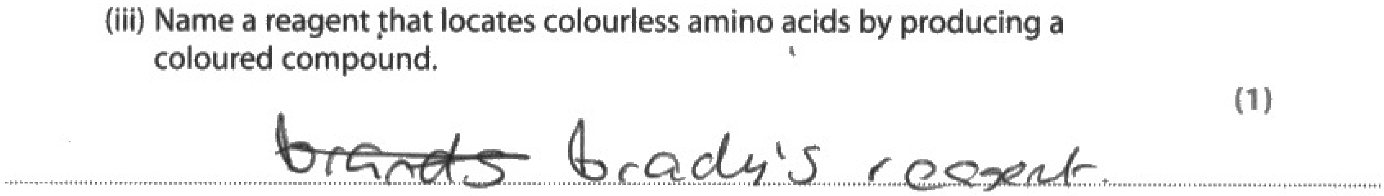
It is clear that this candidate does not understand the meaning of the R_f value because they have given the chromatogram grid an incorrect scale. Responses which changed the dimensions or scale of the chromatogram scored zero.

ResultsPlus
Examiner Tip

Remember that the R_f value will always be between 0 and 1 because it is calculated by dividing the distance moved by the spot by the distance moved by solvent front.

Question 6 (b)(iii)

Approximately half of the candidates scored the mark for ninhydrin. Other locating agents were allowed but not seen. A wide range of incorrect chemicals were suggested and it is hard to understand why some of them were chosen.



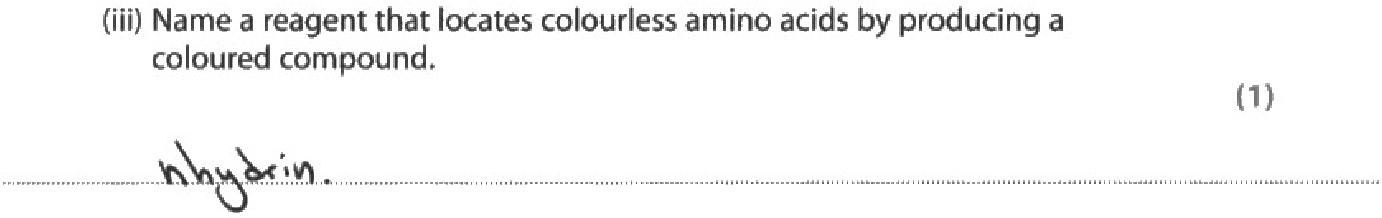
(iii) Name a reagent that locates colourless amino acids by producing a coloured compound.

(1)

~~brands~~ brady's reagent.

ResultsPlus
Examiner Comments

An example of an incorrect response which was possibly chosen because it is a 'reagent'.



(iii) Name a reagent that locates colourless amino acids by producing a coloured compound.

(1)

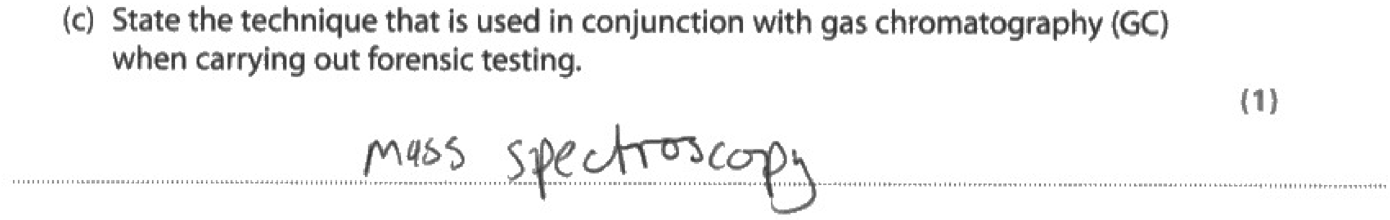
nhydrin.

ResultsPlus
Examiner Comments

The approach taken by examiners was to be generous with the spelling and to make a judgement based on whether the suggested name could be reasonably any other molecule. In this instance, the spelling is incorrect but allowed since it couldn't be confused with anything else.

Question 6 (c)

It was not uncommon to see that the basic principle of separation followed by identification was not understood. Many responses gave a second separation technique such as electrophoresis or TLC. However, just under half of candidates either gave mass spectrometry or infrared spectroscopy.



(c) State the technique that is used in conjunction with gas chromatography (GC) when carrying out forensic testing.

(1)

mass spectroscopy

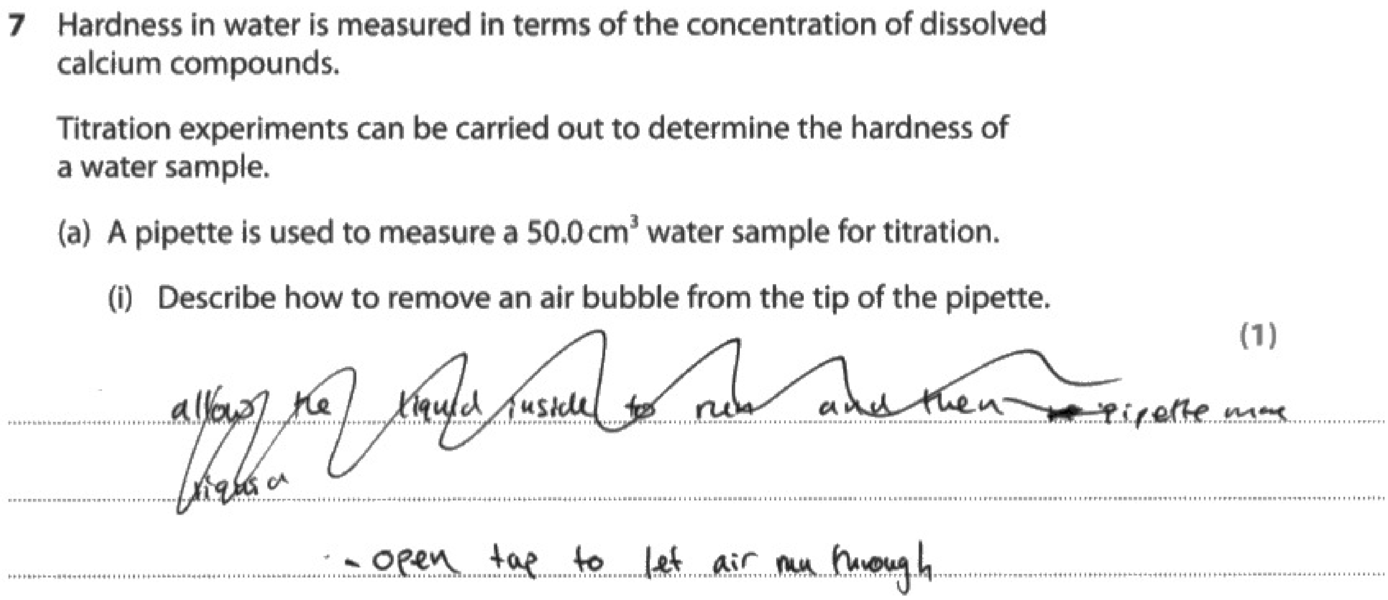
ResultsPlus
Examiner Comments

Although the correct technical term is mass 'spectrometry', it was acceptable for "spectroscopy" to be used as seen here.

Question 7 (a)(i)

Inevitably some candidates confused a pipette with a burette, but many gave acceptable answers. A number of alternatives scored the mark. For example, a "gentle flick" of the pipette was not uncommon as a means of dislodging the air bubble. The removal of the air bubble by letting out some of the water was also frequently seen.

Occasionally, responses were seen which referred to "squeezing" and it was unclear if this was referring to a Pasteur pipette or the 'bulb' of a pipette filler. Centres and their candidates are encouraged to make it abundantly clear which piece of apparatus is being referred to.



7 Hardness in water is measured in terms of the concentration of dissolved calcium compounds.

Titration experiments can be carried out to determine the hardness of a water sample.

(a) A pipette is used to measure a 50.0 cm^3 water sample for titration.

(i) Describe how to remove an air bubble from the tip of the pipette.

(1)

~~allow the liquid inside to run and then to pipette~~ [illegible]

~~liquid~~

- open tap to let air run through

ResultsPlus
Examiner Comments

This is an example of a response which clearly shows the confusion between a burette and a pipette and which did not score.

ResultsPlus
Examiner Tip

Learn the different types of specialist chemical apparatus and what they are used for.

7 Hardness in water is measured in terms of the concentration of dissolved calcium compounds.

Titration experiments can be carried out to determine the hardness of a water sample.

(a) A pipette is used to measure a $50.0\,\text{cm}^3$ water sample for titration.

(i) Describe how to remove an air bubble from the tip of the pipette.

(1)

let all water run out. tip upside down.
a small air bubble should be thea as it is
designed to have this. blow gently from to
of pipette downwards

ResultsPlus
Examiner Comments

Please note that it should never be encouraged for any lab workers, whether they be staff or candidates, to put their lips and to blow through any glassware.

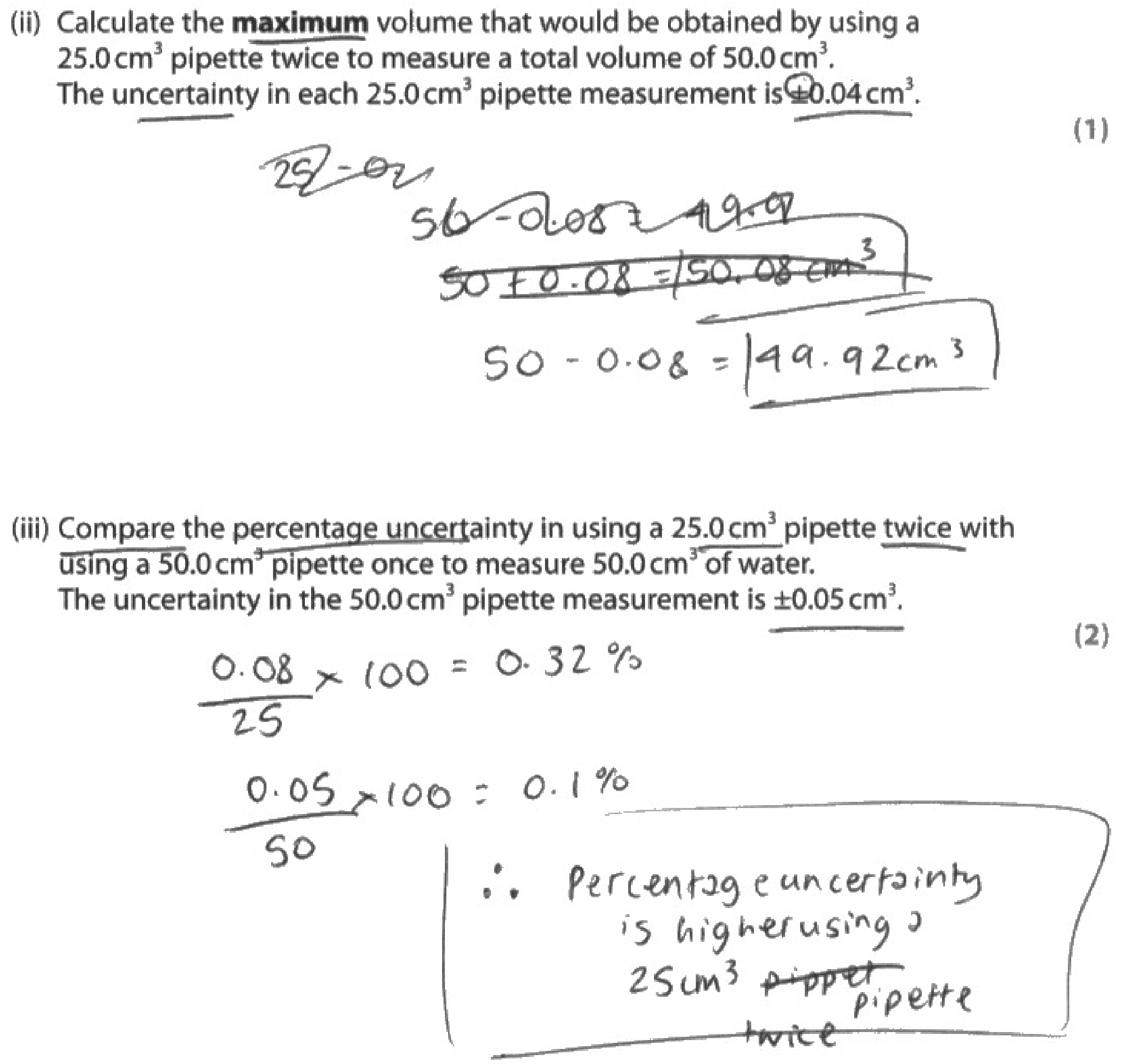
An air bubble can be removed by letting some of the water out, but here the candidate is letting "all" the water out which will not necessarily prevent an air bubble from reappearing when the pipette is refilled. In addition, a pipette should never be inverted because some of the water or solution will likely enter the pipette filler.

