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Examiners' Report
June 2023

GCE Chemistry 9CH0 02

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June 2023

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Introduction

Due to the impact of the coronavirus pandemic, this was only the second series of Chemistry A-Level papers in the June examination series that had been sat by candidates since 2019. Whilst some of the candidates sitting this paper would have experienced public examinations for their AS Levels in 2022; for many this would have been their first experience of public examinations as the summer exams did not run in 2021 when they would have sat their GCSE examinations.

This paper proved accessible to all candidates and provided them with the opportunity to demonstrate their knowledge and understanding of the key concepts in Topics 2, 3, 5, 6, 7, 9 and 16-19 and there was no evidence that any were hindered by not having sufficient time to complete their answers. A number of the questions were found to be demanding and, on a few occasions, a question required more than one statement to score a single mark. It was pleasing to note that many candidates rose to the challenge and demonstrated their knowledge and understanding of A Level chemistry. Nonetheless, there are some key lessons for centres and candidates to learn from the feedback illustrated in the detailed examples in the report.

There were common errors of exam technique such as failing to double-check answers, giving answers to the wrong number of significant figures and not reading the question properly before giving an answer. However, it was clear that many candidates were well-prepared and were able to overcome the challenges of the last few years.

Question 1 (a)

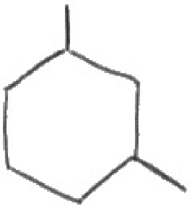
This question assessed the candidate's ability to interpret the name of an organic compound and draw the correct skeletal formula.

Many correct answers were seen, with common errors being to draw 1,3-dimethylcyclopentane as a skeletal formula or to show the methyl groups as structural formulae (CH_3).

1 This question is about some organic compounds.

(a) Draw the **skeletal** formula of 1,3-dimethylcyclohexane.

(1)



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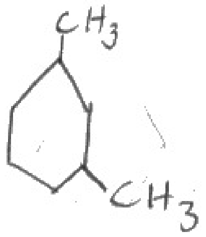
Examiner Comments

This is a fully correct answer which was awarded the mark.

1 This question is about some organic compounds.

(a) Draw the **skeletal** formula of 1,3-dimethylcyclohexane.

(1)



ResultsPlus
Examiner Comments

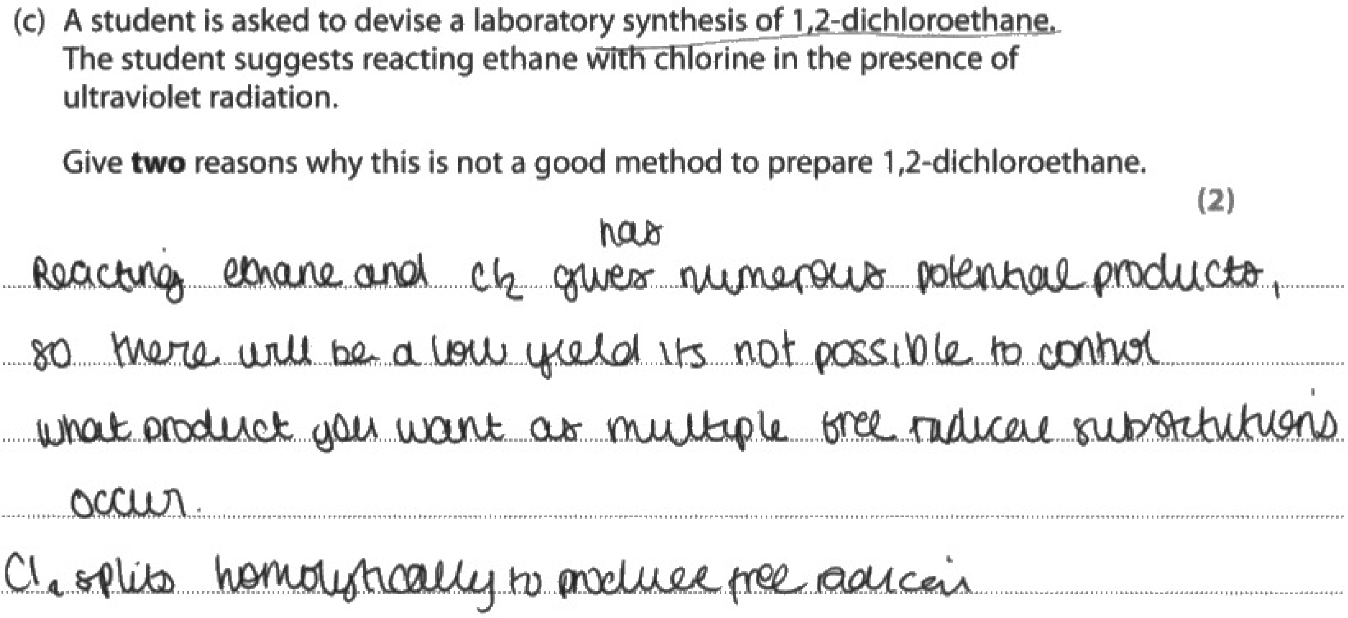
This did not score the mark as the methyl groups are shown (CH_3).

ResultsPlus
Examiner Tip

Remember that in skeletal formulae, any methyl groups are indicated by lines.

Question 1 (c)

This question required the candidates to consider some of the problems in using free radical substitution as a synthetic route. Whilst many candidates realised that it would be difficult to produce the correct product as you would generally obtain of mixture of products, fewer explained that it would make it difficult to separate the products or named a correct unwanted product. Some candidates named hydrogen as an unwanted product. This would not be produced by free radical substitution and so would not be awarded the second mark.



(c) A student is asked to devise a laboratory synthesis of 1,2-dichloroethane.
The student suggests reacting ethane with chlorine in the presence of ultraviolet radiation.

Give **two** reasons why this is not a good method to prepare 1,2-dichloroethane.

(2)

has
Reacting ethane and Cl_2 gives numerous potential products,
so there will be a low yield its not possible to control
what product you want as multiple free radical substitutions
occur.
Cl_2 splits homolytically to produce free radicals

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Examiner Comments

The candidate has stated that there would be other products so has scored M1.

They have not named a specific unwanted product, nor have they explained why unwanted products would cause a problem and so no M2 could be awarded.

A range of products are formed as the free radicals formed from the heterolytic bond fission of Cl_2 are highly reactive & ∴ are imprecise at making one specific targeted product ∴ there is a very small yield. The organic products/impurities are very difficult to separate from 1,2-dichloroethane

(Total for Question 1 = 4 marks)

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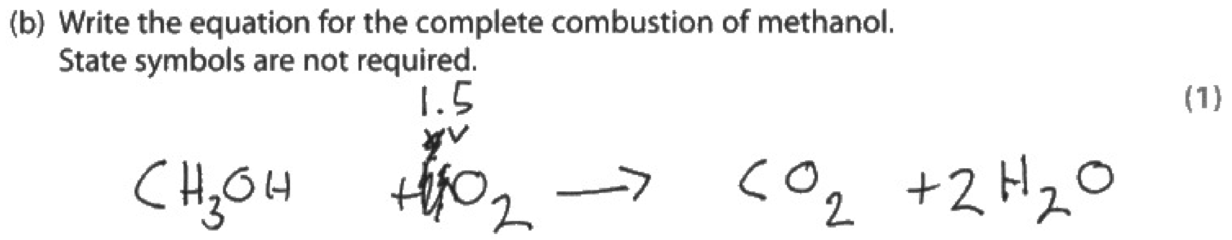
Examiner Comments

This response scored both marks for explaining that a range of products would form (M1) and that these would be difficult to separate (M2).

Question 2 (b)

This was a straightforward question requiring candidates to write and balance a combustion equation. There were many good responses. The majority who did not score gave the wrong number of oxygen atoms in their equation or gave the wrong formula for methanol.



(b) Write the equation for the complete combustion of methanol.
State symbols are not required.

(1)

$CH_3OH \ + \overset{1.5}{\cancel{\ \ }}O_2 \longrightarrow CO_2 + 2H_2O$

ResultsPlus
Examiner Comments

This is an example of a fully correct answer.

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Examiner Tip

Check and correct your work, if necessary, as exemplified by this response.

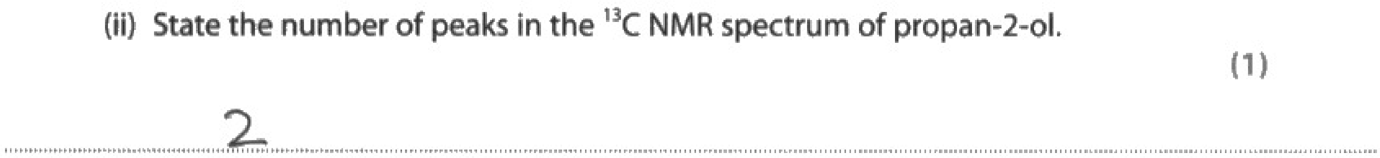
Question 2 (c)

There were a number of options for correct answers for this question. The most common answers seen were 'iodine and red phosphorus' or PI_3. A few candidates suggested HI which was credited and a number suggested the use of H_2SO_4 which was not.

Question 2 (d)(ii)

This was a straightforward question and many correct answers stating that there would be two peaks in the ^{13}C NMR spectrum of propan-2-ol were seen.

This was a straightforward question and was well-answered with many correct answers stating that there would be two peaks in the ^{13}C NMR spectrum of propan-2-ol.



(ii) State the number of peaks in the ^{13}C NMR spectrum of propan-2-ol.

(1)

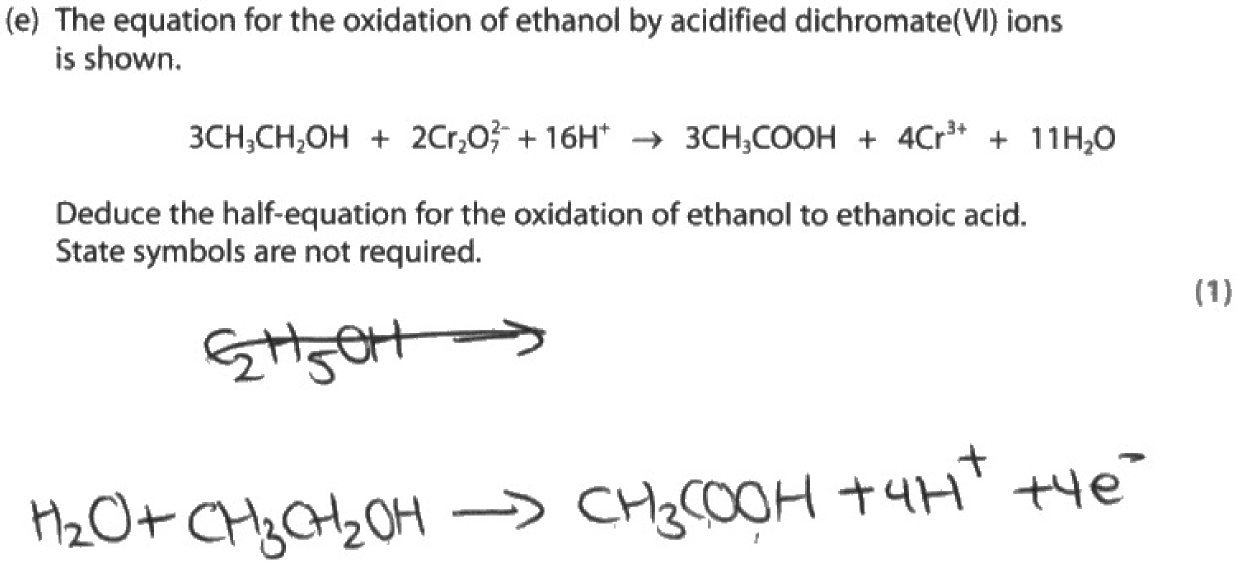
2

ResultsPlus
Examiner Comments

This is an example of a correct answer.

Question 2 (e)

This question required a half-equation for the oxidation of ethanol to form ethanoic acid. Candidates found this surprisingly difficult with many using [O] as an oxidising agent and omitting electrons and H^+ ions. Nevertheless, some completely correct answers were seen.



(e) The equation for the oxidation of ethanol by acidified dichromate(VI) ions is shown.

$$3CH_3CH_2OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3CH_3COOH + 4Cr^{3+} + 11H_2O$$

Deduce the half-equation for the oxidation of ethanol to ethanoic acid. State symbols are not required.

(1)

~~$C_2H_5OH \rightarrow$~~

$H_2O + CH_3CH_2OH \rightarrow CH_3COOH + 4H^+ + 4e^-$

ResultsPlus
Examiner Comments

This candidate has deduced the correct equation and scores the mark.

