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Examiners' Report
June 2025

GCE Chemistry 9CH0 02

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Introduction

Paper 2 in the Pearson Edexcel Level 3 Advanced GCE in Chemistry (9CH0) qualification seemed accessible to many 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.

There were many opportunities for candidates to highlight their knowledge in familiar contexts, such as organic mechanisms, use of the ideal gas equation, testing for organic functional groups and organic preparations, and these were a strength for this cohort.

The multiple-choice questions proved relatively straightforward in most cases with the exception of Q04(c) where only 16% of candidates were able to identify which process does not involve heterolytic fission.

There was no evidence from marked work that candidates ran out of time with all questions being attempted and significant blank spaces seen only in a few cases.

It was pleasing to see that some candidates were extremely well-prepared for the rigor and demands of this paper; the quality of some of the answers or justification provided was very encouraging.

A number of the structured questions were found to be demanding, such as questions 7(b)(ii), 8(e)(i), 8(e)(ii) and 8(f), which provided a significant degree of discrimination. Nonetheless, there are some key lessons for centres and candidates to learn from the feedback illustrated in the detailed examples in this report.

Question 2(b)

Many candidates correctly identified the strongest intermolecular forces between propan-1-ol as being hydrogen bonds and so scored M1. Some candidates either did not make it clear that hydrogen bonding was stronger **and** so requires more **energy** to break and so did not score the second marking point. Probably the most frequent error was either neglecting to mention that the hydrogen bonding required most energy to overcome, or not mentioning that the hydrogen bonding is the strongest intermolecular force of attraction. Both statements were required for M2.

(b) Pentan-1-ol and hexane have the same number of electrons but pentan-1-ol is much less volatile than hexane.

Explain this difference in volatility.

(2)

Pentan-1-ol can form hydrogen bonds between each other, whereas hexane can only form london forces and not hydrogen bonds. Hydrogen bonds are very strong and therefore require lots of energy to break so pentan-1-ol is less likely to evaporate therefore less volatile.

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Examiner Comments

This example identifies hydrogen bonding between molecules of propan-1-ol and links the lower volatility with the strength of hydrogen bonds and that they require more energy to overcome, so scores both marks.

(b) Pentan-1-ol and hexane have the same number of electrons but pentan-1-ol is much less volatile than hexane.

Explain this difference in volatility.

(2)

Pentan-1-ol has an O-H bond. Hydrogen bonding is the strongest type of intermolecular force so this gives pentan-1-ol greater stability than Hexane when forces try to be overcome. Pentan-1-ol also therefore has a dipole whereas Hexane is symmetrical.

ResultsPlus
Examiner Comments

This response identifies the hydrogen bonding between molecules of propan-1-ol together with the strength of the intermolecular forces but does not link this to the energy required to overcome the hydrogen bonding being greater. This scores M1 only.

(b) Pentan-1-ol and hexane have the same number of electrons but pentan-1-ol is much less volatile than hexane.

Explain this difference in volatility.

(2)

Pentan-1-ol is an alcohol and can form hydrogen bonds with other pentan-1-ol molecules whereas hexane cannot - More energy is required to break these hydrogen bonds, hence pentan-1-ol is less volatile than hexane.

ResultsPlus
Examiner Comments

This candidate has identified hydrogen bonding between propan-1-ol molecules and links this to the energy required to overcome, but fails to identify hydrogen bonding as being stronger, so scored one mark.