ResultsPlus
Examiner Tip

Try and imagine carrying out any steps that are described in an answer.

Question 7 (a)(ii-iii)

The majority of candidates understood both question parts and gained credit. A common error in part (ii) was the careless writing of 50.8 instead of 50.08 and the most common error in part (iii) was where the volume of a single 25.0 cm^3 pipette was used to calculate percentage uncertainty rather than the total volume measured of 50.0 cm^3.



(ii) Calculate the **maximum** volume that would be obtained by using a 25.0 cm^3 pipette twice to measure a total volume of 50.0 cm^3.
The uncertainty in each 25.0 cm^3 pipette measurement is ±0.04 cm^3.

(1)

~~25 - 0.2~~

~~50 - 0.08 = 49.9~~

~~50 + 0.08 = 50.08 cm^3~~

$50 - 0.08 = \boxed{49.92\,\text{cm}^3}$

(iii) Compare the percentage uncertainty in using a 25.0 cm^3 pipette twice with using a 50.0 cm^3 pipette once to measure 50.0 cm^3 of water.
The uncertainty in the 50.0 cm^3 pipette measurement is ±0.05 cm^3.

(2)

$\frac{0.08}{25} \times 100 = 0.32\ \%$

$\frac{0.05}{50} \times 100 = 0.1\ \%$

∴ Percentag e uncertainty is higher using a 25cm^3 ~~pippet~~ pipette twice

ResultsPlus
Examiner Comments

In part (ii), this candidate has understood the concept required but given the **minimum** volume rather than the 'maximum' volume required by the question.

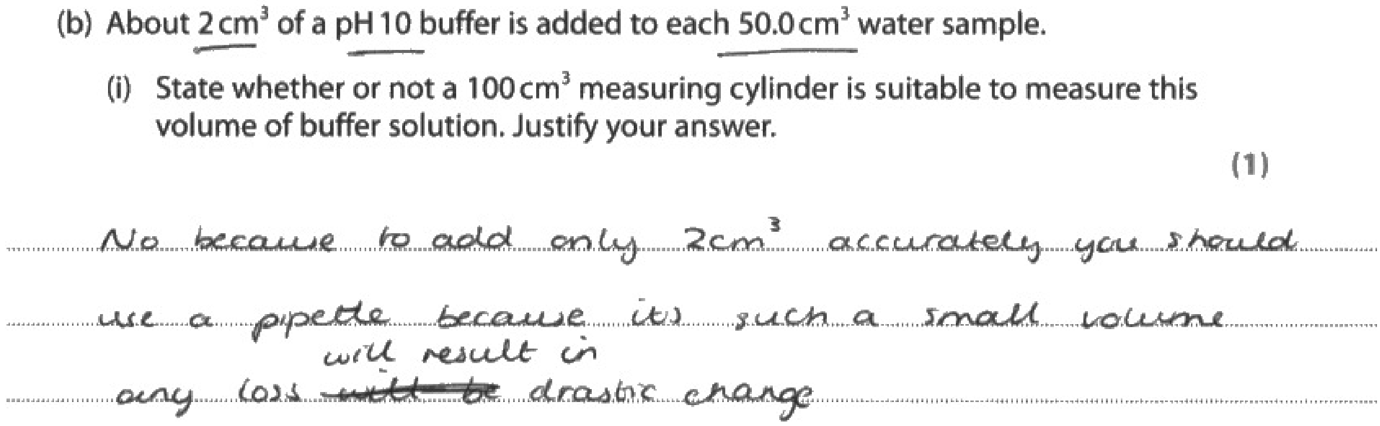
In part (iii), one mark was awarded for the calculation of the percentage uncertainty of the 50.0 cm^3 pipette with a comparison. However, the calculation should have a division by the total volume of 50 and not 25 so this mark was not awarded.

ResultsPlus
Examiner Tip

'Read The Question Twice' – RTQ^2

Question 7 (b)(i)

The vast majority of candidates realised that a 100 cm^3 measuring cylinder is too large to measure a small volume of only 2 cm^3 and often connected it with the previous question by stating that the percentage measurement uncertainty would be too high. One common error was to refer to the measuring cylinder being suitable because 2cm^3 could be added to the 50 cm^3 to give a total of 52 cm^3. These candidates missed the point that the volume of buffer was being measured separately.



(b) About 2 cm^3 of a pH 10 buffer is added to each 50.0 cm^3 water sample.

(i) State whether or not a 100 cm^3 measuring cylinder is suitable to measure this volume of buffer solution. Justify your answer.

(1)

No because to add only 2cm^3 accurately you should use a pipette because its such a small volume any loss ~~will be~~ will result in drastic change

ResultsPlus
Examiner Comments

The question does not ask for an alternative piece of apparatus, but rather why the 100 cm^3 measuring cylinder is suitable or not. Hence responses along these lines do not gain credit. It is true that the large measuring cylinder would not accurately measure such a small volume but this alone is insufficient since a justification is required.

ResultsPlus
Examiner Tip

Make sure that the answer given addresses the question set.

Question 7 (b)(ii)

This was the first of several longer calculations and candidates are reminded of the advantages of well-organised and clearly laid out answers. Well marks are much more likely and errors more easily avoided.

There were many fine answers which 'fell at the last hurdle' by using the molar mass of ammonium instead of **ammonium chloride** as asked in the question. Generally, these candidates knew how to carry out the calculation and worked through it with skill, and so it was disappointing to see the answer given not relate to that which was asked.

A sizeable number of candidates did a weak acid calculation rather than a buffer calculation which was also disappointing. However, some credit was still possible such as the determination of the hydrogen ion concentration from the given pH.

(ii) The pH 10 buffer can be made by adding solid ammonium chloride to an aqueous solution of ammonia of concentration 18.1 mol dm^{-3}.

The relevant equation is

$$NH_4^+ \rightleftharpoons NH_3 + H^+$$

$K_a = 5.62 \times 10^{-10}$ mol dm^{-3}

Calculate the mass of ammonium chloride that must be added to 100 cm^3 of ammonia solution to make the pH 10 buffer.
Assume that there is no change in the volume on the addition of ammonium chloride.

(4)

$$\frac{1}{5.62\times10^{-10}} = \frac{[NH_4^+]}{[NH_3][H^+]}$$

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

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

$= 10^{-10}$

$= 1\times10^{-10}$

$$\frac{1}{5.62\times10^{-10}} = \frac{[NH_4^+]}{(18.1)(1\times10^{-10})}$$

$$[NH_4^+] = \frac{(18.1)\times(1\times10^{-10})}{5.62\times10^{-10}} = 3.22\ moldm^{-3}$$

$= 3.22\times10^{-3}\ moldm^{-3}$

$n = cV$

$n = 3.22\times10^{-3}\times100$

$= 0.322$ mol

$$\frac{Mass}{Mr \mid mole}$$

$N = 14$

$+H_4 = 4$ $= 18$

~~Er~~ 18×0.322

$= 5.796$g

≈ 5.80g

ResultsPlus
Examiner Comments

This is an example of a response which scored three marks and lost the final mark because focus has stuck with the ammonium ion from the calculation resulting in a molar mass value of 18 being used. The attention needed to shift to the compound ammonium chloride as requested in the question.

ResultsPlus
Examiner Tip

'Read The Question Twice' – RTQ^2

(ii) The pH 10 buffer can be made by adding solid ammonium chloride to an aqueous solution of ammonia of concentration 18.1 mol dm^{-3}.

The relevant equation is

$$NH_4^+ \rightleftharpoons NH_3 + H^+$$

$K_a = 5.62 \times 10^{-10}$ mol dm^{-3}

Calculate the mass of ammonium chloride that must be added to 100 cm^3 of ammonia solution to make the pH 10 buffer.
Assume that there is no change in the volume on the addition of ammonium chloride.

(4)

$Ka = \frac{[H^+]^2}{[OH^-]}$ $\quad pH = -\log[H^+]$. $\quad$ moles $= \frac{mass}{Mr}$

moles = conc × vol.

~~4a~~ $10^{-10} = 1\times10^{-10}$ $[H^+]$ in buffer.

$(5.62\times10^{-10}) = \frac{(1\times10^{-10})^2}{[OH^-]} = 0.18$ mol dm^3

~~$\frac{100}{1000}$~~ moles $= \frac{100}{1000} \times 0.18 = 0.018$.

$0.018 = \frac{?}{18} = 0.324$g.

ResultsPlus
Examiner Comments

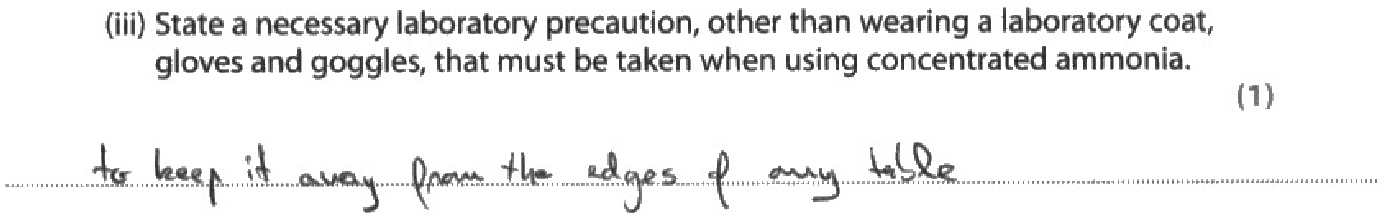
This is an example of how candidates can benefit from the application of transferred error. This candidate scores one mark for the conversion of pH into the hydrogen ion concentration. The K_a expression is incorrect and so loses the second mark, but this candidate does score the third marking point by showing that they understand that the volume used was 100 cm^3 and so multiplied their concentration by 0.1. As with many other candidates, the fourth marking point is lost because of the ammonium ion molar mass being used instead of the ammonium chloride.

ResultsPlus
Examiner Tip

Never leave an answer blank because, even if one or two steps are incorrect, it is possible that transferred error can be applied and credit gained.

Question 7 (b)(iii)

This was one of the more easier questions on the paper and almost all realised that a fume cupboard/hood was required. The few answers referencing a well-ventilated room did not gain the mark.



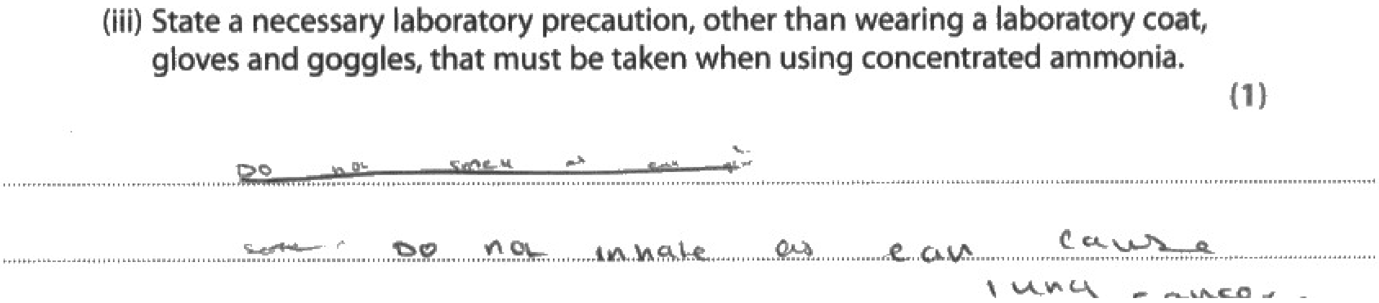
(iii) State a necessary laboratory precaution, other than wearing a laboratory coat, gloves and goggles, that must be taken when using concentrated ammonia.