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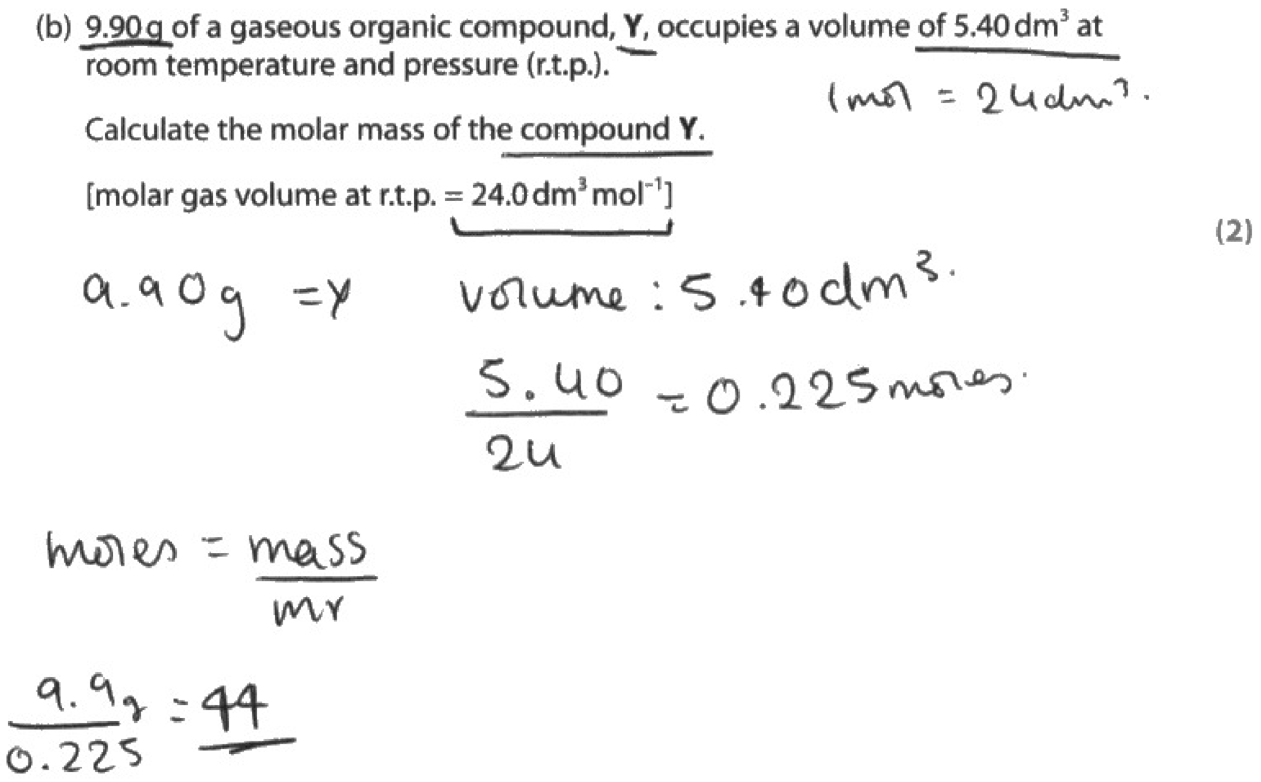
Examiner Tip

Practise writing half-equations for chemical reactions stepwise; balance the elements that are not hydrogen or oxygen, balance the oxygen atoms with water, balance the hydrogen atoms using H^+ ions and finally balance the charges using electrons.

Question 3 (b)

Candidates generally found this straightforward with many correct answers scoring both marks. There were a few transcription errors and some candidates did not score the second mark as they divided the moles (0.225) by the mass (9.9).



(b) 9.90 g of a gaseous organic compound, **Y**, occupies a volume of 5.40 dm³ at room temperature and pressure (r.t.p.).

1 mol = 24dm³.

Calculate the molar mass of the compound **Y**.

[molar gas volume at r.t.p. = 24.0 dm³ mol⁻¹]

(2)

9.90g = Y   volume : 5.40dm³.

$\frac{5.40}{24}$ = 0.225 moles.

moles = $\frac{\text{mass}}{\text{mr}}$

$\frac{9.9g}{0.225}$ = $\underline{44}$

ResultsPlus
Examiner Comments

This is a fully correct answer and laid out clearly.

Units were not required for the final answer, but would be g mol^{-1}.

(b) $\overset{\text{mass}}{9.90}$ g of a gaseous organic compound, **Y**, occupies a volume of 5.40 dm³ at room temperature and pressure (r.t.p.).

Calculate the molar mass of the compound **Y**.

[molar gas volume at r.t.p. = 24.0 dm³ mol⁻¹]

(2)

$Mr = n \times m$

$n = \frac{vol(dm^3)}{24} = \frac{5.4}{24} = 0.225$

$Mr = 0.225 \times 9.9 = 2.2275 = \underline{2.23}$

ResultsPlus
Examiner Comments

This candidate has calculated the number of moles correctly and so scores M1. They have then multiplied the number of moles by mass instead of dividing the mass by the number of moles and so did not score M2.

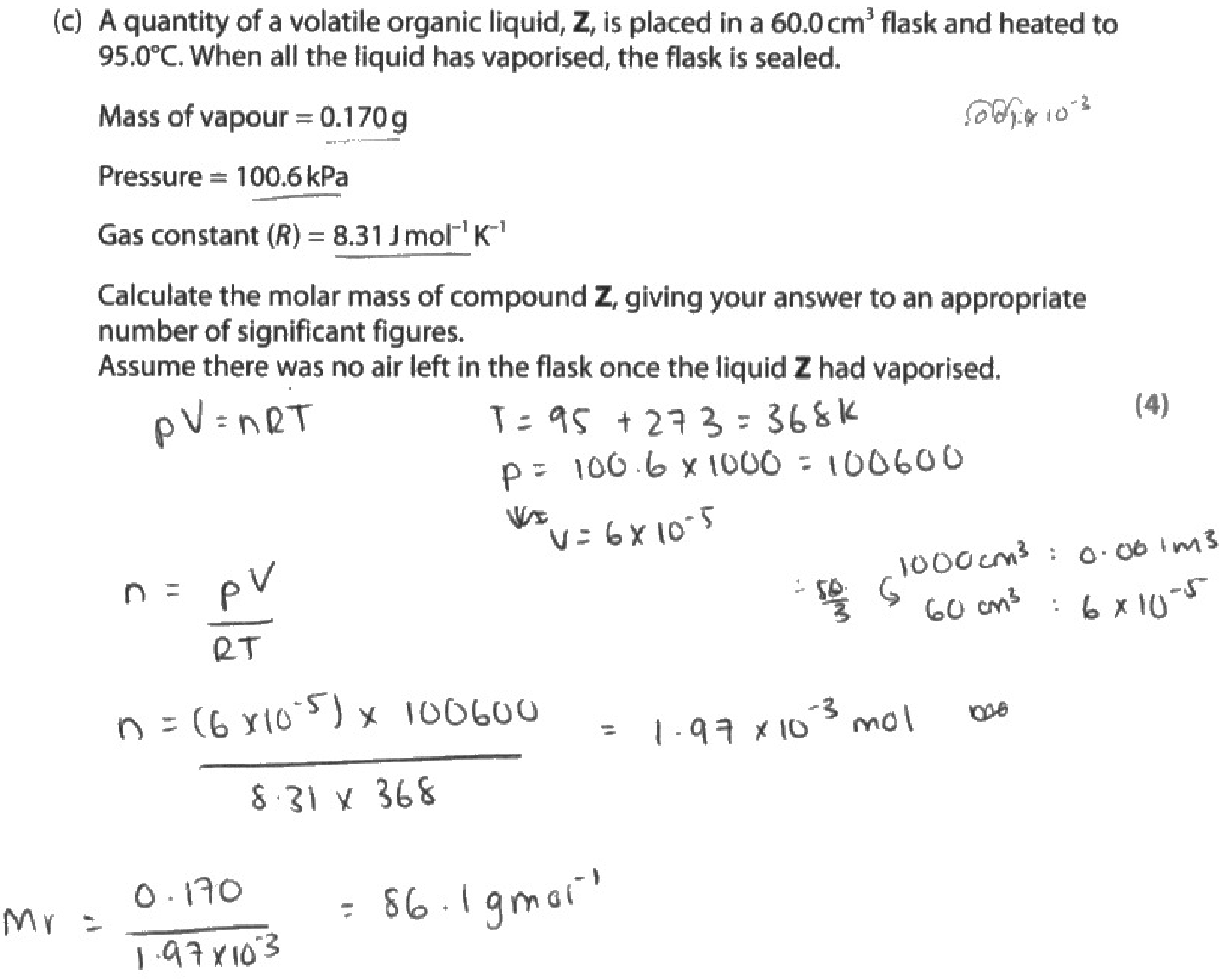
ResultsPlus
Examiner Tip

Check your answer to ensure that it makes sense. In this case, it would not be possible for an organic compound to have a molecular mass of 2.23 g mol^{-1} as the relative atomic mass of carbon is 12.

Question 3 (c)

This question required candidates to use the ideal gas equation to calculate the molar mass of an unknown compound from given data.

The first step required candidates to change the units to the correct SI units and this caused some confusion. Many candidates knew the ideal gas equation and substituted their numbers correctly, but then were not sure what to do for the next steps. Candidates who set out their work clearly were more likely to be able to follow through with a logical progression to get to the correct answer. Frustratingly, some then lost the final mark as they gave their answer to more than three significant figures.



(c) A quantity of a volatile organic liquid, **Z**, is placed in a 60.0 cm^3 flask and heated to 95.0°C. When all the liquid has vaporised, the flask is sealed.

Mass of vapour = 0.170 g

[illegible] $\times 10^{-3}$

Pressure = 100.6 kPa

Gas constant (R) = 8.31 J mol^{-1} K^{-1}

Calculate the molar mass of compound **Z**, giving your answer to an appropriate number of significant figures.
Assume there was no air left in the flask once the liquid **Z** had vaporised.

(4)

$pV = nRT$

$T = 95 + 273 = 368K$

$p = 100.6 \times 1000 = 100600$

$V = 6 \times 10^{-5}$

$\div \frac{50}{3}$ 1000 cm^3 : 0.001 m^3

60 cm^3 : 6×10^{-5}

$n = \frac{pV}{RT}$

$n = \frac{(6 \times 10^{-5}) \times 100600}{8.31 \times 368} = 1.97 \times 10^{-3}$ mol

$Mr = \frac{0.170}{1.97 \times 10^{-3}} = 86.1$ g mol^{-1}

ResultsPlus
Examiner Comments

This is an example of a fully correct answer which scored all of the marks. It is clearly laid out and the answer is given to 3SF and although units were ignored, the units in the answer are correct.

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Examiner Tip

Always lay your work out clearly to help you follow a logical pathway.

(4)

$pV = nRT \qquad n = \frac{pV}{RT}$

$p = 100600\ Pa.$

$V = \frac{60\ cm^3}{1.0 \times 10^6\ cm^3\ m^{-3}} = 6.0 \times 10^{-5}\ m^3$

$T = 273 + 95 = 368\ K.$

$$n = \frac{(100600)(6.0 \times 10^{-5})}{368 \times 8.31}$$

$n = 1.99 \times 10^{-3}\ mol.$

$M_r = \frac{0.170g}{1.99 \times 10^{-3}\ mol}$

$M_r = 84.417\ gmol^{-1}$

$M_r = 84\ gmol^{-1}\ (2sf)$

ResultsPlus
Examiner Comments

This is an example where the candidate has made two slips in their calculations which has resulted in the loss of 2 marks.

The response was awarded 2 marks.

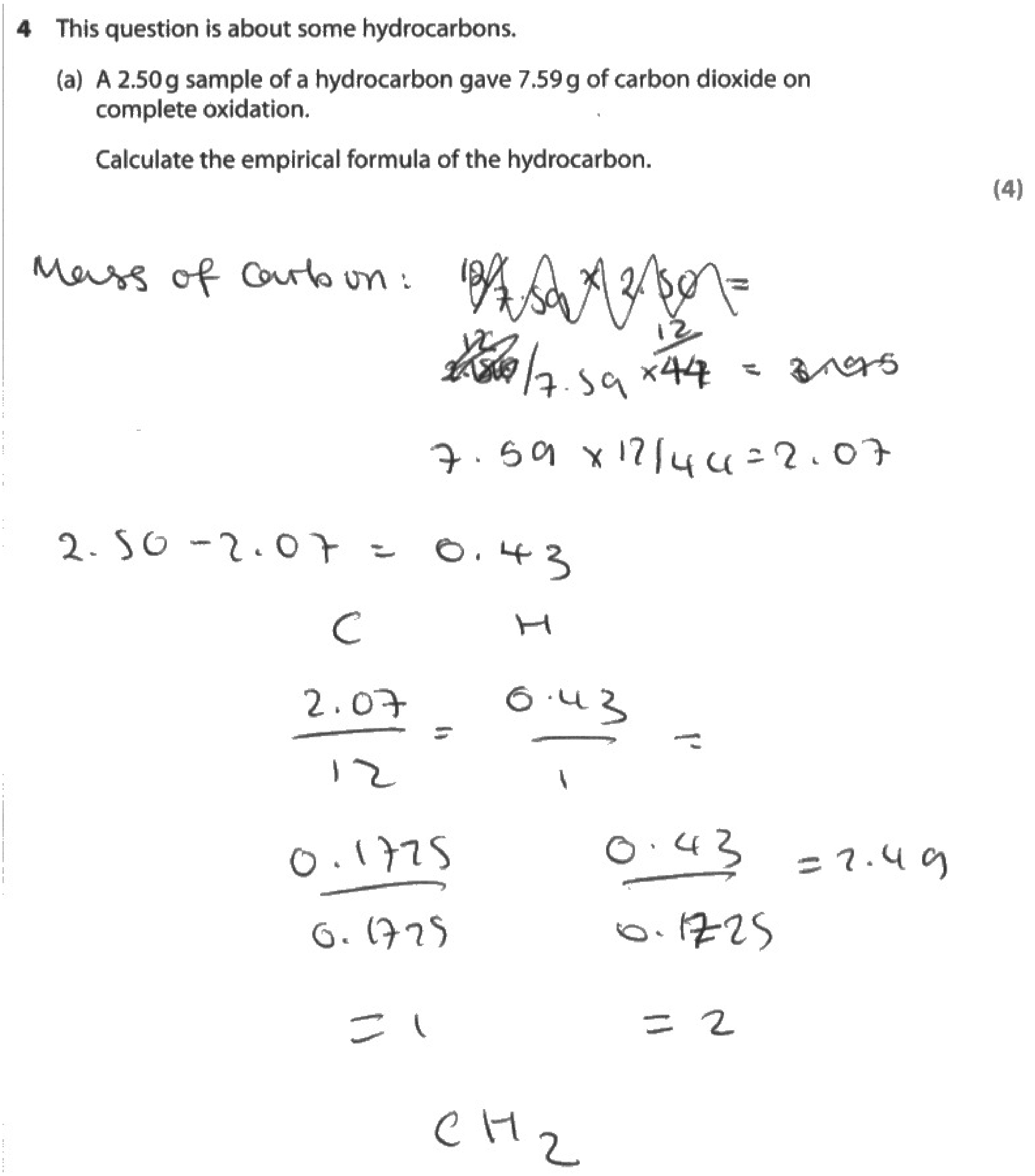
They have converted the units and the Ideal Gas equation is correct and they have substituted the values correctly. However, the answer should be 1.97 and not 1.99 so this was penalised. They then made a second error as their final answer as a transferred error would have been 85 to 3SF and so they also lost the final mark.