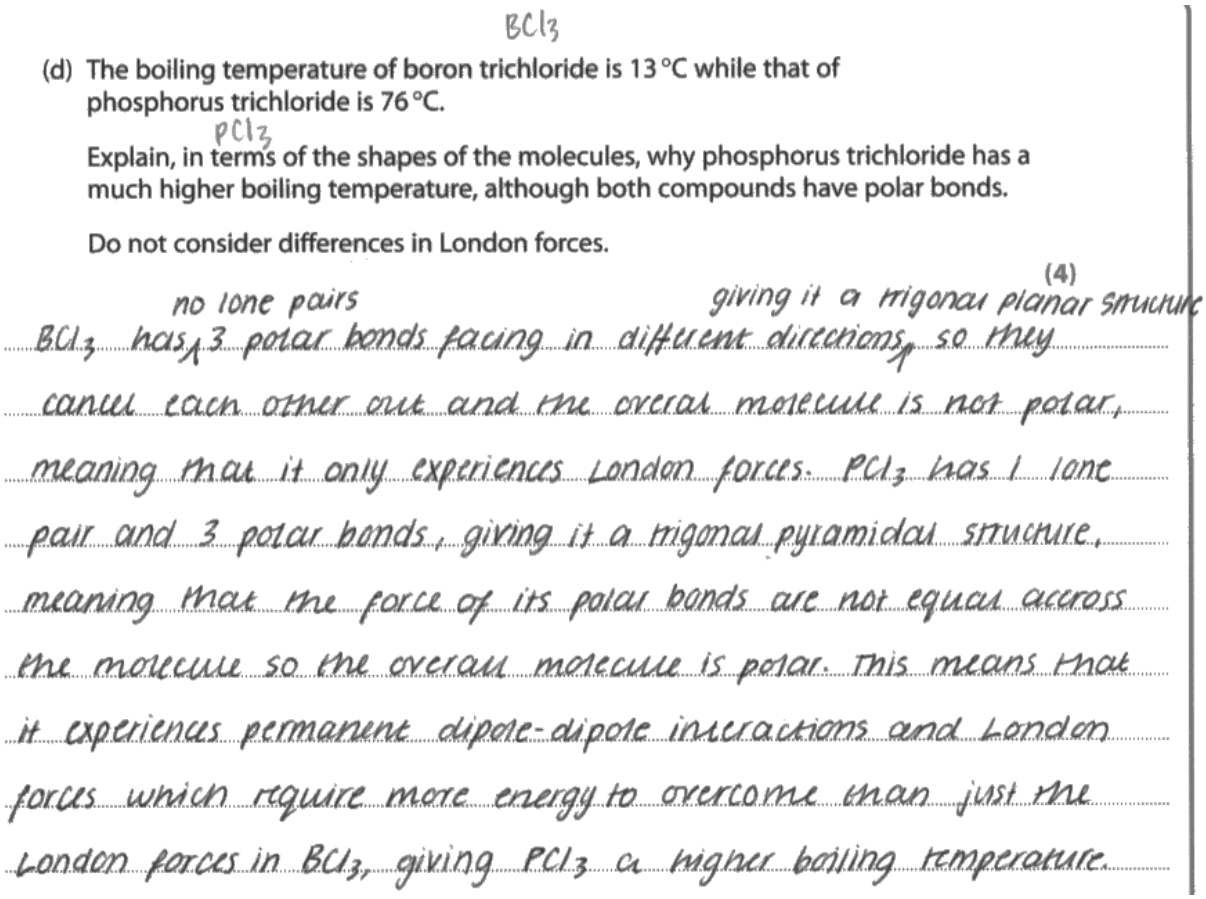
ResultsPlus
Examiner Tip

The question asks the candidate to explain the difference in volatility, so examiners expect candidates to identify the strength of the intermolecular forces of attraction and link this to the energy required to overcome.

Question 2(d)

Most candidates were able to successfully identify the shape of the two molecules and so scored two marks which was also the mode and mean of this question. Many gave detailed explanations of the VSEPR theory to justify the shape and this was not required to explain the difference in boiling temperature.

Candidates found it more challenging to explain how the shape influenced the type of intermolecular forces and gave rise to permanent dipole-dipole interactions.



BCl_3

(d) The boiling temperature of boron trichloride is 13 °C while that of phosphorus trichloride is 76 °C.