(1)

to keep it away from the edges of any table

ResultsPlus
Examiner Comments

A rare response which did not appreciate the need to avoid inhaling ammonia vapour. Care does need to be taken when working on a bench, but these general comments are unlikely to score at A level standard.



(iii) State a necessary laboratory precaution, other than wearing a laboratory coat, gloves and goggles, that must be taken when using concentrated ammonia.

(1)

~~Do not smell at all~~

~~some~~ Do not inhale as can cause lung cancer.

ResultsPlus
Examiner Comments

The hazard has been identified, but the question asks for the precaution that is required to mitigate the risk. Hence no mark was awarded.

ResultsPlus
Examiner Tip

'Repetition is the Mother of Retention' is a common maxim and so is 'Read The Question Twice' – RTQ^2

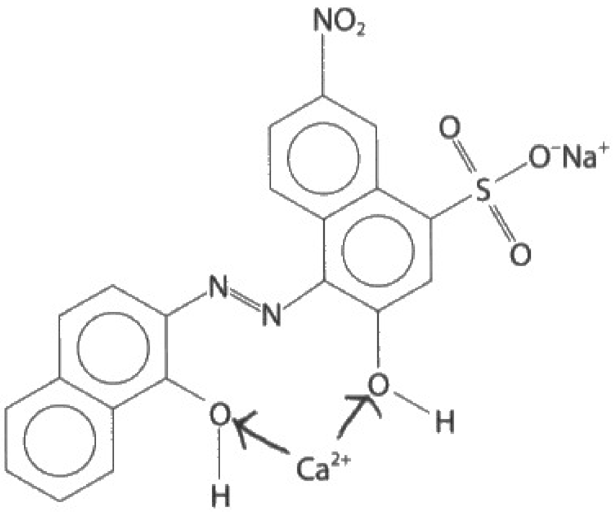
Question 7 (c)(i)

Novel complex ions are not a new topic for exam questions and about half of the candidates could apply their knowledge to this example. The question did ask for three dative covalent or coordinate bonds to be drawn which some candidates appeared to miss from their own drawing, drawing two bonds.

(c) The Eriochrome Black T indicator used in this titration forms an octahedral complex with the calcium ions in the water sample. The structure of Eriochrome Black T is shown with a calcium ion.

(i) Complete the diagram to show how Eriochrome Black T forms three dative covalent or coordinate bonds with the calcium ion.

(1)



ResultsPlus
Examiner Comments

Only two arrows are given instead of three. In a coordinate bond an arrow is an appropriate symbol, but the arrow should go from the atom donating the lone pair of electrons. In this example, the arrows are going in the wrong direction.

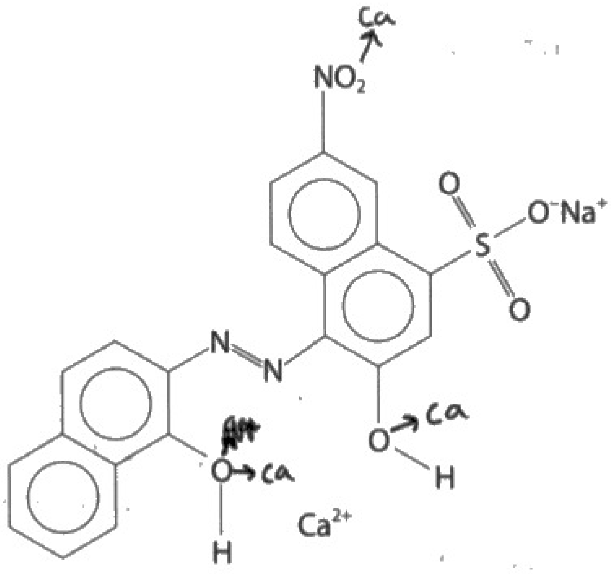
ResultsPlus
Examiner Tip

Just as in organic reaction mechanisms the curly arrow originates from the pair of electrons, it is the same principle with using 'linear' arrows to represent coordinate bonds, they originate from the pair of electrons.

(c) The Eriochrome Black T indicator used in this titration forms an octahedral complex with the calcium ions in the water sample. The structure of Eriochrome Black T is shown with a calcium ion.

(i) Complete the diagram to show how Eriochrome Black T forms three dative covalent or coordinate bonds with the calcium ion.

(1)



ResultsPlus
Examiner Comments

There are three arrows given to represent three coordinate bonds, but the question is clear in requesting these with **the** calcium ion drawn. Hence no additional calcium ions are needed which means that this response did not score.

Question 7 (c)(ii)

This is another example where understanding the question rubric can help or guide a candidate in answering the question. This part (ii) follows on from part (i) and so since the previous part (i) was about the drawing of **three** dative covalent bonds, then in an **octahedral** complex there must be three more to give a total of six. This was deduced by just over half of the candidates.

(ii) State the number of water molecules needed to complete this complex.

(1)

5 / 6

ResultsPlus
Examiner Comments

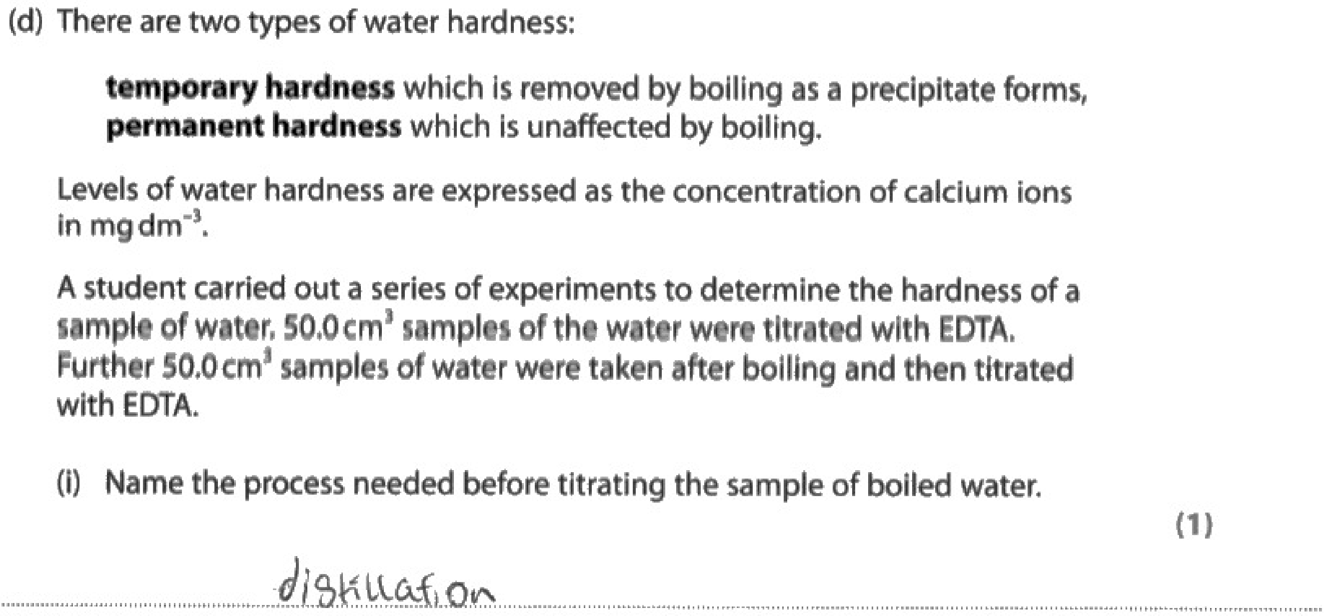
The question clearly states **the** number and so only one number is correct. In this instance, neither number is correct but if one had been then it would have been negated by the second.

ResultsPlus
Examiner Tip

Do not give more than one answer to a question which only requires one answer.

Question 7 (d)(i)

If there is a question which illustrates that candidates need to read the information given better, then this is it. Almost every chemical technique that a candidate would have experienced was suggested. However, it is not difficult to see in the stem information that a precipitate forms which obviously would be removed by filtering. This should have been an 'easy' question, but in fact was one of the eight questions on the paper which statistics classified as 'hard'.



(d) There are two types of water hardness:

temporary hardness which is removed by boiling as a precipitate forms,
permanent hardness which is unaffected by boiling.

Levels of water hardness are expressed as the concentration of calcium ions in mg dm^{-3}.

A student carried out a series of experiments to determine the hardness of a sample of water. 50.0 cm^3 samples of the water were titrated with EDTA. Further 50.0 cm^3 samples of water were taken after boiling and then titrated with EDTA.

(i) Name the process needed before titrating the sample of boiled water.

(1)

distillation

ResultsPlus
Examiner Comments

An example of one of the inappropriate techniques suggested.

ResultsPlus
Examiner Tip

Read the information carefully in the stem of the question since there will be vital guidance included to answer the following questions.

(d) There are two types of water hardness:

temporary hardness which is removed by boiling as a precipitate forms,
permanent hardness which is unaffected by boiling.

Levels of water hardness are expressed as the concentration of calcium ions in mg dm^{-3}.

A student carried out a series of experiments to determine the hardness of a sample of water. 50.0 cm^3 samples of the water were titrated with EDTA. Further 50.0 cm^3 samples of water were taken after boiling and then titrated with EDTA.

(i) Name the process needed before titrating the sample of boiled water.

(1)

purification

ResultsPlus
Examiner Comments

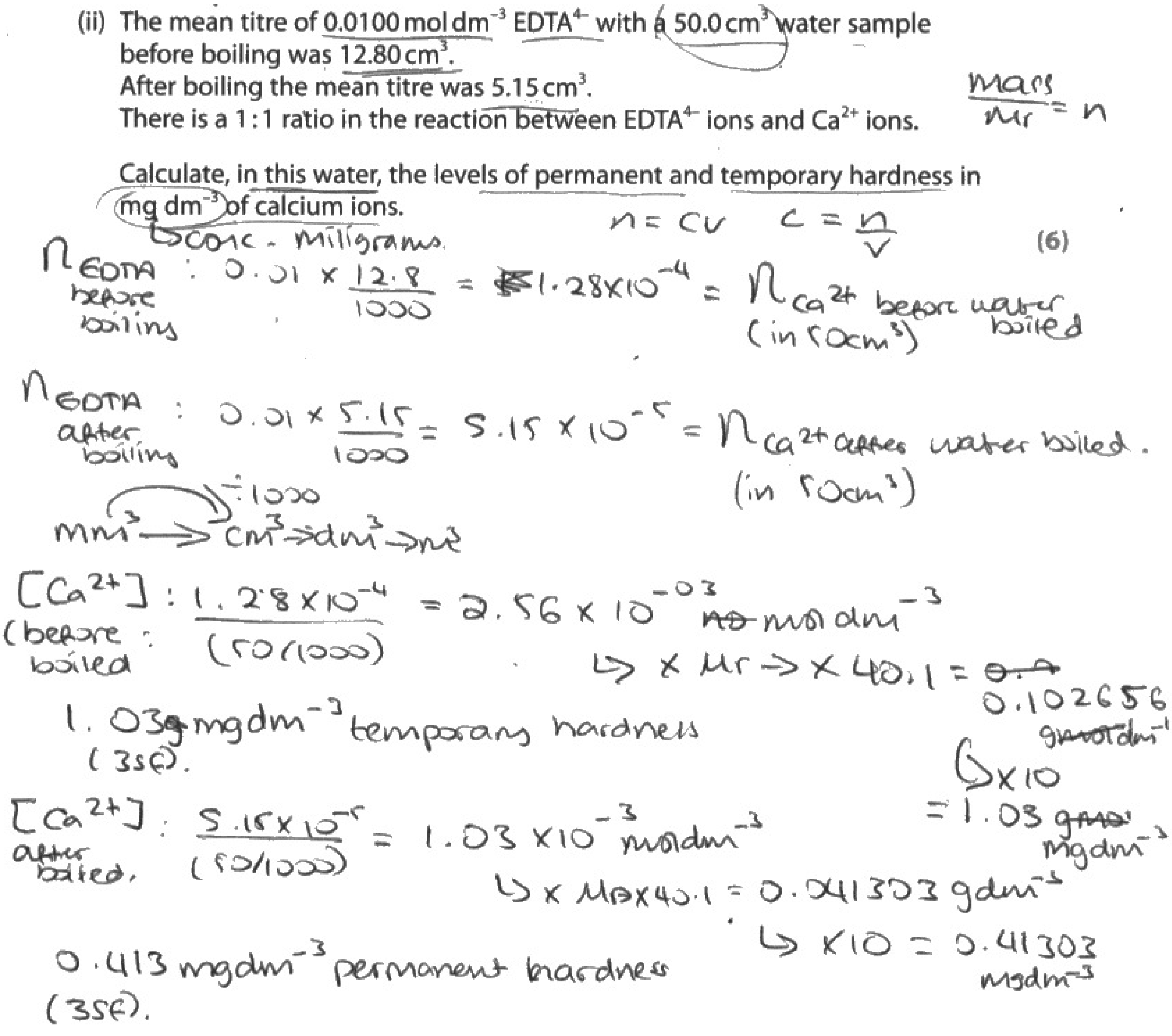
This is an example of a vague response which did not score. It is possible that this candidate is thinking of water treatment, but this involves chlorine which is not part of this question.