ResultsPlus
Examiner Tip

Check all calculations carefully as it is easy for errors to creep in and cost valuable marks.

Question 4 (a)

The multi-step calculation proved challenging for many candidates. Many calculated the moles of CO_2 and hence the mass of carbon, but were unsure how to calculate the mass of hydrogen. Those who completed this step correctly were often able to calculate the ratio as being 1:2.5 but were then unsure how to convert this to an empirical formula. Nevertheless, some good examples of clearly laid out working leading to correct answers were seen.



4 This question is about some hydrocarbons.

(a) A 2.50 g sample of a hydrocarbon gave 7.59 g of carbon dioxide on complete oxidation.

Calculate the empirical formula of the hydrocarbon.

(4)

Mass of carbon: ~~12/7.59 × 2.50~~ =

~~12~~ ~~2.50~~/7.59 × $\frac{12}{44}$ = ~~2.0795~~

7.59 × 12/44 = 2.07

2.50 − 2.07 = 0.43

C H

$\frac{2.07}{12}$ = $\frac{0.43}{1}$ =

$\frac{0.1725}{0.1725}$ $\frac{0.43}{0.1725}$ = 2.49

= 1 = 2

CH_2

ResultsPlus
Examiner Comments

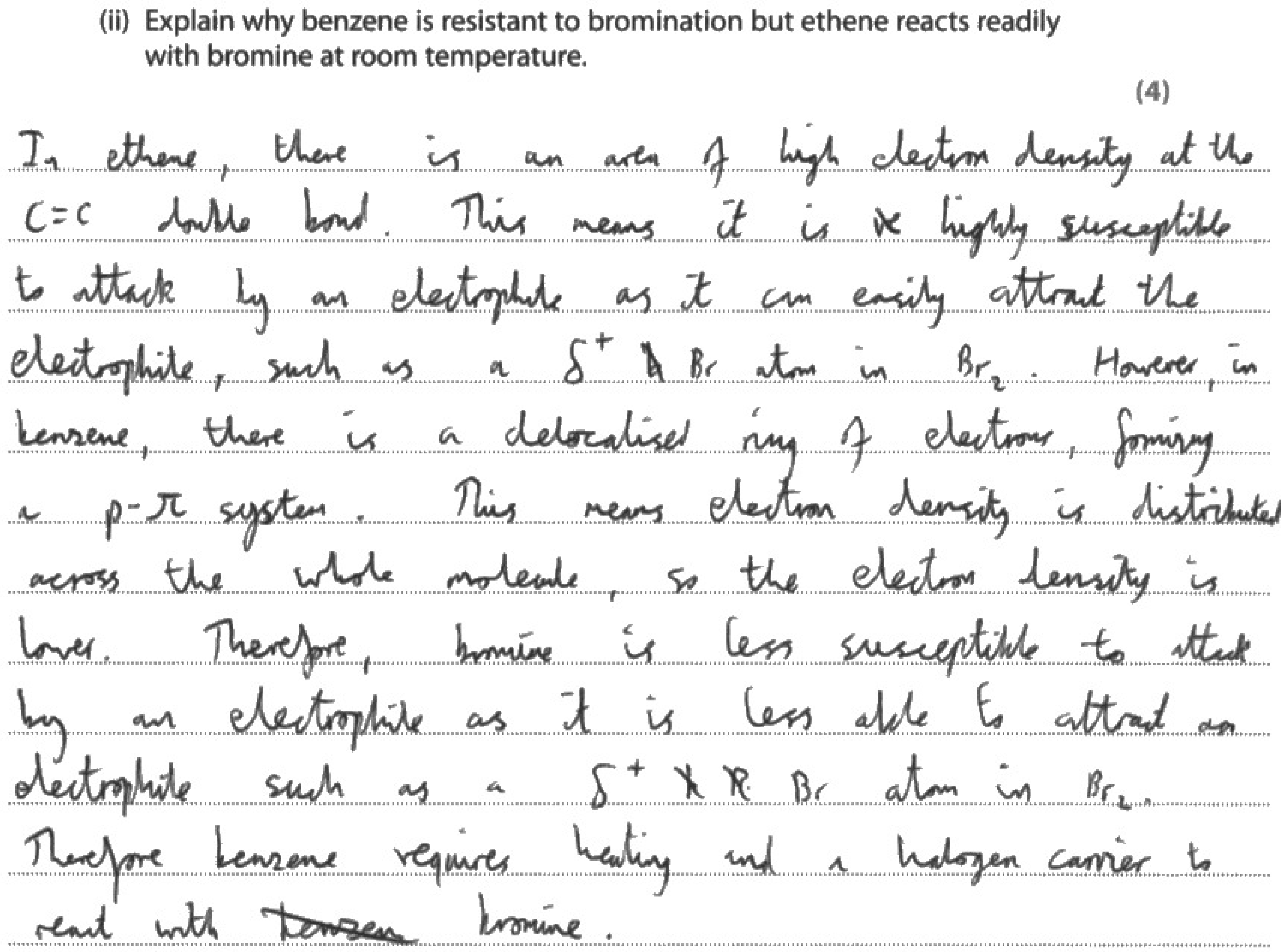
This candidate scored 3 marks out of the 4 marks.

They followed through all of the steps correctly and all of their working is correct apart from at the end where they have calculated a ratio of 1:2.49 but have then calculated the final formula a CH_2 instead of C_2H_5.

Question 4 (b)(ii)

This question comparing the reactivity of benzene or ethene with bromine gave some interesting answers.

Many candidates found it difficult to express their ideas clearly and ended up repeating the stem of the question. However, some good responses were seen which linked the delocalised electrons in benzene to its stability and the high electron density in the double bond of ethene to its susceptibility to electrophilic attack.



(ii) Explain why benzene is resistant to bromination but ethene reacts readily with bromine at room temperature.

(4)

In ethene, there is an area of high electron density at the C=C double bond. This means it is highly susceptible to attack by an electrophile as it can easily attract the electrophile, such as a δ^+ Br atom in Br_2. However, in benzene, there is a delocalised ring of electrons, forming a p-π system. This means electron density is distributed across the whole molecule, so the electron density is lower. Therefore, bromine is less susceptible to attack by an electrophile as it is less able to attract an electrophile such as a δ^+ Br atom in Br_2. Therefore benzene requires heating and a halogen carrier to react with ~~benzene~~ bromine.

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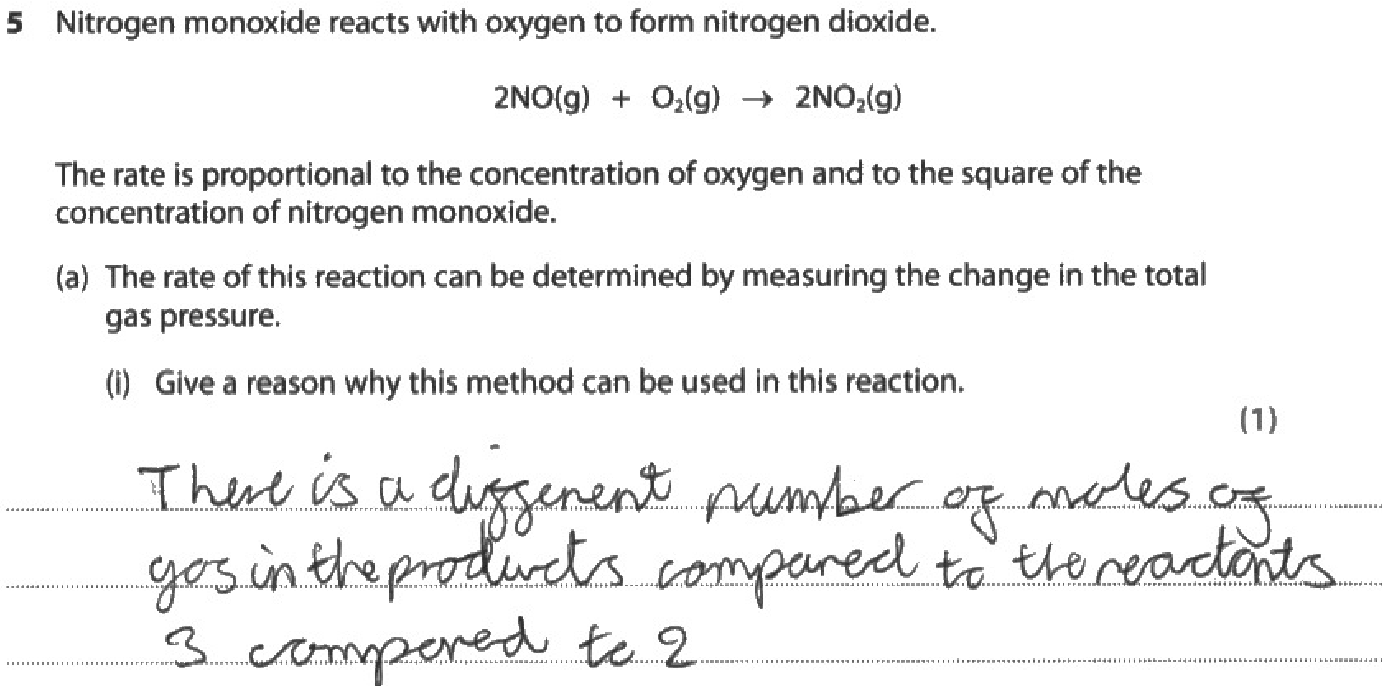
Examiner Comments

This response is excellent and scored all four of the marking points. They have explained why the double bond in ethene is susceptible to electrophilic attack and have compared it to the delocalised electrons in benzene which meant it requires a halogen carrier catalyst in order to react with bromine.

Question 5 (a)(i)

The reaction in the question has three moles of gas on the reactants side and two on the products and many candidates realised that this would mean that there would be a change in overall pressure as the reaction progressed.

Some candidates just said that measuring the pressure would be a suitable method because all of the substances were gases, but this would not be a valid reason in itself.



5 Nitrogen monoxide reacts with oxygen to form nitrogen dioxide.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

The rate is proportional to the concentration of oxygen and to the square of the concentration of nitrogen monoxide.

(a) The rate of this reaction can be determined by measuring the change in the total gas pressure.

(i) Give a reason why this method can be used in this reaction.

(1)

There is a different number of moles of gas in the products compared to the reactants 3 compared to 2

ResultsPlus
Examiner Comments

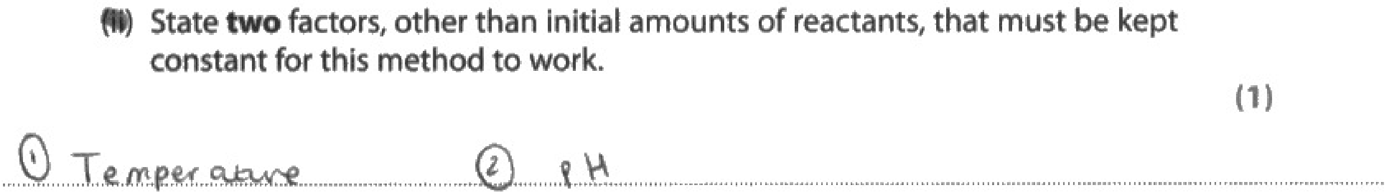
This response is fully correct as they have realised that there would be a change in pressure due to the different number of moles between products and reactants and so scored the mark.

ResultsPlus
Examiner Tip

Take care when quoting numbers to ensure that they are correct as they are here.

Question 5 (a)(ii)

Many candidates identified temperature as a control variable with fewer stating that the volume should also be kept constant. There were some references to pH, catalysts and surface area but the most common incorrect answer was pressure. Candidates should read the question carefully as in part a(ii) it was stated that the change in the total gas pressure would be measured, and therefore keeping the pressure constant would not make sense.



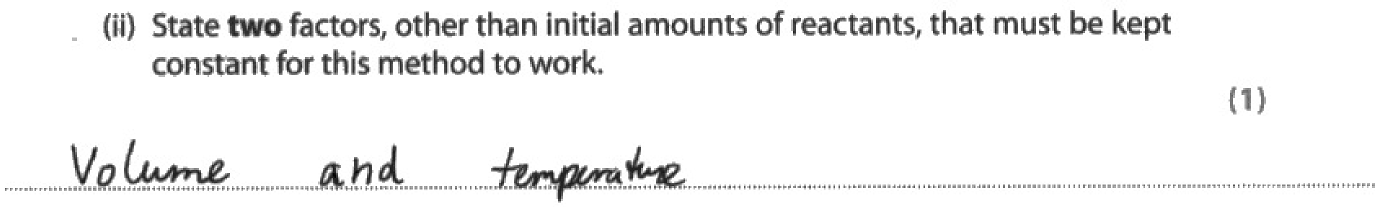
(ii) State **two** factors, other than initial amounts of reactants, that must be kept constant for this method to work.