PCl_3

Explain, in terms of the shapes of the molecules, why phosphorus trichloride has a much higher boiling temperature, although both compounds have polar bonds.

Do not consider differences in London forces.

(4)

no lone pairs — giving it a trigonal planar structure

BCl_3 has 3 polar bonds facing in different directions, so they cancel each other out and the overall molecule is not polar, meaning that it only experiences London forces. PCl_3 has 1 lone pair and 3 polar bonds, giving it a trigonal pyramidal structure, meaning that the force of its polar bonds are not equal accross the molecule so the overall molecule is polar. This means that it experiences permanent dipole-dipole interactions and London forces which require more energy to overcome than just the London forces in BCl_3, giving PCl_3 a higher boiling temperature.

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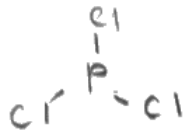
Examiner Comments

This candidate provides a model answer which is well laid out and shows the development of a clear line of logical thinking. This answer scored four marks.

(d) The boiling temperature of boron trichloride is 13 °C while that of phosphorus trichloride is 76 °C.



Explain, in terms of the shapes of the molecules, why phosphorus trichloride has a much higher boiling temperature, although both compounds have polar bonds.

Do not consider differences in London forces.

(4)

Phosphorus trichloride has a lone pair of electrons on the phosphorus this means that the lone pairs will repel more than the bond pairs (3 bonding pairs, 1 lone pair), to minimise repulsion and has a trigonal pyramidal shape. These ~~a st~~ stronger bonding/forces of attraction require more energy to overcome than in boron trichloride which doesn't have any lone pairs., thus higher bp of phosphorus trichloride. whereas boron trichloride is only a trigonal planar (3 bp, 0 lone pairs), less repulsion.

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Examiner Comments

This is an example of a response which has a full explanation of why the molecules have their shapes, but does not explain how this affects the boiling point and so scores two marks.

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Examiner Tip

Remember that questions using the command word 'explain' require a justification/ exemplification of the points in order to score full marks.

Question 4(a)(i)

Although the question was unfamiliar and unusual, many candidates were able to score well on this question and the examining team were impressed by the quality of candidate responses to this question. Even those candidates who were unable to convert nm to m for the wavelength were still able to gain some credit for transposing their values into the equation and evaluating their answer correctly.

4 Covalent bonds can break by either heterolytic fission or homolytic fission.

(a) The reaction of butane and chlorine involves homolytic bond fission of the chlorine molecule, using ultraviolet radiation.

(i) The energy of ultraviolet radiation can be calculated using the formula shown.

$$\text{Energy of one photon} = \frac{h \times c}{\lambda}$$

Planck constant, $h = 6.626 \times 10^{-34}$ J s
Speed of light, $c = 3.00 \times 10^{8}$ m s^{-1}
Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}
Wavelength, λ in metres

The mean C—H bond energy is 413 kJ mol^{-1} compared to 243 kJ mol^{-1} for the Cl—Cl bond.

Show, by calculation, that ultraviolet radiation, with the wavelength 315 nm, can break the Cl—Cl bond but not the C—H bond.

(4)

Energy $= \frac{hc}{\lambda}$

$= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{315 \times 10^{-9}}$

$= 6.31 \times 10^{-19}$

$6.31 \times 10^{-19} \times 6.02 \times 10^{23}$

$= 3.80 \times 10^{5}$ J

$3.80 \times 10^{5} \div 1000$

$= 380$ kJ mol^{-1}.

380 kJ mol^{-1} is larger than 243 kJ mol^{-1} so enough energy to break Cl-Cl bond, but 380 kJ mol^{-1} is less than 413 kJ mol^{-1} so can't break C-H bond.

Although the equation is unfamiliar this candidate follows a logical approach by initially transposing all the data from the question into the equation, including conversion of nanometre to metres. Their method is clear and they have evaluated their answers to explain why the Cl-Cl bond can be broken and the C-H bond cannot. This response scored four marks.