Question 7 (d)(ii)

This was the second of several longer calculations and again it is worth reminding candidates of the advantages of well-organised and clearly laid out answers. Well marks are much more likely and errors more easily avoided.

There was further evidence of candidates not reading the information given in the stem properly because there were many responses where candidates calculated the total water hardness and thought that it was the temporary water hardness. Looking up on the page to the text in bold font would have quickly and easily corrected this matter, but it seems that this wasn't done.

Another common error, which was rather surprising, was the incorrect conversion from grams to milligrams. Oftentimes, the multiplication by 10 or by 100 instead of by 1000. There was also the error of dividing by 100o instead of multiplying.



(ii) The mean titre of 0.0100 mol dm^{-3} EDTA^{4-} with a 50.0 cm^3 water sample before boiling was 12.80 cm^3.
After boiling the mean titre was 5.15 cm^3.
There is a 1 : 1 ratio in the reaction between EDTA^{4-} ions and Ca^{2+} ions.

$\frac{mass}{Mr} = n$

Calculate, in this water, the levels of permanent and temporary hardness in mg dm^{-3} of calcium ions.

↳ conc - milligrams.

$n = cv \quad c = \frac{n}{v}$

(6)

n_{EDTA} before boiling : $0.01 \times \frac{12.8}{1000} = 1.28 \times 10^{-4} = n_{Ca^{2+}}$ before water boiled (in 50cm^3)

n_{EDTA} after boiling : $0.01 \times \frac{5.15}{1000} = 5.15 \times 10^{-5} = n_{Ca^{2+}}$ after water boiled. (in 50cm^3)

$\div 1000$

$mm^3 \rightarrow cm^3 \rightarrow dm^3 \rightarrow m^3$

$[Ca^{2+}]$ (before boiled : $\frac{1.28 \times 10^{-4}}{(50/1000)} = 2.56 \times 10^{-03}$ ~~no~~ mol dm^{-3}

↳ × Mr → × 40.1 = ~~0.4~~ 0.102656 ~~gmol~~ dm^{-1}

↳ × 10 = 1.03 ~~gmol~~ mgdm^{-3}

1.03~~g~~ mgdm^{-3} temporary hardness (3sf).

$[Ca^{2+}]$ after boiled. : $\frac{5.15 \times 10^{-5}}{(50/1000)} = 1.03 \times 10^{-3}$ moldm^{-3}

↳ × Mr × 40.1 = 0.041303 gdm^{-3}

↳ × 10 = 0.41303 mgdm^{-3}

0.413 mgdm^{-3} permanent hardness (3sf).

ResultsPlus
Examiner Comments

There are two errors in this response and so four marks were awarded.

Firstly, the conversion from grams to milligrams has been done by multiplying by 10 instead of 1000. Secondly, there has been no subtraction to give the temporary water hardness from the total water hardness.

Question 8 (a)(i)

This was another of the questions categorised as 'hard' by the statistics which was rather surprising and could have been relatively simply corrected by candidates. Many, many candidates referred to titration in their answer which is ok up to a point, but when determining data for reaction rate then the mixture needs to be quenched to prevent further reaction which would change the results. This reference to quenching was rarely seen. In addition, the 'bald' reference to titration without stating what with is also insufficient.

It may be helpful for centres and their candidates to reflect on the point that pH is a logarithmic scale and so, in this context, it is not an appropriate technique for measuring changes in the rate of reaction.

A sizeable number of candidates appreciated that there would be a colour change due to the production of iodine, but the question asked for experimental techniques that could be used to monitor this. Hence reference to colour change alone did not score. There had to be a mention of use of a colorimeter and this was seen occasionally. There was even mention of a spectrophotometer which was, of course, fine.

8 This question is about reaction kinetics and the Arrhenius equation.

(a) Different iodine clock reactions are often used to investigate reaction kinetics.

(i) The iodine clock reaction with hydrogen peroxide involves the reaction shown.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow I_2 + 2H_2O$$

Deduce **two** possible experimental techniques which could be used to monitor the progress of this reaction.

(2)

- Put a cross under a beaker measure time taken for cross to not be visible is through solution and find rate.
- Use gas syringe to measure volume of gas produced over given time

ResultsPlus
Examiner Comments

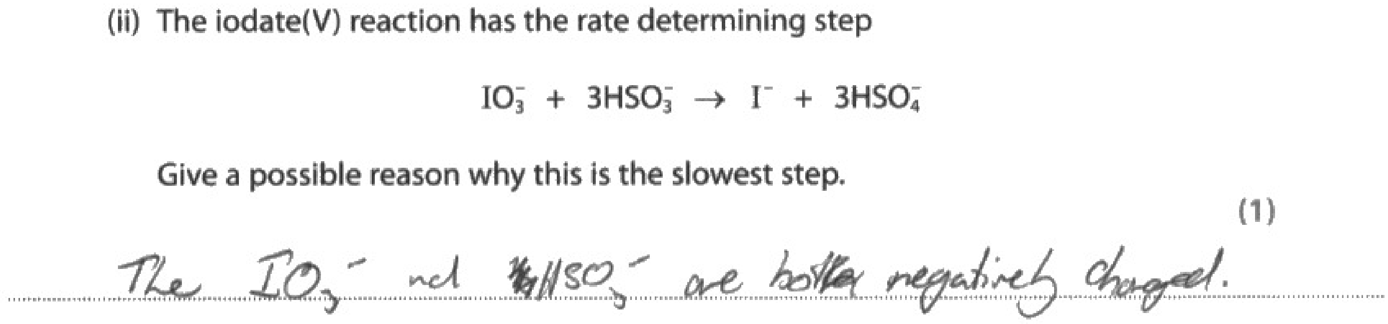
This is an example of a response where the candidate has given the experimental techniques that they have either seen or used but, unfortunately, are not suitable for the example given in this question.

ResultsPlus
Examiner Tip

Make sure that the techniques suggested match the situation. If there is no gas present, then a gas syringe is of no use.

Question 8 (a)(ii)

Just over half of the candidates realised that because both ions are negatively charged that there would be repulsion between them and so this would be the reason for this being the slowest step in the reaction mechanism.



(ii) The iodate(V) reaction has the rate determining step

$$IO_3^- + 3HSO_3^- \rightarrow I^- + 3HSO_4^-$$

Give a possible reason why this is the slowest step.

(1)

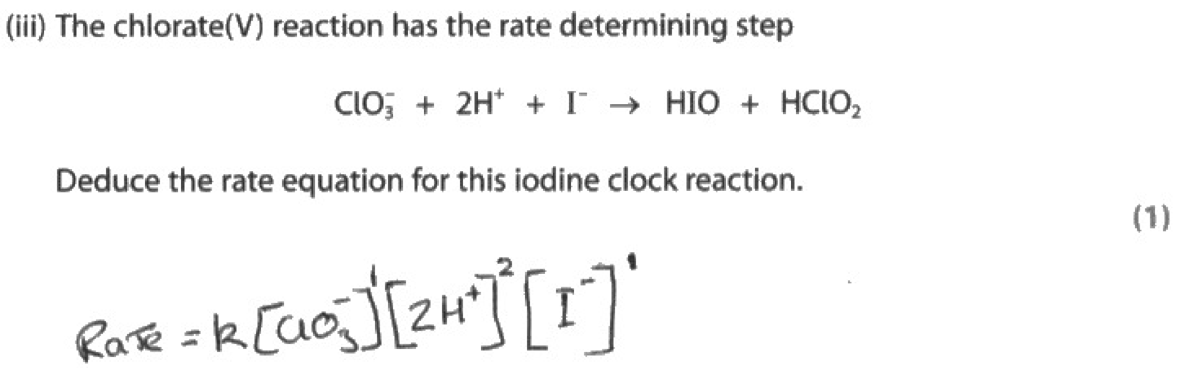
The IO_3^- and HSO_3^- are both negatively charged.

ResultsPlus
Examiner Comments

An example of a response which identifies only part of the issue. The question asks for why this is the slowest step and simply stating that both ions are negatively charged is not enough. There needed to be reference to the repulsion between ions of the same charge.

Question 8 (a)(iii)

Occasionally some Kc expressions were seen but most candidates did give some type of rate equation. Common errors were to omit the H^+ or its power of 2 or to write $[2H^+]$. There were also rare responses where the charges on the ions were missing due to careless transposition.



(iii) The chlorate(V) reaction has the rate determining step

$$ClO_3^- + 2H^+ + I^- \rightarrow HIO + HClO_2$$

Deduce the rate equation for this iodine clock reaction.

(1)

$$Rate = k[ClO_3^-]^1[2H^+]^2[I^-]^1$$

ResultsPlus
Examiner Comments

An unfortunate possible lapse in concentration here. The candidate clearly understands that the reaction order is derived from the number of moles in the rate determining step. However, the formulae of all the species should be given without their molar ratio.

(iii) The chlorate(V) reaction has the rate determining step

$$ClO_3^- + 2H^+ + I^- \rightarrow HIO + HClO_2$$

Deduce the rate equation for this iodine clock reaction.

(1)

$k = [ClO_3^-]\,[H^+]^2\,[I^-]$

ResultsPlus
Examiner Comments

This response possibly highlights the need for more practise because this candidate does understand how to derive the reaction orders and knows that the rate constant should be part of the expression. Further practise at this type of exercise may have reinforced the correct way that rate equations are written.

ResultsPlus
Examiner Tip

Practise, practise and more practise!

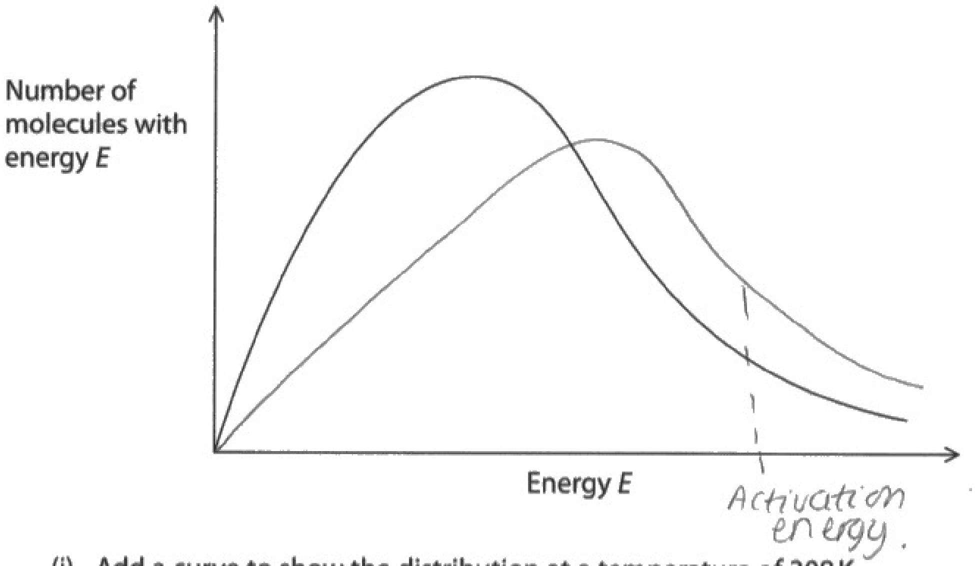
Question 8 (b)

The poor overall standard of curves drawn in part (i) was commonly commented on by examiners. Even ones which did score were far from ideal. Frequent errors were: the curve added in such a way that it crossed the first curve twice, the curve started to go up at the end on the right, the curve plateaued at some considerable height from the x axis or went too far down and crossed the x axis.