(1)

① Temperature ② pH

ResultsPlus
Examiner Comments

This candidate did not score the mark as although temperature is correct, pH is not a variable that would need to be controlled as it is not relevant to the experiment.



(ii) State **two** factors, other than initial amounts of reactants, that must be kept constant for this method to work.

(1)

Volume and temperature

ResultsPlus
Examiner Comments

This is a correct answer which scores the mark.

Question 5 (d)(i)

There were three marks available for this question and the vast majority of candidates scored the first mark showing the enthalpy of the products to be less than the reactant in this exothermic reaction.

The second mark was for an arrow showing the enthalpy change for the reaction. Whilst many candidates drew an arrow pointing downwards and labelled it correctly, there were a number of responses with incorrect double-headed arrows or arrows with incorrect labels. The third mark, which was for two curves showing enthalpy with a catalyst, was rarely awarded. Many candidates drew two different single curves, one higher than the other and labelled 'without catalyst' and 'with catalyst'.

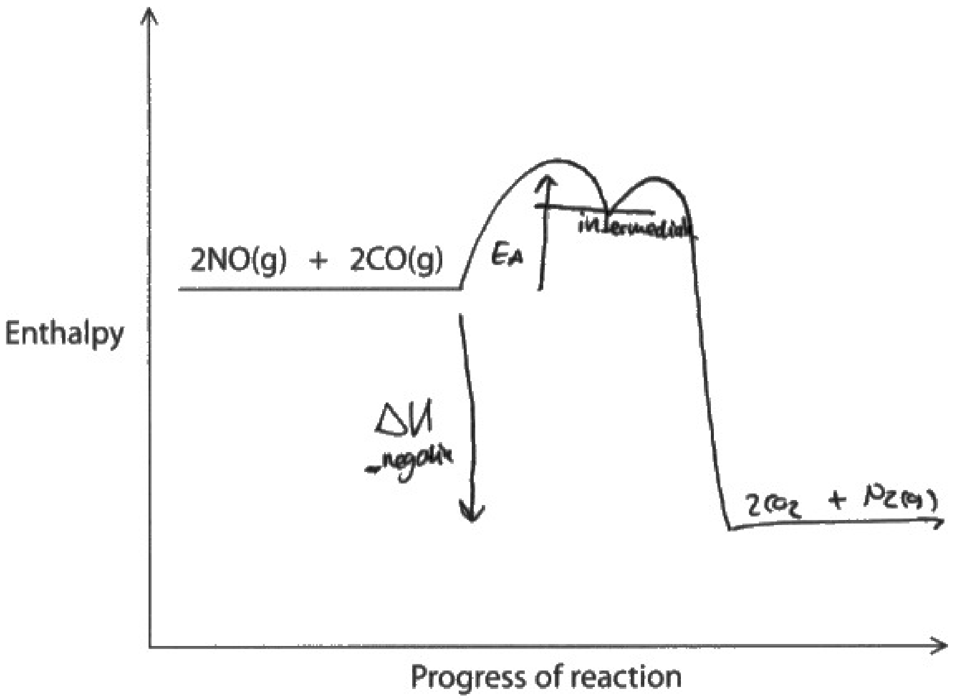
(d) Nitrogen monoxide is formed in car engines. It is removed by the catalytic converter in the car exhaust.

$$2NO(g) + 2CO(g) \rightarrow 2CO_2(g) + N_2(g)$$

The reaction is exothermic and the most active catalyst is platinum.

(i) Complete the labelled reaction profile for the **catalysed** reaction.

(3)



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Examiner Comments

This response scored all 3 marks.

The first 2 marks for the products line and the enthalpy change were awarded.

There are two curves above the enthalpy level of the reactants and although the label was not necessary, it is present and so the third mark was given as well.

ResultsPlus
Examiner Tip

Reaction profiles showing a catalysed reaction should have two curves showing the intermediate.

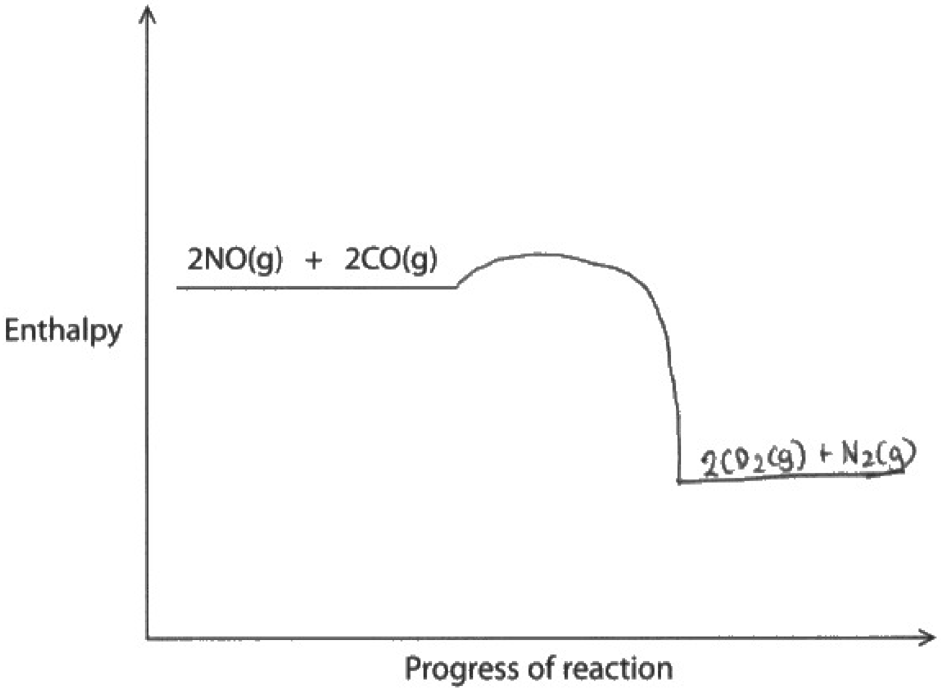
(d) Nitrogen monoxide is formed in car engines. It is removed by the catalytic converter in the car exhaust.

$$2NO(g) + 2CO(g) \rightarrow 2CO_2(g) + N_2(g) \qquad -\Delta H$$

The reaction is exothermic and the most active catalyst is platinum.

(i) Complete the labelled reaction profile for the **catalysed** reaction.

(3)



ResultsPlus
Examiner Comments

This response just scored 1 mark for the correctly positioned line and label for the products.

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Examiner Tip

Reaction profiles need to show the progress of the reaction and the energy change.

Question 5 (d)(ii)

Many candidates were able to access at least one of the two marks available. Many candidates explained that a catalyst lowers the activation energy but did not link this to being able to use a lower temperature for the reaction and so reduce energy costs to the increasing the speed of the reaction.

- Less production of toxic / poisonous chemicals such as CO
- ∴ less disruption to workers health and is more environmentally friendly

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Examiner Comments

This is an example of a response that did not score as, although the candidate has considered some advantages of using a catalyst, they have not read the question and tailored their answer to economic reasons.

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Examiner Tip

Read your answer and check that it answers the question.

Lower activation energy, so less money spent on powering reaction, using for example by use of fossil fuels.

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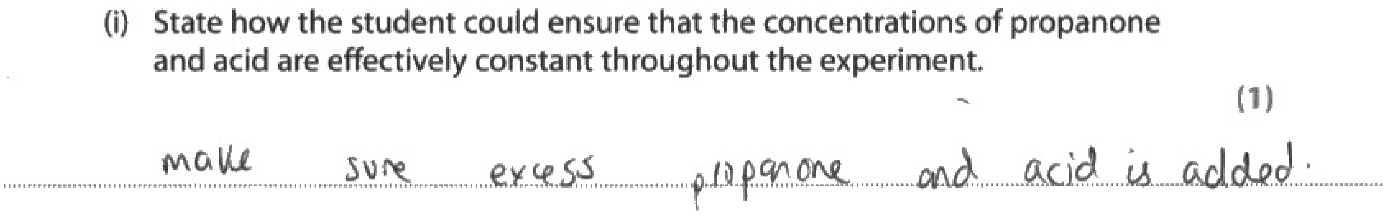
Examiner Comments

This scores 1 mark for the comment about reducing the use of fossil fuels. However, this was not linked to using a lower temperature for the reaction and so the second mark was not awarded.

Question 6 (a)(i)

The question required the candidates to consider the design of an experiment in order to obtain valid results. In this case it was to investigate the kinetics of a reaction between iodine and propanone in acidic conditions and the purpose was to find out the order of the reaction with respect to iodine. Some candidates realised that to keep the concentration of a reagent constant you need a large excess so that small changes in concentration do not make a lot of difference. There were a variety of incorrect answers including using a pH meter, stirring and keeping the volume the same. It would help candidates to ensure that they pay attention to understanding the methods associated with each core practical.



(i) State how the student could ensure that the concentrations of propanone and acid are effectively constant throughout the experiment.

(1)

make sure excess propanone and acid is added.

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Examiner Comments

This is a correct answer scoring the mark.

Question 6 (a)(ii)

A good proportion of the candidates scored at least one mark by referring either to the neutralisation of the catalyst or to the reaction being stopped. When candidates scored the second mark, they often went on to explain that the reaction needed to be quenched so that the titration would be representative of that time point. Incorrect answers referred to the sodium hydrogencarbonate being used as a drying agent or to remove impurities.

(ii) Explain why sodium hydrogencarbonate is added.

(2)

To neutralise the excess acid and to quench the reaction.

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Examiner Comments

This is a succinct answer which scored both marks.

to neutralise the H^+ ~~and so that~~

ResultsPlus
Examiner Comments

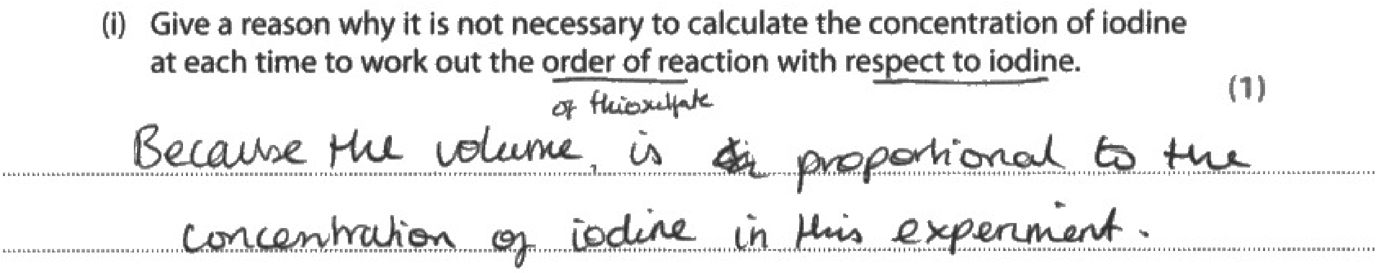
This response scored 1 mark for the neutralisation of the acid.

ResultsPlus
Examiner Tip

If there are 2 marks for a question, try and extend your answer beyond just a single statement.

Question 6 (b)(i)

A number of fully correct concise answers were seen with a correct statement that the concentration of iodine is directly proportional to the volume of thiosulfate. Some candidates used vague terms such as 'links', 'reflects' or 'is related to'. Common incorrect answers centred around knowing that in the reaction mixture that volume is proportional to concentration and giving that as the answer without qualification. Some stated that as the reaction was zero order with respect to iodine, that the concentration of iodine was not important.



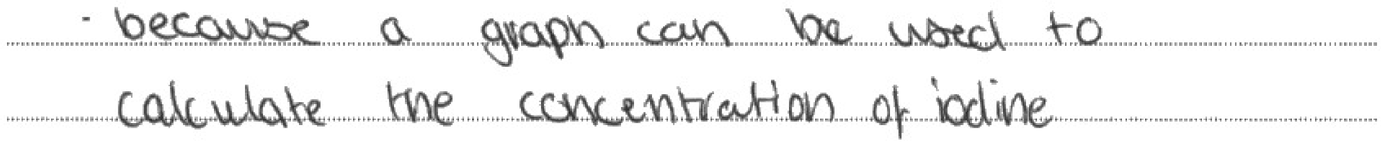
(i) Give a reason why it is not necessary to calculate the concentration of iodine at each time to work out the order of reaction with respect to iodine.

(1)

Because the volume of thiosulfate, is proportional to the concentration of iodine in this experiment.

ResultsPlus
Examiner Comments

This is a fully correct response scoring the mark.