When using an unfamiliar equation, always start by transposing all the data for the question into the equation.

4 Covalent bonds can break by either heterolytic fission or homolytic fission.

(a) The reaction of butane and chlorine involves homolytic bond fission of the chlorine molecule, using ultraviolet radiation.

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Show, by calculation, that ultraviolet radiation, with the wavelength 315 nm, can break the Cl—Cl bond but not the C—H bond.

(4)

$E_{photon} = \frac{h \times c}{\lambda} = \frac{6.626 \times 10^{-34} \times 3.00 \times 10^{8}}{315 \times 10^{-9}} = 6.31 \times 10^{-19}$ J

E (1 ~~C—C~~ Cl—Cl bond) $= \frac{243 \times 10^{3}}{6.02 \times 10^{23}} = 4.04 \times 10^{-19}$ J

$4.04 \times 10^{-19} < 6.31 \times 10^{-19}$ so UV radiation can break the Cl—Cl bond

E (1 C—H bond) $= \frac{413 \times 10^{3}}{6.02 \times 10^{23}} = 6.86 \times 10^{-19}$ J

$6.86 \times 10^{-19} > 6.31 \times 10^{-19}$ so UV radiation cannot break the C—H bond

ResultsPlus
Examiner Comments

This was a really interesting and fully correct alternative approach which was accepted for full marks. The candidate has correctly worked out the energy required to break one Cl-Cl bond and one C-H bond and compared these values to the energy in one photon.

Question 4(a)(ii)

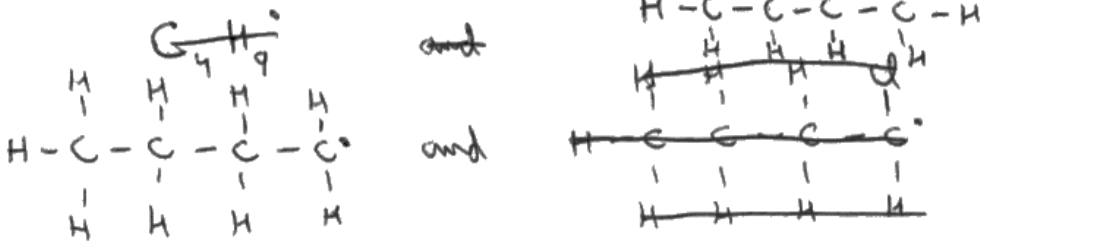
Most candidates knew the structure of the primary butyl radical but the second answer given was more challenging.

Common errors include giving a chlorinated species and commonly $CH_3CH_2^{\bullet}CH_2CH_3$. Some candidates gave a response involving equations rather than the structures that the question asked for.

(ii) In the reaction of chlorine with butane, the propagation stage produces two different butyl radicals.

Write the structural formulae of these two radicals.

(2)



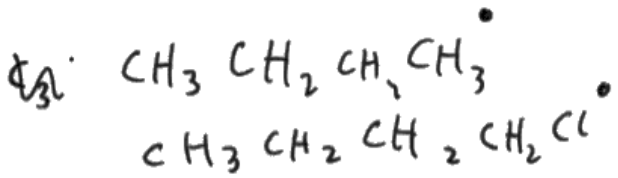
ResultsPlus
Examiner Comments

This candidate has given fully displayed and fully correct primary and secondary radicals and scores two marks.

(ii) In the reaction of chlorine with butane, the propagation stage produces two different butyl radicals.

Write the structural formulae of these two radicals.

(2)



ResultsPlus
Examiner Comments

This candidate has unfortunately made two errors and so scores no marks. The first radical given has too many hydrogen atoms on the terminal carbon atom and the second radical is chlorinated which was not allowed as an acceptable answer.

(ii) In the reaction of chlorine with butane, the propagation stage produces two different butyl radicals.

Write the structural formulae of these two radicals.