Centres and their candidates would benefit from further practise at drawing such curves to ensure that these errors are eliminated.

In part (ii) the mark for more particles having or exceeding the activation energy was very often awarded. The second mark proved much more elusive. The candidates who labelled their diagram with a possible activation energy had much more chance of success.

(b) The diagram shows a sketch of the Maxwell-Boltzmann curve for the distribution of molecular energies of a reaction mixture at temperature 298 K.



(i) Add a curve to show the distribution at a temperature of 308 K.

(1)

(ii) Explain why a temperature rise from 298 K to 308 K results in a large increase in the rate of reaction.
Refer to the Maxwell-Boltzmann distribution in your answer.

(2)

~~A larger proportion~~ The molecules have more kinetic energy so a larger proportion have $E \geq E_a$ required for the reaction as there is a larger area under the curve past the activation energy line so more frequent successful collisions occur with sufficient activation energy so more reactions.

ResultsPlus
Examiner Comments

An example of a response which scored all available marks.

In part (i), the peak of the curve has been suitably shifted to the right and lower.

In part (ii), there is clear reference to how the diagram shows that more particles have or exceed the activation energy.

Question 8 (c)(i)

The calculation of activation energy has been asked many times before and candidates are becoming quite familiar with the process. There remains the issue of giving the activation energy a negative sign which a candidate would quickly check if the definition of activation energy was recalled.

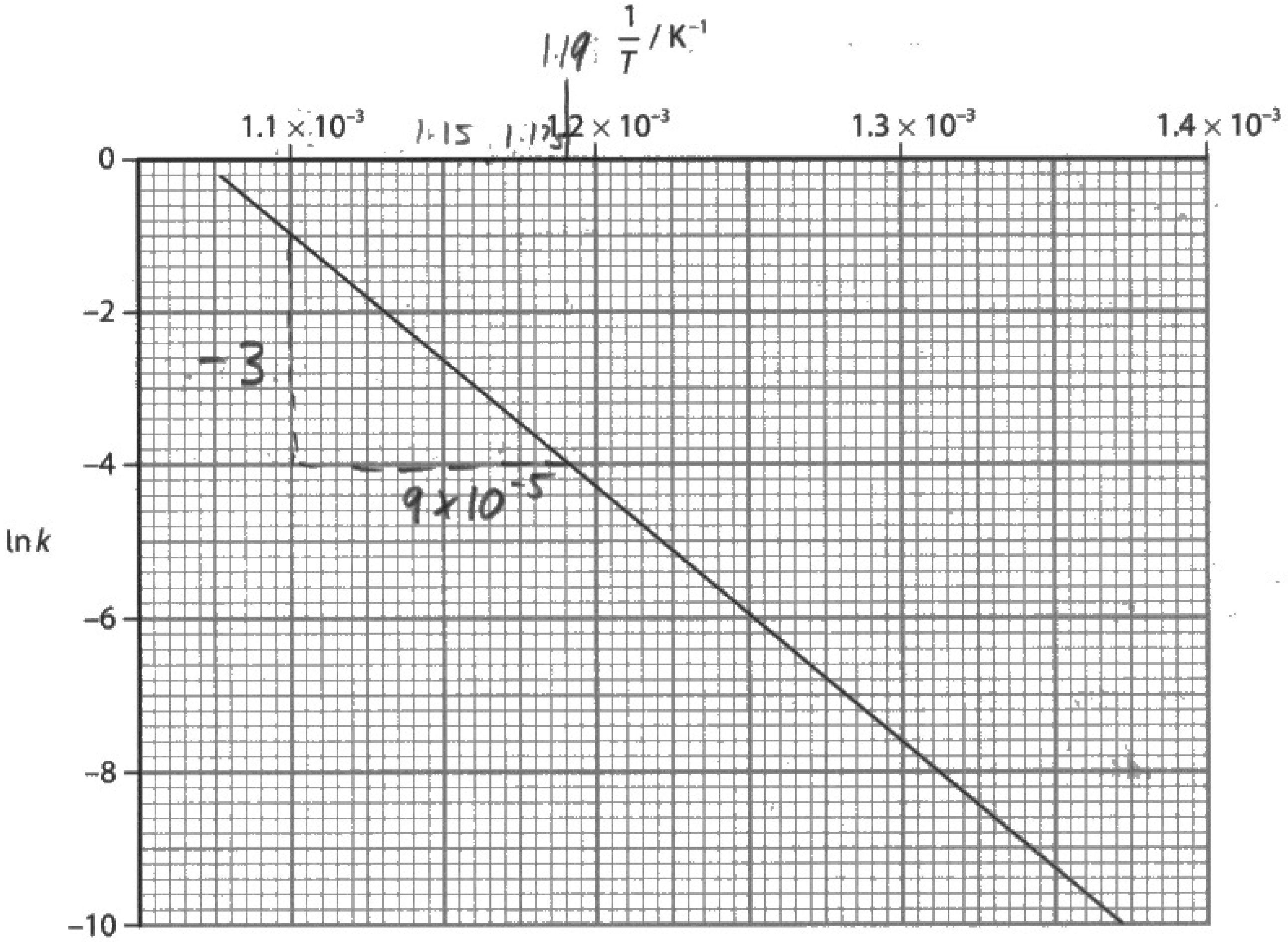
There was also a sizeable number of candidates who calculated a gradient significantly outside the acceptable range and so further practise at determining gradients is recommended.

(c) The Arrhenius equation may be written in a logarithmic or an exponential form.

$$\ln k = -\frac{E_a}{RT} + \ln A \qquad k = A e^{-\frac{E_a}{RT}}$$

A is a constant.

(i) The rate constant, k, for the isomerisation of cyclopropane to propene was measured at various temperatures.
The data obtained were used to draw the graph shown.



Determine the activation energy, E_a, from the gradient of the graph.
Include units in your answer.

(3)

$$\frac{-3}{9 \times 10^{-5}} = -33333.\dot{3}$$

$$-33333.\dot{3} \times -8.31 = 277000 \text{ J}$$

$$277 \text{ kJ}$$

ResultsPlus
Examiner Comments

A rather careless slip at the end results in a loss of a mark. The units should, of course, be kJ mol^{-1}

ResultsPlus
Examiner Tip

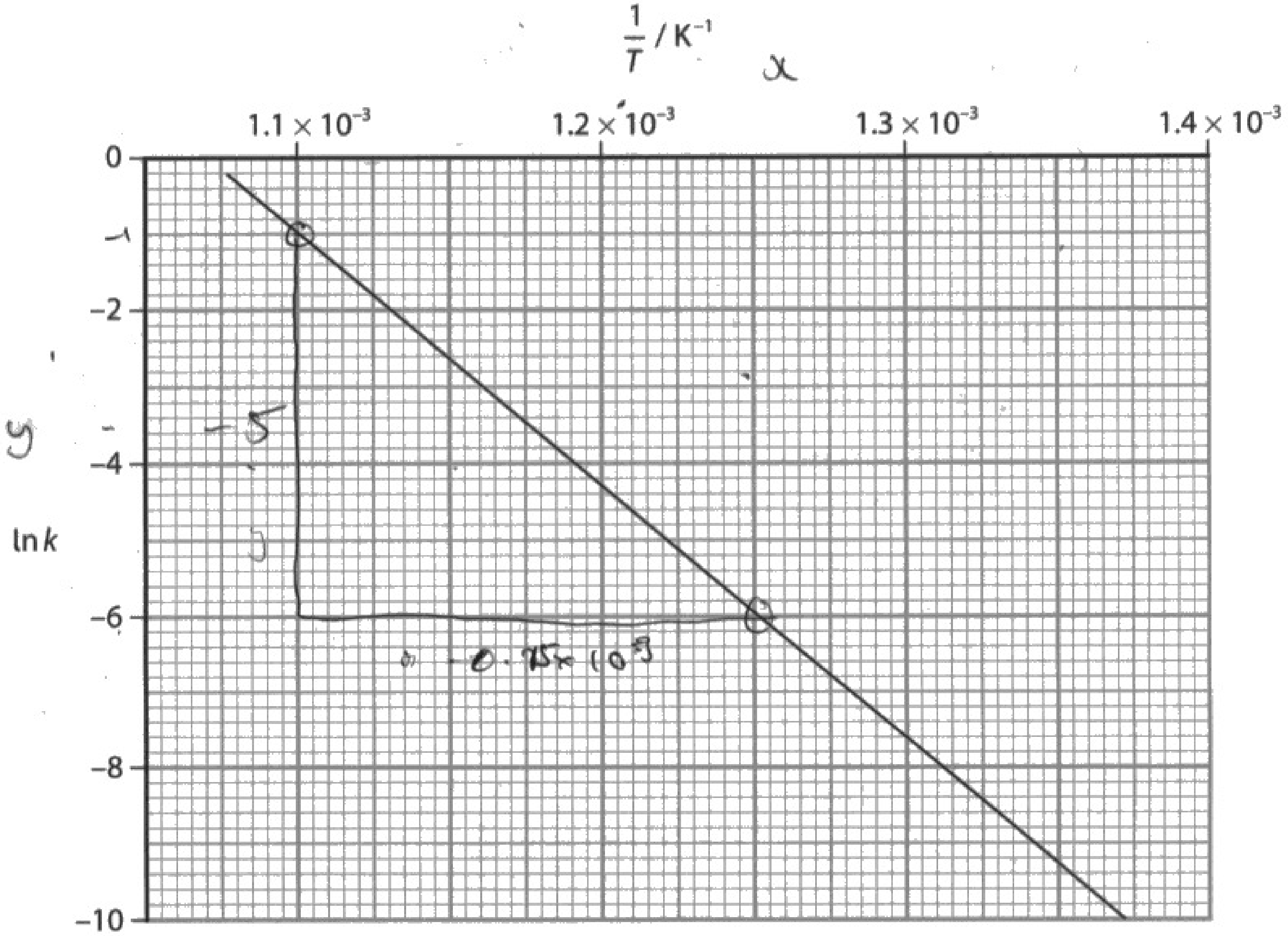
Make precious time to check for errors which can simply and quickly be fixed.

(c) The Arrhenius equation may be written in a logarithmic or an exponential form.

$$\ln k = -\frac{E_a}{RT} + \ln A \qquad k = A e^{-\frac{E_a}{RT}}$$

A is a constant.

(i) The rate constant, *k*, for the isomerisation of cyclopropane to propene was measured at various temperatures.
The data obtained were used to draw the graph shown.



Determine the activation energy, E_a, from the gradient of the graph.
Include units in your answer.

(3)

$m = \frac{\Delta y}{\Delta x}$ ∴ $\Delta y = {}^{2}$, -7

$\Delta x = 1.1 \times 10^{-3}$

∴ $= -909.09090 91$

$\frac{-5}{0.15 \times 10^{-3}} = -33333.\overset{6}{3} = 33333.3$ J mol⁻¹

ResultsPlus
Examiner Comments

This is an example of a response where it appears that the candidate thinks that the gradient is the activation energy. The candidate knows the units of activation energy and so simply adds them to the value of the gradient.

ResultsPlus
Examiner Tip

When calculating the gradient from a graph do include the units in the working since this will help in determining the final units.

Question 8 (c)(ii)

A large number of candidates could successfully use the mathematical expression given and calculate the fraction of molecules for the two given activation energies. Hence two marks were frequently awarded. However, the question asked for a comment as to why this lead to such a **large** increase in reaction rate. Hence it was not enough to simply that one fraction was larger than the other. There needed some appreciation expressed of how different these fractions were. Some candidates did this by showing that the fraction at the lower activation energy was over 20,000 times larger, while other candidates expressed it qualitatively.

(ii) At a temperature T, the fraction of molecules with energy equal to or greater than the activation energy is given by the expression

$$\text{fraction of molecules} = e^{-\frac{E_a}{RT}}$$

When a catalyst is added, the activation energy for a reaction is lowered.

Explain, using calculations, why lowering the activation energy from 50 000 J mol^{-1} to 25 000 J mol^{-1} at 298 K results in a large increase in the rate of reaction.