- because a graph can be used to calculate the concentration of iodine

ResultsPlus
Examiner Comments

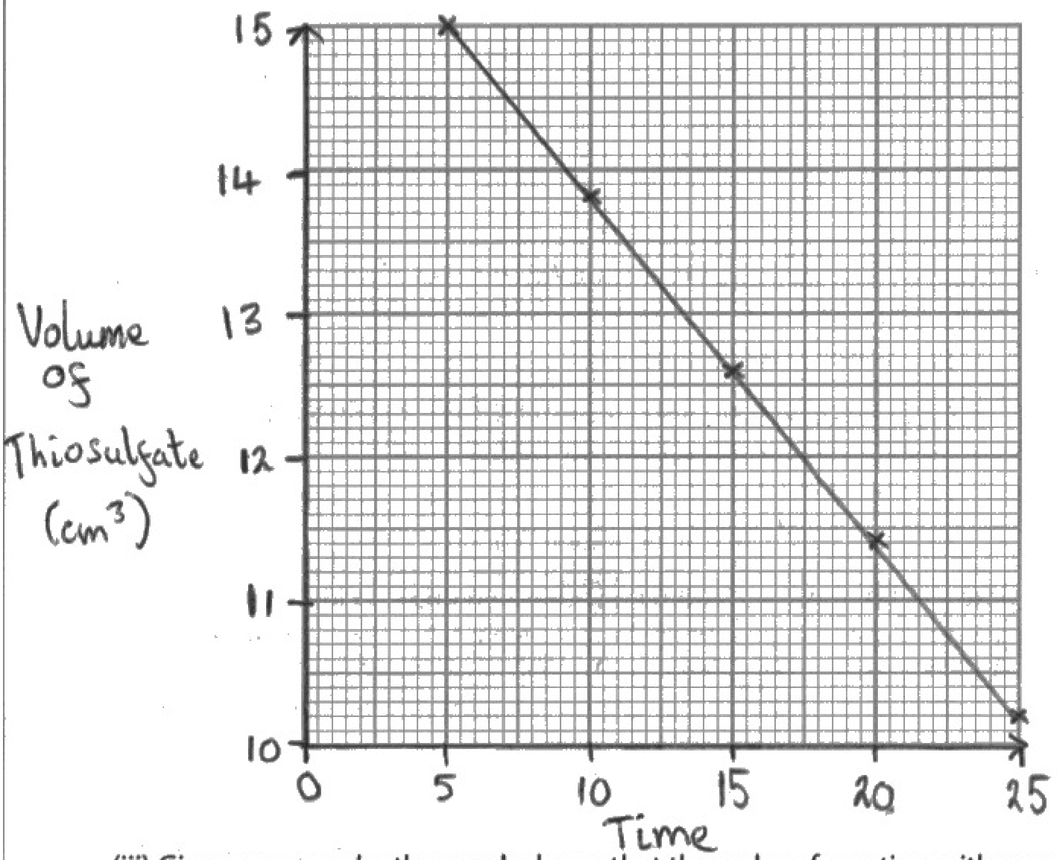
This response did not score as it did not answer the question.

Question 6 (b)(ii-iii)

Many correct graphs were seen, with some slips in labelling of the axes. Some scales did not allow the points to cover at least half the axes in both directions, and some points were not plotted correctly. It would have been clear that the graph was a straight line and so this would have given candidates an opportunity to check that all of their points were plotted correctly. The second part of this question was generally well-answered, although a few candidates restated the question and just wrote 'iodine is zero order'.

(ii) Plot a graph to show that the order of reaction with respect to iodine is zero.

(2)



(iii) Give a reason why the graph shows that the order of reaction with respect to iodine is zero.

(1)

The line of best fit is linear (it is constant) for volume against time

ResultsPlus
Examiner Comments

This a clearly plotted graph. However, the units are missing on the x-axis and so only 1 mark was awarded.

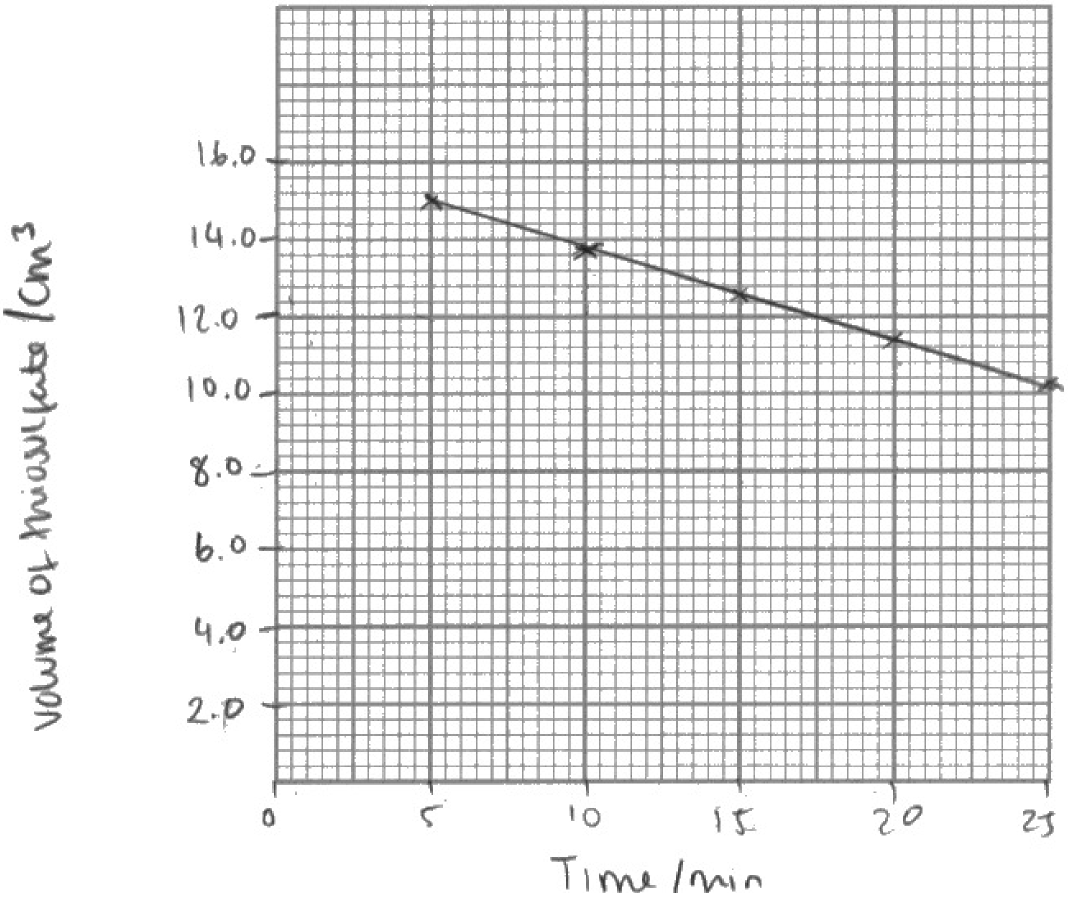
The response to part (iii) is correct and so this mark was awarded.

ResultsPlus
Examiner Tip

When drawing a graph, ensure that is covers at least half of the axes in both directions and ensure that the labels are correct with units. These can be found in the headings on the table of data.

(ii) Plot a graph to show that the order of reaction with respect to iodine is zero.

(2)



ResultsPlus
Examiner Comments

This is an example of a graph that scored just 1 mark as the scale does not allow the points to cover at least half the axes in both directions.

Question 6 (c)(i)

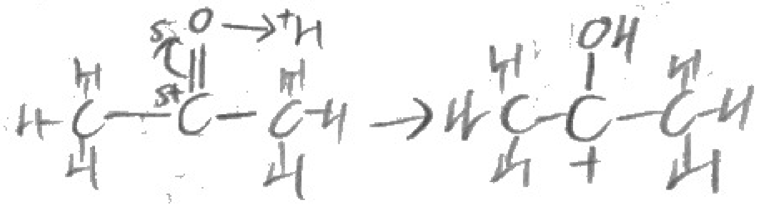
Candidates found this question challenging. It was more common to see correct reactants than the correct product as some candidates correctly linked their answer to the species in the rate equation. Where a product was suggested, this was often missing the positive charge or was incorrect and H_2 was given as an additional product. Iodine was often included in the reactants or the products despite candidates being aware that iodine was not in the rate equation.

(c) Further experiments showed that the correct overall rate equation is

$$\text{rate} = k[CH_3COCH_3(aq)][H^+(aq)][I_2(aq)]^0$$

(i) Deduce a possible rate determining step in the mechanism of this reaction. Curly arrows are not required.

(2)



ResultsPlus
Examiner Comments

This is a fully correct answer where the candidate, in addition to giving the correct species, has also attempted a mechanism using a curly arrow.

(slow) $CH_3COH_3 + I_2 \longrightarrow CH_3COH_2I + H^+$

~~$CH_3COH_3 + I_2 + H^+ \rightarrow CH_3$~~

ResultsPlus
Examiner Comments

This is an example where the candidate has attempted to include iodine in the rate determining step and hence did not score any marks.

$CH_3COCH_3 + H^+ \rightarrow CH_3COCH_2^+ + H_2$

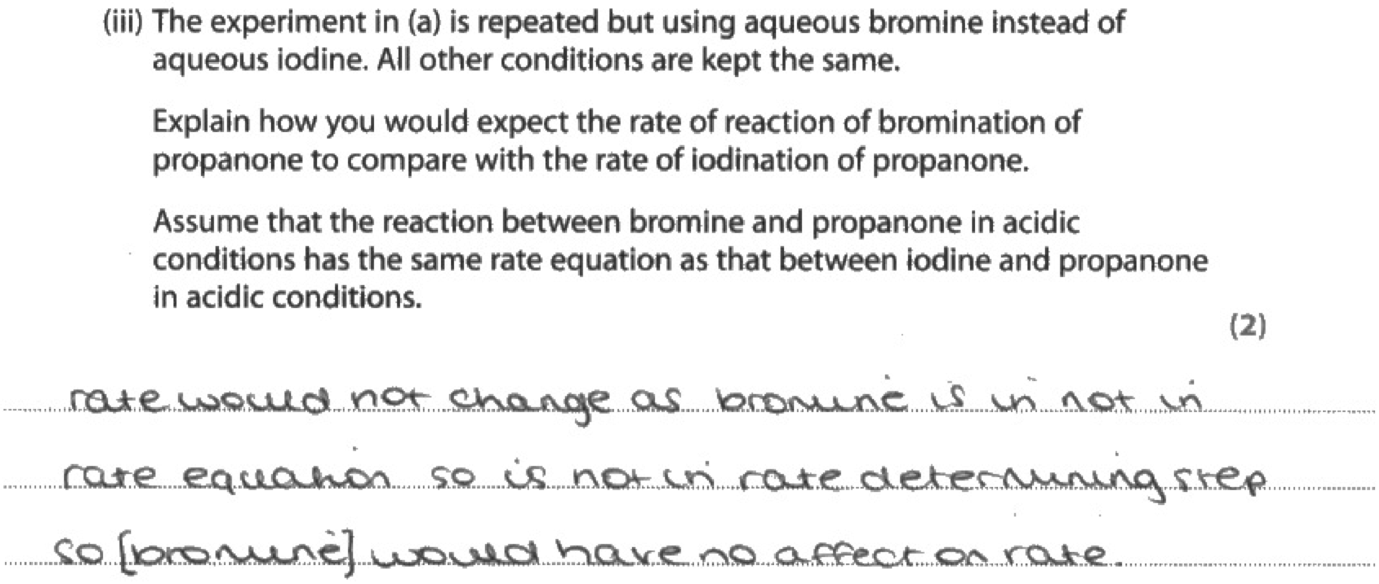
ResultsPlus
Examiner Comments

This is an example that scored 1 mark for the correct reactants.

The product side is incorrect.

Question 6 (c)(iii)

This question proved interesting. Many candidates responded with arguments about the relative reactivity or electronegativity of bromine compared of iodine. This is where careful reading of the question would have helped enormously, as the candidates had already been made aware that the order of reaction with respect to iodine was 0. A few realised this and made the correct deduction that the rate of reaction of bromination and iodination would be the same as neither bromine nor iodine would be in the rate determining step as they are not in the rate equation.



(iii) The experiment in (a) is repeated but using aqueous bromine instead of aqueous iodine. All other conditions are kept the same.

Explain how you would expect the rate of reaction of bromination of propanone to compare with the rate of iodination of propanone.

Assume that the reaction between bromine and propanone in acidic conditions has the same rate equation as that between iodine and propanone in acidic conditions.

(2)

rate would not change as bromine is in not in rate equation so is not in rate determining step so [bromine] would have no affect on rate.

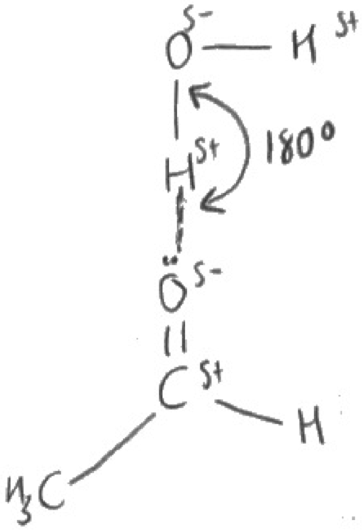
ResultsPlus
Examiner Comments

This is a clear answer scoring both marks.

Question 7 (a)

This question required candidates to explain the solubility of ethanal and ethanoic acid in water and also the difference in boiling point between the two compounds. There was also a requirement to draw a diagram showing why ethanal is soluble in water. The vast majority of candidates drew a diagram showing ethanal hydrogen bonding with water, with many showing the oxygen of the aldehyde hydrogen bonded to the hydrogen of a water molecule with an angle of 180°. However, some showed the hydrogen bond originating from one of the hydrogen atoms of ethanal and bonding to the oxygen of water which is incorrect. There was a good understanding of how these substances dissolved in water by forming hydrogen bonds.

The second part of the question concerned intermolecular forces with most candidates realising that ethanoic acid would form intermolecular hydrogen bonds which would be the strongest intermolecular forces and therefore take a lot of energy to break. However, some candidates also stated that ethanal would form intermolecular hydrogen bonds which is incorrect. There was also some mention of the relative strengths of the London Forces between molecules of ethanal and between molecules of ethanoic acid, but these would not be relevant in the context of the strong hydrogen bonds between ethanoic acid molecules.