(3)

$$e^{-\frac{50000}{8.31\times298}} = 1.70319\times10^{-9}$$

$$e^{-\frac{25000}{8.31\times298}} = 4.1269\times10^{-5}$$

$$4.1269\times10^{-5} > 1.70319\times10^{-9}$$

when the activation energy is decreased from 50 000 Jmol^{-1} to 25000 Jmol^{-1} the fraction of molecules with that activation energy, or greater increases, meaning more particles have sufficient energy to overcome the activation energy if the activation energy is decreased.

(Total for Question 8 = 13 marks)

ResultsPlus
Examiner Comments

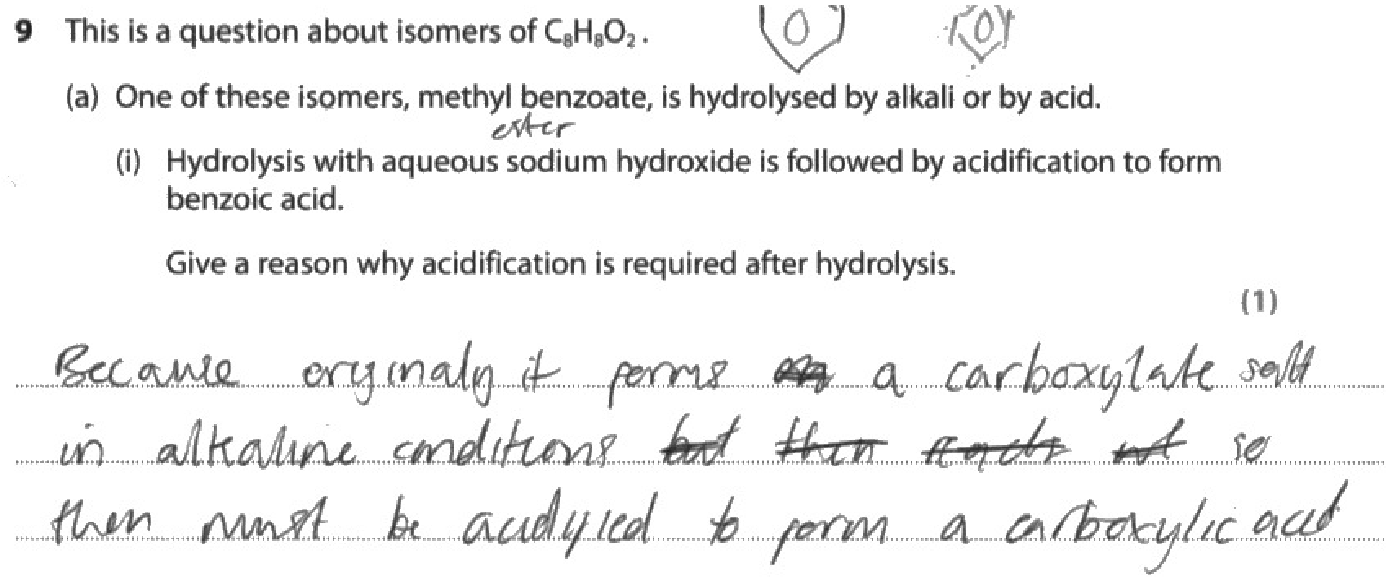
This is an example of a response which was only given two marks. The calculations are fine, but it was not enough to simply state that one number was more than or greater than the other.

ResultsPlus
Examiner Tip

At times an awareness or appreciation of what the numbers calculated actually means is required. Practise this in different contexts such as K_c because more can sometimes be required than simply stating an equilibrium is more to the products or reactants but how much more.

Question 9 (a)(i)

This question has been asked in a variety of different forms over recent times and it was evident that the understanding of the need for acidification has much improved. Only a few incorrect responses were seen which simply mentioned the neutralisation of the alkali, which was good.



9 This is a question about isomers of $C_8H_8O_2$.

(a) One of these isomers, methyl benzoate, is hydrolysed by alkali or by acid.

ester

(i) Hydrolysis with aqueous sodium hydroxide is followed by acidification to form benzoic acid.

Give a reason why acidification is required after hydrolysis.

(1)

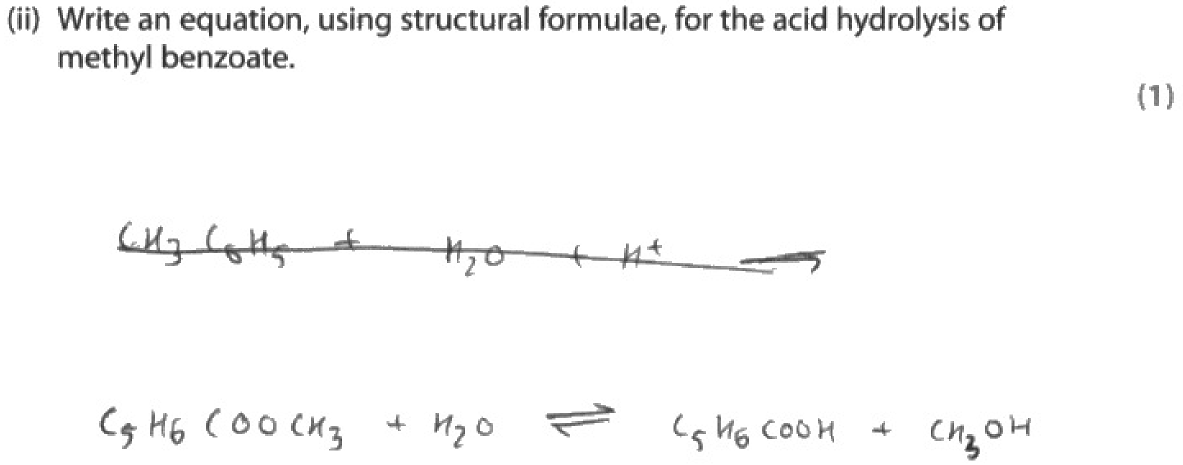
Because orginaly it forms ~~as~~ a carboxylate salt in alkaline conditions ~~but~~ ~~then~~ ~~reacts~~ ~~wit~~ so then must be acidyied to form a carboxylic acid

ResultsPlus
Examiner Comments

An example of a good answer which clearly explains why acidification is required.

Question 9 (a)(ii)

It was disappointing that this question was one of the eight questions classified by the statistics as hard because this shouldn't have been the case. It is possible that because the equation for the acidic hydrolysis was asked immediately after the alkaline hydrolysis was considered that candidates got confused. However, there were only a few responses which gave the wrong equation. More frequent errors were in the structural formulae and the balancing of the equations.



(ii) Write an equation, using structural formulae, for the acid hydrolysis of methyl benzoate.

(1)

~~$CH_3C_6H_5 + H_2O + H^+ \rightarrow$~~

$C_5H_6COOCH_3 + H_2O \rightleftharpoons C_5H_6COOH + CH_3OH$

ResultsPlus
Examiner Comments

A somewhat unusual example where the numbers of carbon and hydrogen atoms in the benzene ring have been muddled up and so the mark is lost.

ResultsPlus
Examiner Tip

At times, a quick glance to check can mean a simple error is spotted which can then be corrected.

Question 9 (b)

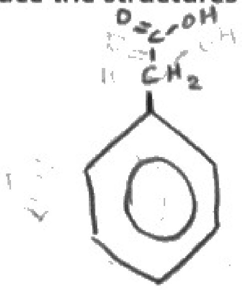
This question proved to be an effective discriminator and provided the vast majority of candidates with the opportunity to gain some credit. The structure of Y was the one that was most often correct, then Z and then W, with finally X being the least likely structure to be correct. The reasoning for Y being a carboxylic acid from the test with a carbonate proved to be the most accessible, possibly because there was the least information to process. It was pleasing to see many candidates understood that six peaks in a ^{13}C NMR spectrum for Z meant six different carbon environments for Z and that this led onto a 1,4 or para-substituted benzene ring. In the consideration of the structures of W and X, it was apparent that some candidates missed the significant statement that W and X had the **same functional group** because methyl benzoate was suggested instead of phenyl ethanoate.

(b) Four other $C_8H_8O_2$ isomers were investigated.

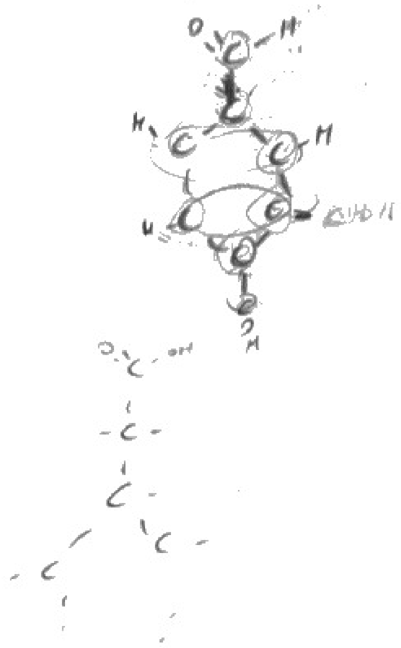
- **W** and **X** are mono-substituted aromatic compounds with the same functional group as methyl benzoate but only **W** is made from methanoic acid
- **Y** is a mono-substituted aromatic compound which reacts with sodium carbonate to give carbon dioxide carboxylic acid
  Na_2CO_3
- **Z** is a disubstituted aromatic compound with six peaks in its ^{13}C NMR spectrum and forms a sweet-smelling compound on reaction with ethanol

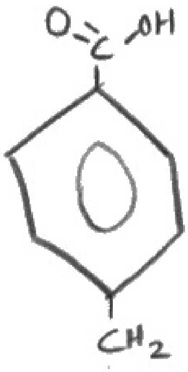
Deduce the structures of isomers **W, X, Y** and **Z**. Justify your answers.

(7)

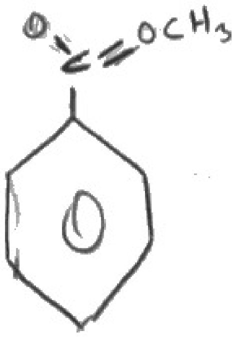


Y

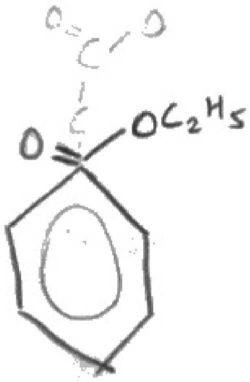




Z



W



X

CH3COOH

Y - carboxylic acids react with sodium carbonate and give off CO_2

- also a mono substituted aromatic compound.

Z - disubstituted - has two groups showing carboxylic acid and alkyl.

- has 6 peaks on ^{13}C NMR

ResultsPlus Examiner Comments

The first structure Y is correct and the comment on the second page scores the justification mark.

Unfortunately, the structure of Z has a CH_2 instead of a CH_3 so loses that mark and the comment on the second page does not add anything significantly more than that given in the question, so does not score.

Neither structures W nor X are correct. There is clearly some confusion with the number of bonds that oxygen and carbon atoms have.

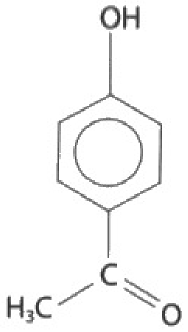
ResultsPlus Examiner Tip

At times, it can be helpful to draw out a displayed formula for a benzene ring as this can highlight where the hydrogen atoms should and shouldn't be, plus how other substituents join.

Question 9 (c)(i)

Centres and their candidates are to be commended for the vast improvement in the drawing of electrophilic substitution reaction mechanisms. There were many completely correct mechanisms and a reduction in the careless placement of arrows and such.