ResultsPlus
Examiner Comments

This is a clear diagram showing hydrogen bonding between the oxygen of ethanal and the hydrogen of a water molecule with the bond angle of 180° clearly indicated.

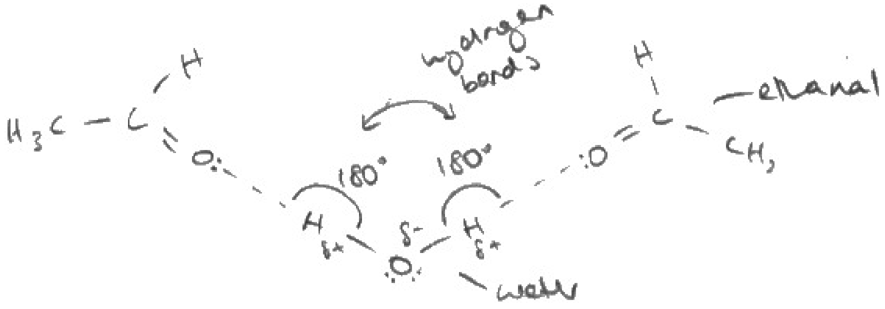
7 This question is about carbonyl compounds.

(a) Ethanal, CH_3CHO, and ethanoic acid, CH_3COOH, are both soluble in water but ethanoic acid has a much higher boiling temperature than ethanal.

Explain these physical properties of ethanal and ethanoic acid in terms of intermolecular forces.

Include a labelled diagram to show why ethanal is soluble in water.

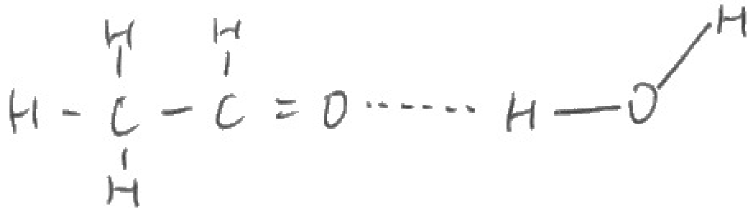
(4)



Both ethanal and ethanoic acid have London forces and permanent dipole-dipoles. Ethanoic acid has stronger London forces as it has more electrons. Ethanoic acid can also hydrogen bond with itself. Hydrogen bonds are very strong. Ethanal cannot hydrogen bond to itself as it doesn't have the very polar O–H bond that ethanoic acid does. As ethanoic acid has much stronger intermolecular forces, more energy is needed to break the molecules apart. However, they're both soluble in water. ~~Etha~~ They can both hydrogen bond with water, therefore disrupting water's own hydrogen bonding. Ethanal can hydrogen bond with water but not itself due to the lone pair of electrons on its oxygen atom. (See diagram for ethanal's hydrogen bonds with water).

ResultsPlus
Examiner Comments

This is an excellent response scoring all 4 marks.



They're both soluble because they both can form hydrogen bondings with water, which are stronger than London forces and permanent dipole-dipole.

Ethanoic acid has a higher boiling temperature because they each can form two hydrogen bondings with water, which is stronger than that of ethanal and requires more energy to break when melting.

ResultsPlus
Examiner Comments

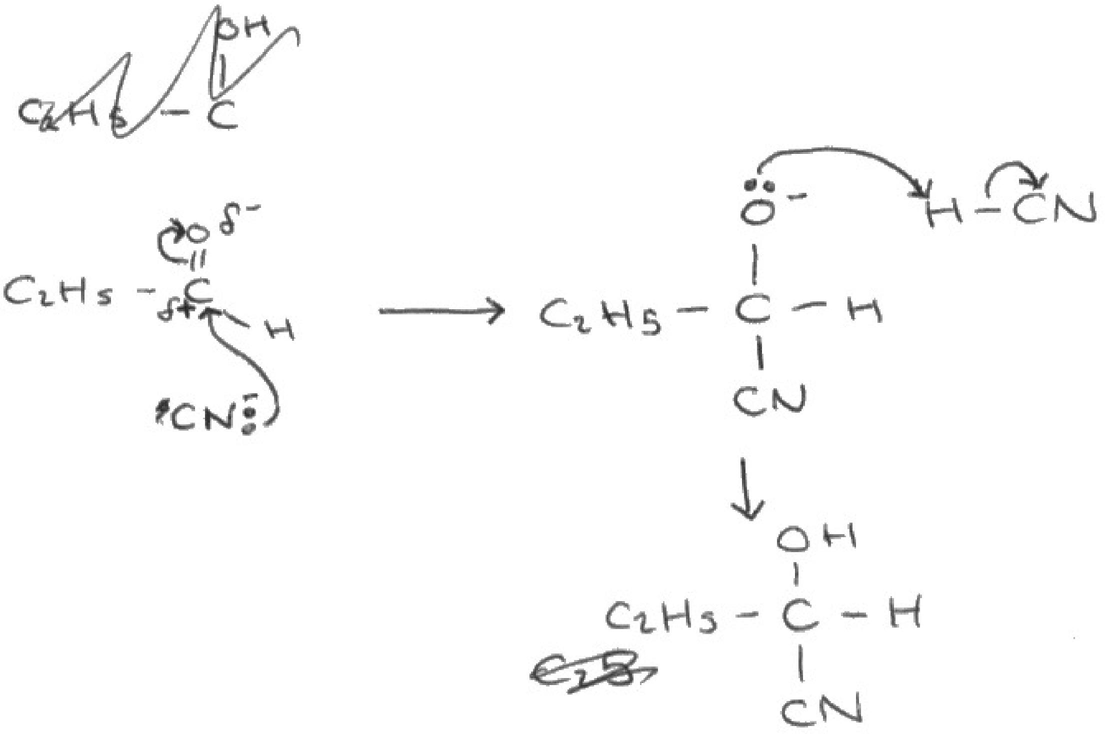
This scored the first 2 marks, but the candidate has confused the information about boiling points with the solubility and so was unable to access the final 2 marks.

ResultsPlus
Examiner Tip

Read carefully through your response to ensure that you have addressed the points in the question.

Question 7 (b)(i)

Those who could recall the mechanism for this reaction gave some excellent answers. The main errors seen were the long pair on the nitrogen instead of the carbon atom or omitting the charge on the cyanide ion. The intermediate was sometimes shown with a positive charge on the central carbon or on the nitrogen atom, or with a partial negative charge on the oxygen. Other marks were lost for poor placing of curly arrows or arrows drawn in the wrong direction.



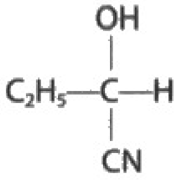
ResultsPlus
Examiner Comments

This mechanism is almost correct except that the candidate has shown the lone pair of the cyanide ion on the nitrogen atom instead of the carbon and so the first mark could not be awarded so the overall score was 3.

ResultsPlus
Examiner Tip

The lone pair on a cyanide ion is on the carbon atom.

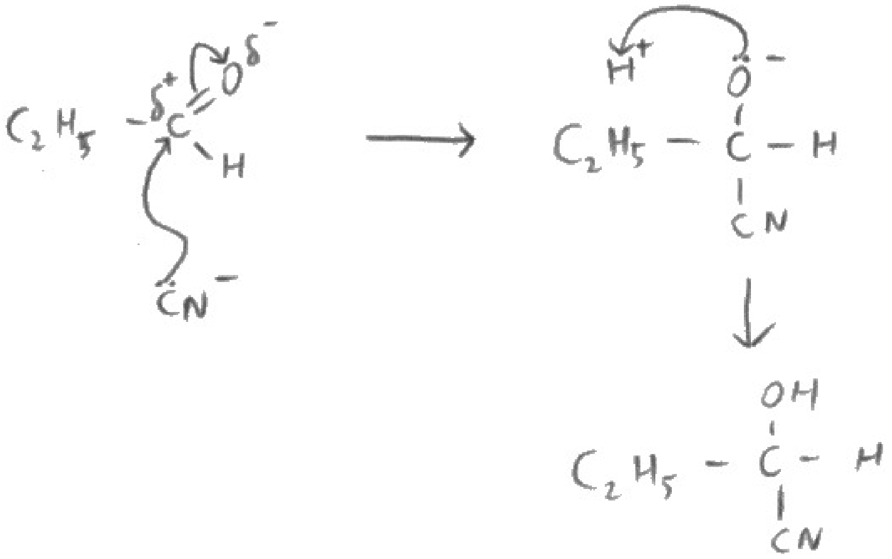
(b) Propanal reacts with hydrogen cyanide in the presence of potassium cyanide to form 2-hydroxybutanenitrile.



$$C_2H_5-\overset{\displaystyle OH}{\underset{\displaystyle CN}{C}}-H$$

(i) Draw the mechanism for this reaction.
Include curly arrows and any relevant lone pairs and dipoles.

(4)



ResultsPlus
Examiner Comments

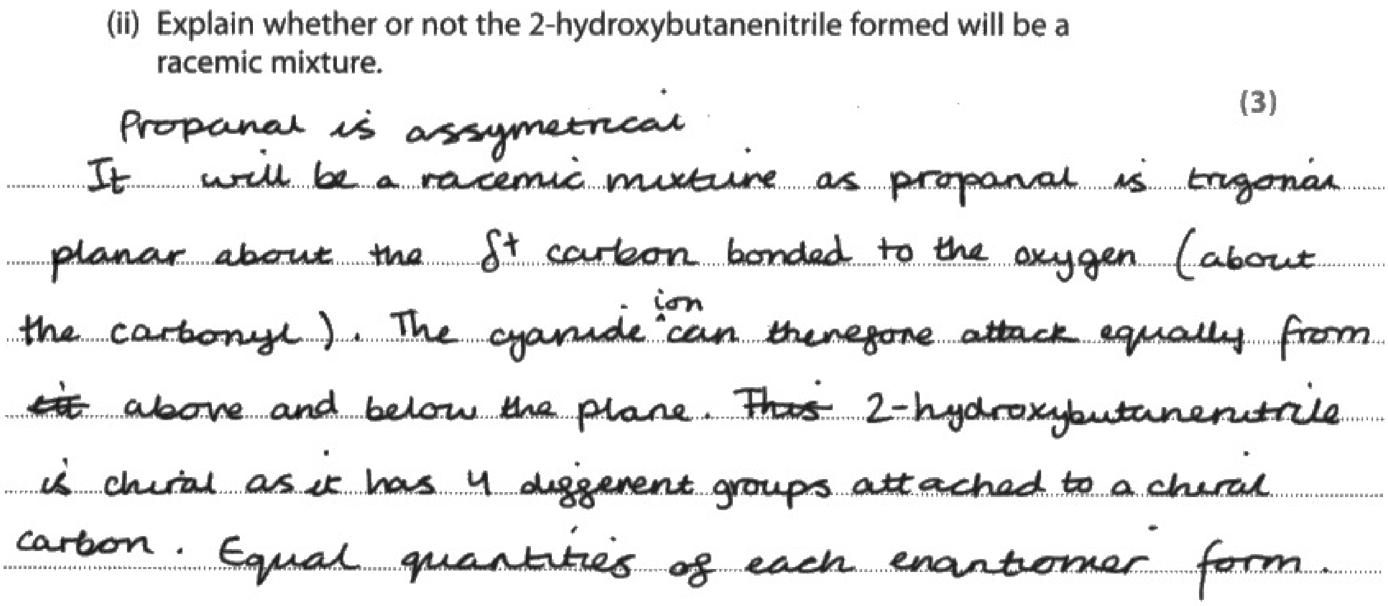
This is a clearly drawn correct mechanism scoring all of the marks.

ResultsPlus
Examiner Tip

When drawing a mechanisms ensure that all of the dipoles, charges and lone pairs are clearly drawn.

Question 7 (b)(ii)

Many candidates understood the principle behind this question and gained some credit. There was a general understanding that a racemic mixture would be formed as two enantiomers would be formed in equal amounts. Marks were lost for stating that the whole propanal molecule was planar instead of referencing the C=O as being planar.



(ii) Explain whether or not the 2-hydroxybutanenitrile formed will be a racemic mixture.

(3)

Propanal is assymetrical

It will be a racemic mixture as propanal is trigonal planar about the δ^+ carbon bonded to the oxygen (about the carbonyl). The cyanide$^-$ ion can therefore attack equally from ~~it~~ above and below the plane. ~~This~~ 2-hydroxybutanenitrile is chiral as it has 4 different groups attached to a chiral carbon. Equal quantities of each enantiomer form.

ResultsPlus
Examiner Comments

This is a good response scoring all 3 marks.

the 2 hydroxynitrile will be a racimic
as propanal is planar molocule and undergos
~~SN2~~ reaction ~~SN2~~ there ~~is~~ are 2 species in rate
determining step. The cianide ion (C≡N) can attack
from above or below ~~or~~ so 50% of each enantiomer
will be produced.
and the carbon is shiral as it has 4 different
functional Groups would be an optical isomer.

ResultsPlus
Examiner Comments

This response scored 2 of the 3 available marks.

The candidate has said that the whole propanal molecule would be planar rather than that it would be planar around the C=O. Although there is no charge on the cyanide ion formula, they have referred to it by name, and so this mark was awarded as was the final mark.

ResultsPlus
Examiner Tip

Take care when giving both a name and a formula that both are consistent as discrepancies are often penalised (although not in this case).

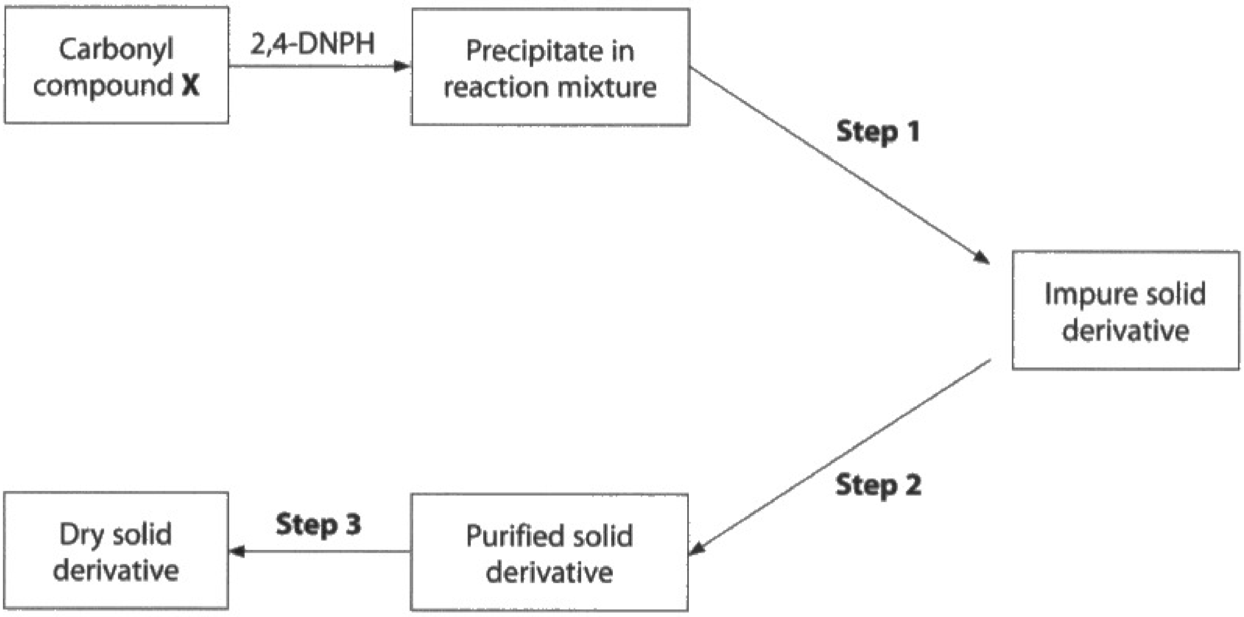
Question 7 (c)(i)

This question was not well-answered, especially with the amount of information given in the question. Many candidates did not make the link between the description of the method for making the derivative and the steps required for the answer. Some candidates just wrote 'filtration' in every box. Descriptions of the recrystallisation process were often incorrect. 'Drying', for the third step, was given in the question and should have prompted candidates to consider a more detailed answer. Some candidates mentioned adding a drying agent directly to the product instead of into a desiccator.

(c) Carbonyl compounds can be identified by reacting them with 2,4-dinitrophenylhydrazine (2,4-DNPH) to form a solid derivative. These derivatives have characteristic melting temperatures.

(i) Identify the steps required to prepare a sample of a pure, dry derivative of a carbonyl compound **X**.

(3)



Step 1

Filter and dry precipitate

Step 2

recrystallise impure solid derivative

Step 3

Dry using a desiccator or filter paper

ResultsPlus
Examiner Comments

This response was awarded all 3 marks. It is not necessary to dry the product after the filtration step, but this was ignored.

Step 3

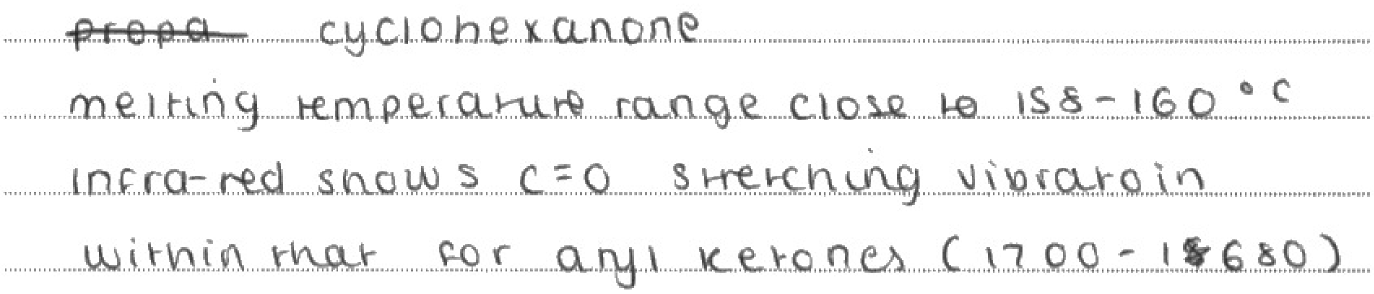
(filter then) dry with $MgSO_4$ or another anhydrous drying agent.

ResultsPlus
Examiner Comments

Here the candidate did not score the third mark as they have added the $MgSO_4$ to the product instead of placing the product in a desiccator and adding the drying agent underneath.

Question 7 (c)(ii)

This question was generally well-answered, although some candidates identified the wrong infrared absorption and some had not read the question correctly and identified substances that were not one of the options. A few thought that cyclohexanone would be aromatic and so quoted the wrong range for the infrared absorption.



~~propa~~ cyclohexanone
melting temperature range close to 158-160 °C
infra-red shows C=O stretching vibratoin
within that for aryl ketones (1700-1680)

ResultsPlus
Examiner Comments

This response scored 1 of the 2 marks available.

They correctly identified the substance as cyclohexanone, but gave the wrong range for the infrared absorption.

ResultsPlus
Examiner Tip

Remember that cyclic molecules can be aliphatic or aromatic depending on their structure.

(ii) The melting temperature ranges of the derivatives of some carbonyl compounds that could be **X** are shown in the table.

Carbonyl compound	Melting temperature range of derivative / °C
ethanal	165 – 168
propanal	154 – 156
propanone	127 – 129
cyclohexanone	158 – 160

The melting temperature of the derivative of carbonyl compound **X** is 156–158 °C and **X** has an absorption at 1717 cm^{-1} in its infrared spectrum.

Deduce the identity of **X**. Justify your answer. 1720-1700 = alkyl ketone

(2)

Cyclo hexanone because peak at ~~[illegible]~~ 1717 is due to C=O group in alkyl ketones. Melting temperature is 156-158 so could be propanal or cyclo hexanone however propanal would not have a peak at 1717.

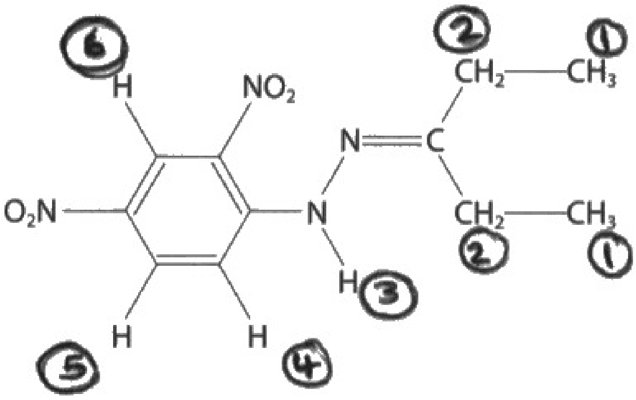
ResultsPlus
Examiner Comments

This is a good response scoring both marks.

Question 7 (c)(iii)

Many candidates were able to label the hydrogen environments on the benzene ring and on the nitrogen correctly, but failed to realise that the two CH_2 groups would form one environment and that the two CH_3 groups would form another. A few candidates labelled carbon environments instead.

(iii) These carbonyl compounds may also be identified using modern methods such as proton NMR spectroscopy.
The structure of the pentan-3-one derivative formed with 2,4-DNPH is shown.



Label the different proton environments that would give rise to the peaks in the low resolution proton NMR spectrum.

ResultsPlus
Examiner Comments

This is an excellent answer scoring both marks with the hydrogen environments clearly labelled.

Question 8 (b-cii)

Most candidates found the first part of this question (8b) straightforward and drew a correct mechanism for electrophilic addition.

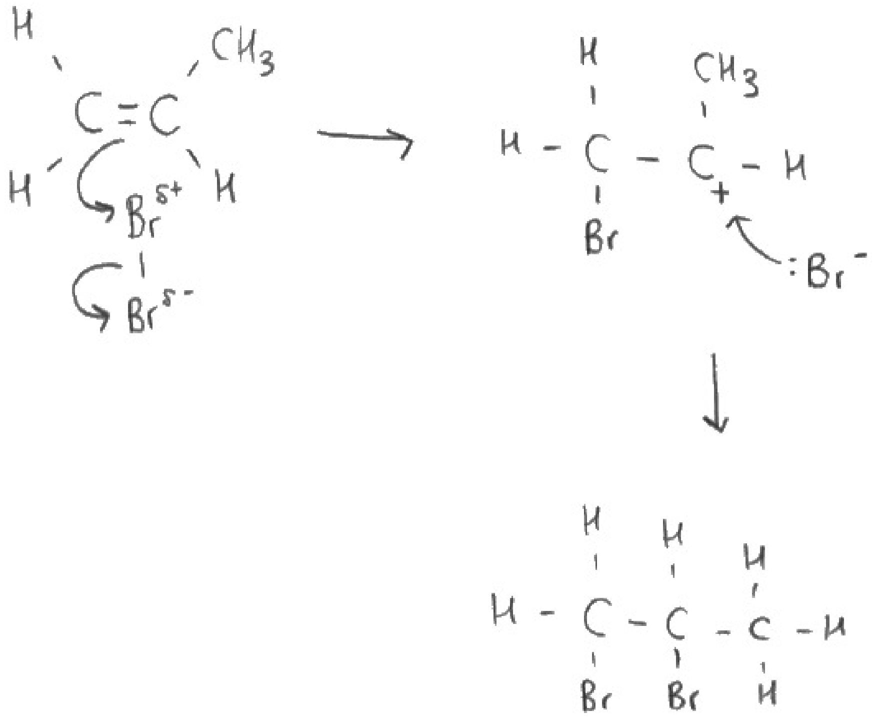
The second part (8ci-ii) was more complex and candidates found these questions more challenging. For 8(c)(i), they needed to consider the mechanism that they had drawn in 8(b) in the light of the new information given and made the connection that Cl^- ions would not be able to attack first as they would not act as an electrophile. Very few candidates did this, with lots of answers comparing the covalent bond strength in bromine with that of chlorine, or making comments about the relative electronegativities of the elements.

Part (c)(ii) was more accessible and required recognition that the preferential formation of 1-bromo-2 chloropropane would be due to relative stability of a secondary carbocation compared to a primary carbocation during the reaction.

(b) Propene reacts with bromine to form 1,2-dibromopropane as the only product.

Draw the mechanism for the reaction between propene and bromine.
Include curly arrows and any relevant lone pairs and dipoles.

(3)



(c) When propene reacts with a mixture of bromine and sodium chloride, it forms 1,2-dibromopropane, 1-bromo-2-chloropropane and 2-bromo-1-chloropropane but no 1,2-dichloropropane.

(i) Explain, by reference to your mechanism in (b), why no 1,2-dichloropropane forms.

(2)

NaCl contains ~~Strong~~ ionic bonding, with a lattice of opposilely charged ions. Therefore, it cannot be polarised by the carbon to carbon double bond. ~~Equal to the strong~~. It only react when the carbocation is formed, as it Cl^- will be strongly attracted to it.

(ii) Explain why far more 1-bromo-2-chloropropane forms than 2-bromo-1-chloropropane.

(2)

1-bromo-2-chloropropane is the major product (more formed) whereas 2-bromo-1-chloropropane is the minor product (less formed). This is because when a double bond is broken in an asymetrical alkene, the carbocation formed is more likely to be the one with the most alkyl groups attached as they are electron pushing, in this case the second carbon on the carbon chain. ~~Therefore, bromine is more~~ This is because this carbocation is more stable than the primary (in secondary). Therefore, the bromine is most likely to bond with the first carbon in the carbon chain.

ResultsPlus
Examiner Comments

This response has a fully correct mechanism and so scores the three marks in 8(b).

In part 8(c)(i), the candidate has explained that there are Cl^- ions in sodium chloride which would only be able to react once the carbocation had formed so scores the second marking point.

They have omitted to mention that initial attack needs to be by an electrophile and so have not scored the first marking point.

For the final part 8(c)(ii), they have explained the effect of the stability of the primary and secondary carbocations and linked this to the formation of 1-bromo-2-chloropropane and so have scored both marks.

ResultsPlus
Examiner Tip

Remember that negative charges will repel and so a Cl^- ion would be repelled by a region of high electron density such as in a double bond and so will not act as an electrophile.

(ii) Explain why far more 1-bromo-2-chloropropane forms than 2-bromo-1-chloropropane. **(2)**

region of negative charge on the C=C bond

→ The secondary carbocation formed in the intermediate step of the reaction forming 1-bromo-2-chloropropane is more stable than the 1° carbocation formed in the intermediate step in the reaction forming 2-bromo-1-chloropropane, due to the positive inductive effect of the additional $-CH_3$ group.

→ Hence this more stable carbocation is more likely to exist long enough for the Cl^- ion to attack.

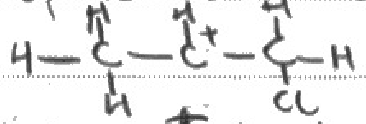
ResultsPlus
Examiner Comments

This response scored both marks for the comparison of the stability of the primary and secondary carbocations. The explanation is clear and even includes reference to why the secondary carbocation is more stable.