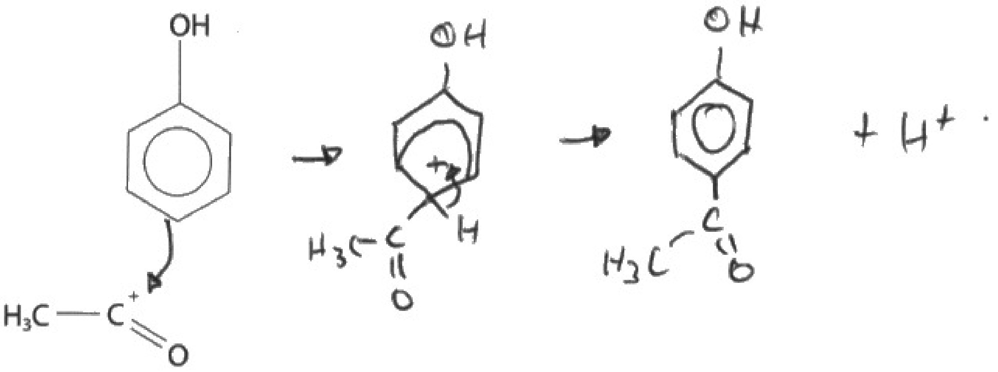
(c) Piceol is found in the needles of Norway spruce trees. Its structure is shown.



(i) Piceol can be produced from the reaction of ethanoyl chloride and phenol. Assume the mechanism for the reaction with phenol is similar to that with benzene and involves the use of an aluminium chloride catalyst, which produces the electrophile $[CH_3C{=}O]^+$.

Complete the diagram, including curly arrows, to show the mechanism for this reaction to produce piceol.
Include the regeneration of the catalyst.

(4)



ResultsPlus
Examiner Comments

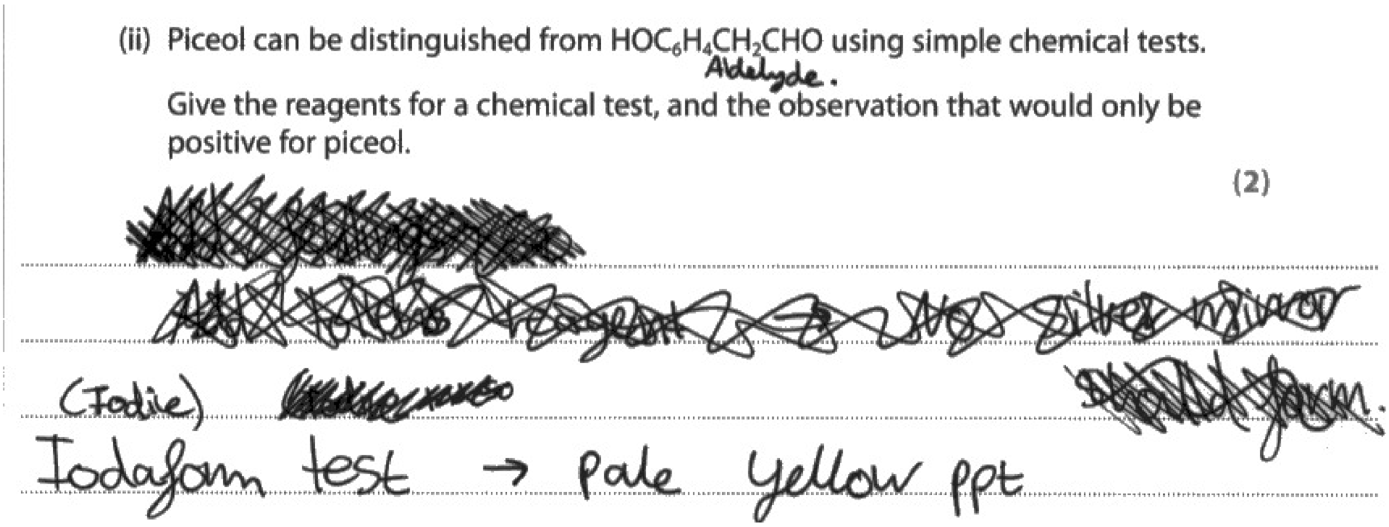
A rare example of some errors. Note that the initial curly arrow doesn't originate from the delocalised ring and so loses the mark. The subsequent marks for the intermediate and the deprotonation are awarded but the question specifically states to include the regeneration of the catalyst which is missing.

Examiner Tip

'Read The Question Twice' – RTQ^2

Question 9 (c)(ii)

The majority of candidates did not score on this question. The request for a reagent resulted in all manner of different chemical reagents being suggested. The most common of these reagents was Brady's reagent but this cannot be used to distinguish piceol from the compared aldehyde. The iodoform test was needed and generally if this was identified then the positive result was also given. Occasionally just iodine was given without the necessary alkaline conditions and this was viewed as a 'near miss' and the second mark, though not the first, could be awarded.



(ii) Piceol can be distinguished from $HOC_6H_4CH_2CHO$ using simple chemical tests.

Aldehyde.

Give the reagents for a chemical test, and the observation that would only be positive for piceol.

(2)

~~Add Tollens Reagent~~ ~~silver mirror~~

(Iodine) ~~Iodoform.~~

Iodaform test → pale yellow ppt

ResultsPlus
Examiner Comments

The reference to "Iodaform test" (sic) was viewed as enough of a 'near-miss' for the pale yellow precipitate to score one mark for the positive result.

(ii) Piceol can be distinguished from $HOC_6H_4CH_2CHO$ using simple chemical tests.

Give the reagents for a chemical test, and the observation that would only be positive for piceol.

(2)

~~2,4-DNPH would go from green solution to orange precipitate~~

~~If~~ If $AgNO_3$ is added piceol will not produce a silver mirror but $HOC_6H_4CH_2CHO$ will

ResultsPlus
Examiner Comments

The point that this candidate is making in this response has merit because piceol will not produce a silver mirror, but the other substance would. However, this is not the question. The requirement is for a test which is positive only for piceol and so this response does not score.

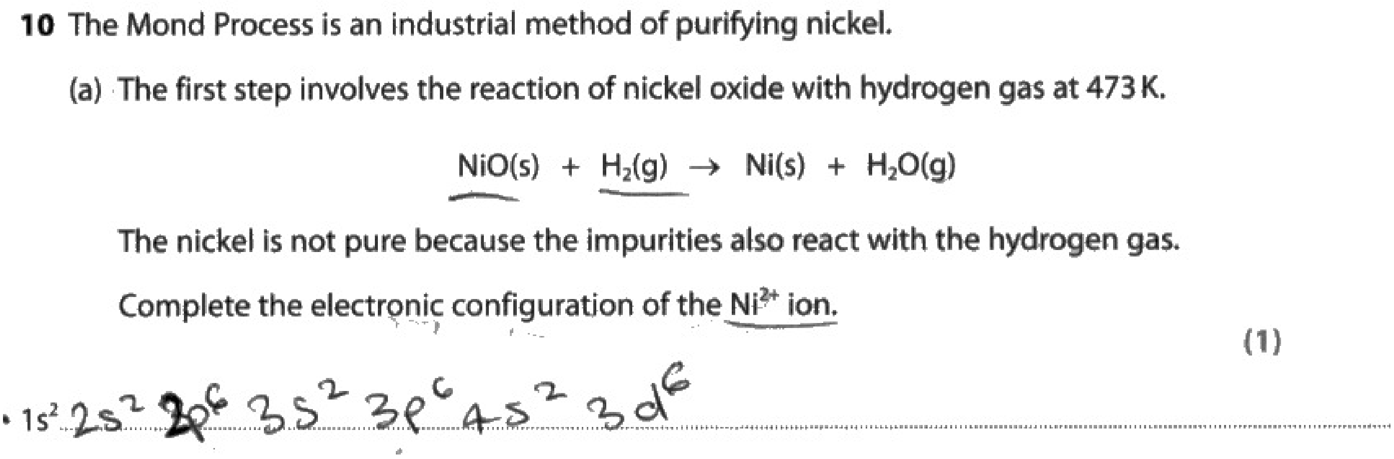
It is worth noting that the silver mirror test involves more than just silver nitrate since it has to be in an ammonia solution.

ResultsPlus
Examiner Tip

Make sure that the answer given matches the demand of the question.

Question 10 (a)

Approximately half of the candidates could correctly give the electronic configuration of the nickel(II) ion.



10 The Mond Process is an industrial method of purifying nickel.

(a) The first step involves the reaction of nickel oxide with hydrogen gas at 473 K.

$$NiO(s) + H_2(g) \rightarrow Ni(s) + H_2O(g)$$

The nickel is not pure because the impurities also react with the hydrogen gas.

Complete the electronic configuration of the Ni^{2+} ion.

(1)

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

ResultsPlus
Examiner Comments

An example of the problem when an electronic configuration is written in the order that the orbitals are 'filled up'. The number of electrons in the 3d subshell is then written after the 4s electrons and so when there is a loss of electrons it seems obvious to remove them from the last orbital. However, this is incorrect since electrons are lost from the 4s orbital before losing those from the 3d subshell.

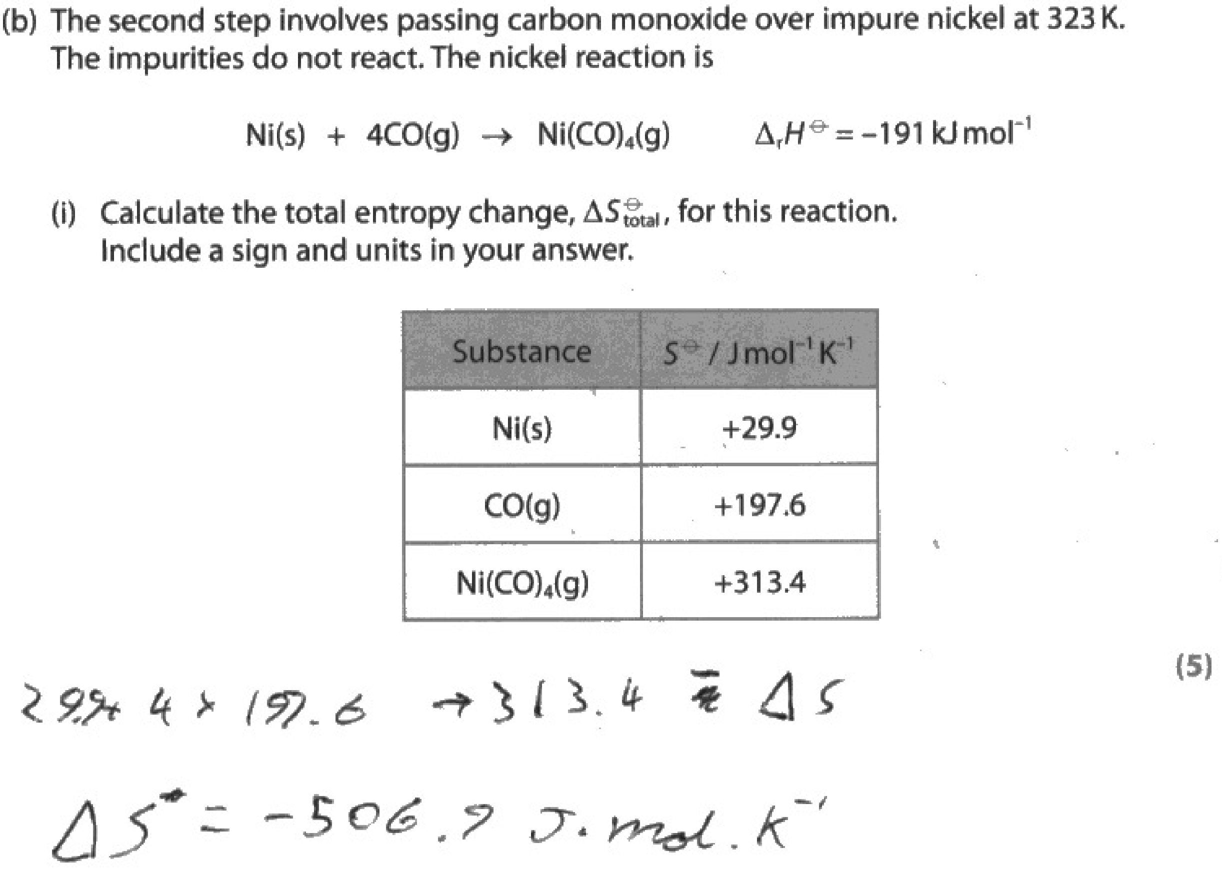
ResultsPlus
Examiner Tip

Write all the orbitals in the same energy level together, so couple together the 3s with the 3p and also with the 3d.

Question 10 (b)(i)

Many, many candidates scored full marks on this calculation and were not hampered significantly by a poor layout. These entropy calculations have clearly been well practised by centres and their candidates, and this has paid off.

The frustrating error seen relatively frequently was the omission of the sign and units required in the question.