(c) When propene reacts with a mixture of bromine and sodium chloride, it forms 1,2-dibromopropane, 1-bromo-2-chloropropane and 2-bromo-1-chloropropane but no 1,2-dichloropropane.

(i) Explain, by reference to your mechanism in (b), why no 1,2-dichloropropane forms.

(2)

- The first attack is electrophilic by $Br^{\delta+}$ but $:Cl^-$ cannot act as an electrophile as it cannot accept a pair of electrons
- Therefore no  $H-\underset{H}{\overset{H}{C}}-\overset{H}{C^{+}}-\underset{Cl}{\overset{H}{C}}-H$ is made thus a $:Cl^-$ ion cannot attack the C^+ to form 1,2-dichloropropane
- As NaCl is a salt it only exists as Na^+ and Cl^- in solution

ResultsPlus
Examiner Comments

This response scored both marks.

They have explained clearly that Cl^- ions cannot act as electrophiles, and also that once the carbocation is formed then Cl^- will be able to bond to it. Additionally, they have commented on that Br delta$^+$ would be the electrophile that would attack first.

Question 8 (d)

This extended writing question required candidates to discuss different types of stereoisomerism.

Most candidates were able to demonstrate their understanding of the topic, with some excellent explanations and diagrams seen. The best answers contained detailed explanations of each of the points in the question. For the E-Z isomers, many good diagrams of the alkenes were seen, and candidates also stated that these isomers arose due to restricted rotation around the C=C. However, fewer gave a good explanation of how the priorities were assigned to groups. We did allow reference mass rather than atomic number this time, but candidates should note that the E/Z nomenclature is based on the atomic number of the attached atoms. For the optical isomers, many good diagrams were seen, although some candidates did not show the full 3D structure with appropriate wedges. Many candidates appreciated that the optical isomerism arose because of chiral carbon and went on to describe the ability of the enantiomers to rotate plane polarised light but did not mention that this would be in opposite directions and so were not awarded the final mark.

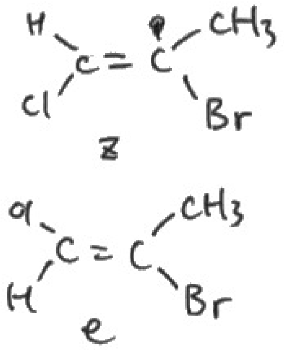
*(d) Discuss the different types of stereoisomerism that occur in organic compounds. Use only molecules **A** and **B** as examples.

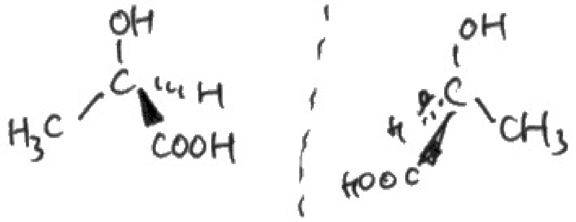
$CHCl{=}C(CH_3)Br$ **A** $CH_3CH(OH)COOH$ **B**

Include in your answer:

- how the different types of isomerism arise
- the naming of alkenes with the formula **A**
- the properties of isomers with the formula **B**
- diagrams of the different isomers.

(6)





(cis-trans)

Geometric isomers arise both ~~due~~ because ~~&~~ double bonds and rings cannot rotate. When ~~the~~ doubly ~~dou~~ bonded carbon is attached to 2 other different groups, geometric isomers arise such as A. When the groups with the highest mass are on the same side, it is z; when they are on opposite sides, it is e.

Optical isomers arise when a central carbon is attached to 4 different groups, such as B. The central carbon is chiral. The mirror images of B are non-superimposible, and the endutiomers rotate plane-polarised light in opposite directions.

ResultsPlus
Examiner Comments

This response was awarded 6 marks.

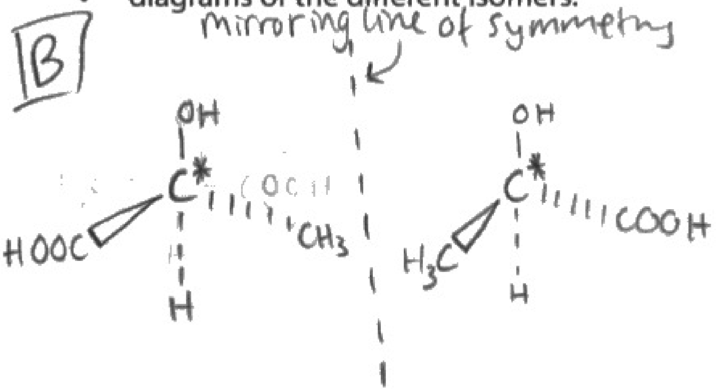
The candidate produced clear, labelled diagrams and their explanations of the characteristics of each isomer was clearly explained. This is an example where the use of atomic mass instead of atomic number for assigning the priority groups was awarded the mark. This may not be the case in future exam series.

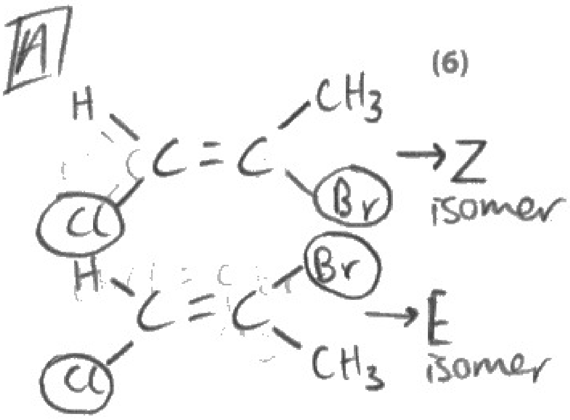
ResultsPlus
Examiner Tip

If you set out your explanations clearly, then it is easier for the examiner to see where to award the marks and easier for you to write logically.

- diagrams of the different isomers.

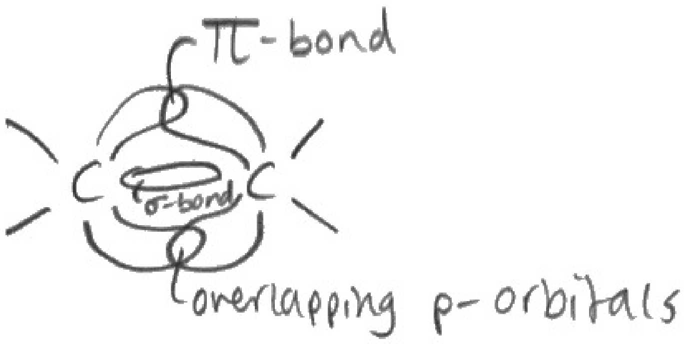
(6)





Isomers with formula B ~~can~~ are chiral* compounds, because the central carbon* is bonded to 4 different groups. These isomers are non-superimposable, and are mirror reflections of each other, and can rotate ~~pla~~ the plane of polarised light. Isomers with formula A have E-Z isomerism, where the Z-isomer has the atoms with the priority groups on the same side of the C=C, and E-isomers have the priority groups on opposite sides of the C=C. This happens because the double bond of C=C is formed by ~~op~~ overlapping p orbitals forming a π bond, - the p orbitals overlap above and below the σ bond, meaning the π bond cannot rotate, therefore isomers are produced.

A



ResultsPlus
Examiner Comments

There were 2 marks awarded for correct diagrams in this question (IP3 and IP5) and this candidate scored 1 of the 2 available.

The diagrams of the E/Z isomers are clear and correct and so IP3 was awarded.

However, the wedges on the 3D diagram of the optical isomers are not exact mirror images and so IP5 was not scored.

ResultsPlus
Examiner Tip

Check diagrams carefully when you draw them, particularly the 3D representations.

Question 9 (a)

The question required candidates to follow through a sequence of organic reactions and to identify the correct structures at each stage. This question proved accessible with many candidates giving good answers. Common errors were to start with 1-chloropropane instead of 2-chloropropane, to draw structures with missing hydrogen atoms, and to give the wrong product which would be derived from the Grignard structure.

9 This question is about the analysis of some organic compounds.

(a) A compound **A** (C_3H_7Cl) reacts with dilute aqueous sodium hydroxide to produce **B** (C_3H_8O). **B** can be oxidised to **C** (C_3H_6O), which cannot be oxidised any further.

alcohol ketone.

haloalkane. grignard reagent.

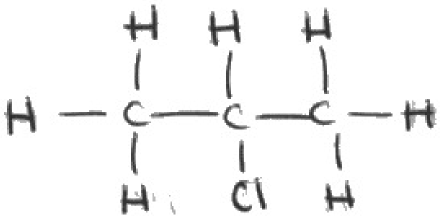
A reacts with magnesium in dry ether to give **D** (C_3H_7MgCl). When carbon dioxide is passed through the solution of **D**, followed by acidification, **E** ($C_4H_8O_2$) is formed.

carboxylic acid.

Identify the structures of **A** to **E**.

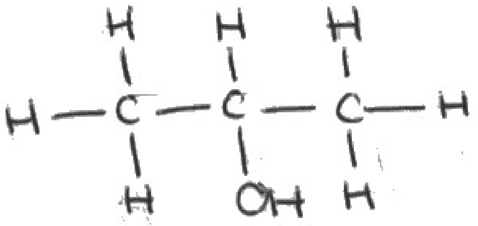
(5)

A



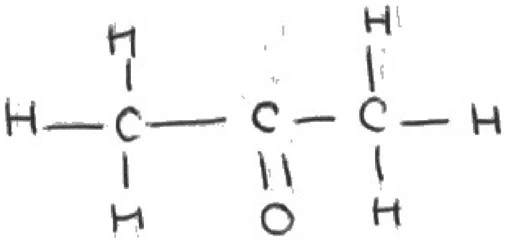
2-chloropropane

B



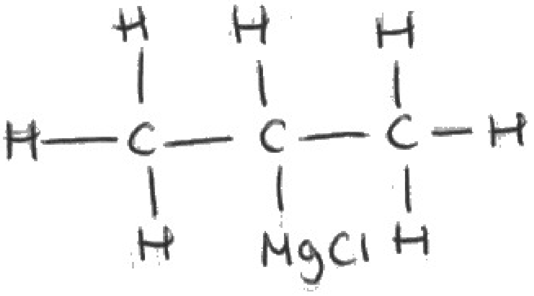
propan-2-ol

C



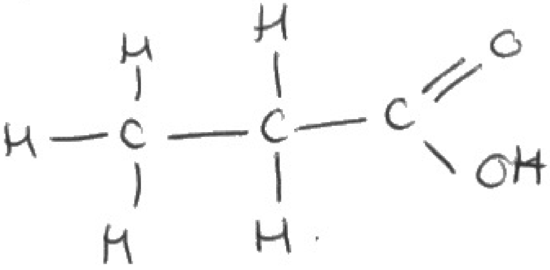
propanone.

D



grignard reagent.

E



propanoic acid.

ResultsPlus
Examiner Comments

This is an example of a response that scored 4 marks.

Every structure was correct apart from the final one which should have been 2-methylpropanic acid and not butanoic acid.

ResultsPlus
Examiner Tip

Remember that a Grignard reagent is designed to add carbon atoms on to the carbon to which it is attached.

Question 9 (b)

This question assessed the candidate's ability to deduce the steps required for a multi-step calculation and carry them out in a logical sequence. This proved to be a challenge for many candidates as expected for the last question on the paper. Many gained the mark for calculating the amount of NaoH in the mean titre (M1) and also the amount of HCl at the start (M3). However, a number of candidates failed to carry out the multiplication by 4 to obtain the amount of unreacted HCl in the reaction. The subtraction step was often omitted and from then on only the more proficient candidates were able to work out what to do to obtain the correct answer.

(b) An organic compound, **Q**, contains carbon, hydrogen and nitrogen only.

When a 1.19 g sample of the compound was heated with sodium hydroxide solution, all of the nitrogen was converted into ammonia. The ammonia was passed into 100.0 cm^3 of 0.225 mol dm^{-3} hydrochloric acid.

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

25.0 cm^3 portions of the resulting solution containing unreacted hydrochloric acid required a mean titre of 15.5 cm^3 of 0.100 mol dm^{-3} sodium hydroxide for neutralisation.

Calculate the percentage of nitrogen in **Q**.

(5)

$HCl + NaOH \rightarrow NACl + H_2O$

	HCl	NaOH
c		0.1 mol dm^{-3}
V	25 cm^3	15.5×10^{-3}
M	1.55×10^{-3}	1.55×10^{-3}
r	1	: 1

$\frac{100}{25} = 4$

$4 \times 1.55 \times 10^{-3} = 6.2 \times 10^{-3}$

6.2×10^{-3} moles left over in 100 cm^3

$100 \times 10^{-3} \times 0.225 = 0.0225$

$0.0225 - 6.2 \times 10^{-3}$

0.0163

$NH_3 + HCl \rightarrow NH_4Cl(aq)$

0.0163 0.0163

0.0163 moles of Nitrogen

mass = moles x mr

$0.0163 \times 14 = 0.2282$ g

$\frac{0.2282}{1.19} \times 100 = 19.18\%$

ResultsPlus

Examiner Comments

This is an example of a fully correct response which scored all of the marks.

Paper Summary

Based on their performance on this paper, candidates should:

- Check calculations carefully and give answers to the appropriate number of significant figures.
- Take care with the origin of curly arrows which should start at a lone pair or a bond.
- Pay attention to understanding practical techniques, particularly of recrystallisation.
- Be clear of the definitions of nucleophile and electrophile.
- Practise drawing reaction profiles of reactions involving a catalyst.
- Understand the relationship between a rate equation and the rate determining step.
- Take care when transcribing information from the data book.

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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