(b) The second step involves passing carbon monoxide over impure nickel at 323 K. The impurities do not react. The nickel reaction is

$$Ni(s) + 4CO(g) \rightarrow Ni(CO)_4(g) \qquad \Delta_r H^\ominus = -191\ kJ\ mol^{-1}$$

(i) Calculate the total entropy change, $\Delta S^\ominus_{total}$, for this reaction. Include a sign and units in your answer.

Substance	$S^\ominus$ / J mol^{-1} K^{-1}
Ni(s)	+29.9
CO(g)	+197.6
$Ni(CO)_4(g)$	+313.4

(5)

$29.9 + 4 \times 197.6 \rightarrow 313.4 = \Delta S$

$\Delta S^\ominus = -506.9\ J.mol.K^{-1}$

ResultsPlus
Examiner Comments

This is an example of a response which scores two marks for the calculation of the entropy change of the system. The total entropy change was the requirement of the question. The large number of marks and the extra data provided suggest more is required than has just been done. However, this candidate has calculated what they know and is given credit for that, which is much better than leaving the area blank.

ResultsPlus
Examiner Tip

Be guided by the number of marks available, and by the data provided, as to how much is required by the question.

(b) The second step involves passing carbon monoxide over impure nickel at 323 K. The impurities do not react. The nickel reaction is

$$Ni(s) + 4CO(g) \rightarrow Ni(CO)_4(g) \qquad \Delta_r H^\ominus = -191\ \text{kJ mol}^{-1}$$

(i) Calculate the total entropy change, $\Delta S^\ominus_{total}$, for this reaction. Include a sign and units in your answer.

Substance	$S^\ominus$ / J mol^{-1} K^{-1}
Ni(s)	+29.9
CO(g)	+197.6
$Ni(CO)_4$(g)	+313.4

(5)

$\Delta S_{sys} = 313.4 - 29.9 + 4(197.6)$

$313.4 - 29.9 + 790.4$

$313.4 - 820.3$

$= -506.9$

$\Delta S_{surr} = \frac{-191000\ \text{J mol}^{-1}}{323} = 591.3$ $\qquad \Delta S_{surr} = \frac{-Q}{T}$

$\Delta S_{total} = -506.9 + 591.3$

$= +84.4$

ResultsPlus
Examiner Comments

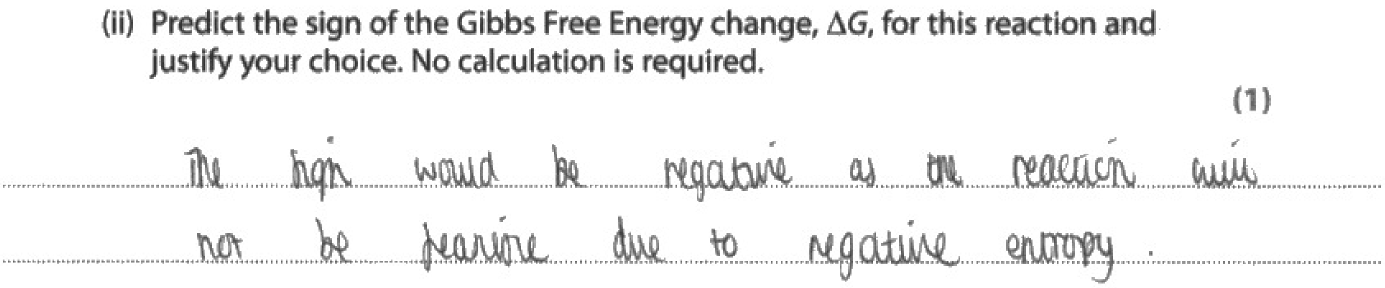
An example of a response which is nicely laid out and clearly the candidate understands what is required. All the more disappointing to see that the units are missing and so four marks are awarded rather than five.

ResultsPlus
Examiner Tip

Check and double check and triple check that the answer given includes all the features required by the question.

Question 10 (b)(ii)

This was one of the easier questions at the end of the paper. It was hoped that candidates would appreciate that the reaction was feasible because it was carried out in industry so the sign for Gibbs Free Energy Change had to be negative. However, this was rarely seen. The majority of candidates reasoned on the fact that the total entropy value was positive and so the reaction must be feasible, but this was fine for the mark. A small number of candidates did try to reason on the magnitude of the TΔS value compared to the enthalpy change, which was acceptable but harder to express correctly.



(ii) Predict the sign of the Gibbs Free Energy change, ΔG, for this reaction and justify your choice. No calculation is required.

(1)

The sign would be negative as the reaction will not be feasible due to negative entropy.

ResultsPlus
Examiner Comments

Unfortunately, a contradiction is given. If Gibbs Free Energy Change is negative, then the reaction is feasible.

ResultsPlus
Examiner Tip

Remember that the reaction is feasible if the total entropy change is **positive** and if the Gibbs Free Energy Change is **negative**.

Question 10 (b)(iii)

It was pleasing to see that this far into the paper that candidates still had the stamina for a long calculation. The criticisms of the poor layout remain, but there was no evidence of candidates having run out of time.

Occasionally, there were intermediate errors such as confusing mole fractions with partial pressures. There were also a few candidates who included solid nickel in their K_p expressions which meant that they could only score a maximum of three.

(iii) 50.0 mol of carbon monoxide is mixed with excess impure solid nickel at 323 K in an industrial reactor.
At equilibrium, 0.750 mol of carbon monoxide remains. The pressure is maintained at 1.5 atm throughout.

Calculate the value of K_p at 323 K. Include units with your answer.

(6)

$Ni + 4CO_{(g)} \rightarrow Ni(CO)_4$

	Ni	4CO	Ni(CO)4
initial mol	not INC (5)	50	0
equilibrium	/	0.75	12.3125
reacted		49.25	

0.75 + 12.3125

~~partial pressure CO =~~

mol fraction = $\frac{0.75}{13.0625}$ CO = 0.057

mol fraction $\frac{12.3125}{13.0625}$ = 0.9426

partial pressure = mol fraction × total

CO = 0.861

$Ni(CO)_4$ = 1.4139

$kp = \frac{(1.4139)}{(0.861)^4}$ = kp = 2.57

$mol^{-3}\,dm^9$

~~mol dm³~~

ResultsPlus
Examiner Comments

This response has made two errors and so scores four and not six marks.

The calculation is all fine until the partial pressure for the carbon monoxide is written. Unfortunately, there is a missing zero since the partial pressure should be 0.0861 and not 0.861.

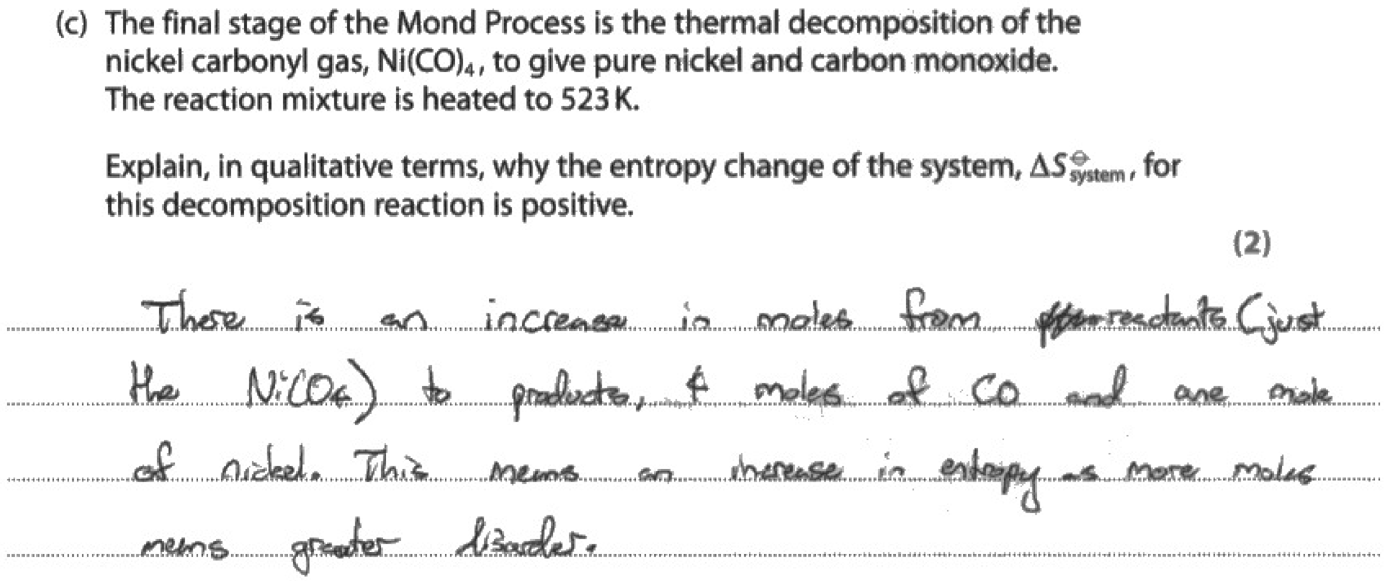
The second error is that the units are not concentration units but those of pressure, so should be atm^{-3}.

ResultsPlus
Examiner Tip

Make time to check calculations. It is very likely that this missing zero would have been spotted and corrected.

Question 10 (c)

Centres and their candidates are reminded that the rigor or demand of the paper is designed to increase progressively through the paper. Hence this question, which seems relatively straightforward and similar to previous entropy qualitative questions, has greater demand than might usually be expected. The mark scheme was kept strict and so this was a low-scoring question. It was not sufficient to simply refer to an increase in moles as a reason for the positive entropy change of the system. The crucial point is that there is an increase in the number of **gaseous** moles. The second mark was only given to the most astute candidates. The formation of a solid in the reaction serves to decrease the entropy of the system but is more than offset by the increase in moles of gas from one to four.



(c) The final stage of the Mond Process is the thermal decomposition of the nickel carbonyl gas, $Ni(CO)_4$, to give pure nickel and carbon monoxide.
The reaction mixture is heated to 523 K.

Explain, in qualitative terms, why the entropy change of the system, $\Delta S^{\ominus}_{system}$, for this decomposition reaction is positive.

(2)

There is an increase in moles from ~~[illegible]~~ reactants (just the Ni(CO4) to products, 4 moles of CO and one mole of nickel. This means an increase in entropy as more moles means greater disorder.

ResultsPlus
Examiner Comments

This is an example of a response which did not score because there is no reference to an increase in gaseous moles. It was not sufficient to simply refer to more moles of carbon monoxide since it had to be explicitly stated that this is a gas.

ResultsPlus
Examiner Tip

Remember that the demand of the paper increases progressively and so questions at the end of the paper require more.

(c) The final stage of the Mond Process is the thermal decomposition of the nickel carbonyl gas, $Ni(CO)_4$, to give pure nickel and carbon monoxide. The reaction mixture is heated to 523 K.

Explain, in qualitative terms, why the entropy change of the system, $\Delta S^{\ominus}_{system}$, for this decomposition reaction is positive.

(2)

The reaction starts with 1 mol of gas and the products have 4 moles of gas. This means there are more moles of gas in the products so disorder has increased which means than the value for entropy will be positive.

(Total for Question 10 = 15 marks)

ResultsPlus
Examiner Comments

This response does score one mark for the reference to the increase in moles but there is no comparison to the solid for the second mark.

Paper Summary

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

- RTQ^2 – Read The Question Twice to make sure that your answer matches all the requirements of the question.
- Check, double check and triple check your answer to make sure that it is error free and matches the demands of the question.
- Manage your time carefully by making time to read the question carefully and to check your answer.
- Practise, practise, practise to ensure that you know how to do key things like titration calculations.
- Review your practical work, including, but not limited to, the Core Practicals.
- Really appreciate the value of practical work and take part in as much as you are able.
- Make sure that you understand why a particular practical procedure is carried out and what would happen if the apparatus or method was changed.
- Take care to layout calculations in a clearly labelled and methodical manner.
- Do study the whole of the specification and not just the parts which you may feel are important.
- Pay attention to the rubric or format of the question because a part which follows on such as (i) then (ii) and so on, may provide necessary guidance in an earlier part which helps in answering a subsequent question effectively.

Grade boundaries

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

https://qualifications.pearson.com/en/support/support-topics/results-certification/grade-boundaries.html

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