(2)

$Cl_2 \rightarrow Cl\cdot + Cl\cdot$

$Cl_2 \rightarrow 2Cl\cdot$

~~$C_4H_{10} + Cl\cdot \rightarrow$~~

$C_4H_{10} + Cl\cdot \rightarrow C_4H_9Cl\cdot + HCl$

$C_4H_9Cl\cdot + Cl\cdot \rightarrow$ ~~incorrect~~ $C_4H_9Cl + HCl\cdot$

ResultsPlus
Examiner Comments

Although the candidate has written the initiation step and the two propagation steps, the questions asks candidates to write the structural formula of the two butyl radicals so unfortunately does not score.

ResultsPlus
Examiner Tip

Always check what the question is asking you to do before you give your answer.

Question 4(a)(iii)

This proved to be a challenging question and most candidates frequently lost the first mark by stating that the 1-chlorobutane is formed from a primary **carbocation,** and the 2-chlorobutane forms from a secondary **carbocation**, rather than from the respective **radical**.

Most candidates were able to score the second mark for stating the relative stability of the intermediates with 1 being the mode for this question.

(iii) The reaction of chlorine with butane produces 2-chlorobutane (72 %) and 1-chlorobutane (28 %).

Explain, by application of your knowledge of the stability of carbocations, why there is a higher yield of 2-chlorobutane.

(2)

The secondary radical ($CH_3C{\cdot}HCH_2CH_3$) is more stable than the primary radical ($\cdot CH_2CH_2CH_2CH_3$) as there are more electron ~~donat~~ donating alkyl groups around the carbon with the unpaired electron in the secondary radical, hence more of the secondary radical is formed so there is a higher yield of 2-chlorobutane than 1-chlorobutane as this reaction:

$$CH_3C{\cdot}HCH_2CH_3 + Cl_2 \longrightarrow CH_3C(Cl)HCH_2CH_3 + Cl{\cdot}$$

happens more frequently than this reaction:

$$\cdot CH_2CH_2CH_2CH_3 + Cl_2 \longrightarrow ClCH_2CH_2CH_2CH_3 + Cl{\cdot}$$

ResultsPlus
Examiner Comments

In this response the candidate logically presents the fully correct explanation and so scores two marks.

(iii) The reaction of chlorine with butane produces 2-chlorobutane (72%) and 1-chlorobutane (28%).

Explain, by application of your knowledge of the stability of carbocations, why there is a higher yield of 2-chlorobutane.

(2)

Secondary carbocation is more stable as alkyl groups donate electron density, so secondary carbocation more likely to add with Cl

ResultsPlus
Examiner Comments

The examining team marked a large number of responses similar to this example with the candidate only stating that the secondary carbocation is more stable than a primary carbocation, so scoring one mark.

ResultsPlus
Examiner Tip

Always read the question twice to ensure that you understand what the question is asking.

Question 4(b)

This was generally very well answered by candidates with the structure of the hydroxide ion almost always being correct.

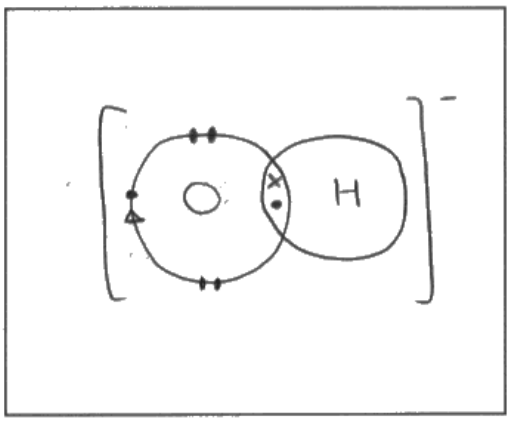
The structure of the radical proved to be more challenging for some with candidates commonly adding too many electrons, an extra 'dot', or a charge, and so not scoring the mark.

(b) Water molecules can undergo either heterolytic fission to form a hydroxide ion or homolytic fission to form a hydroxyl radical.

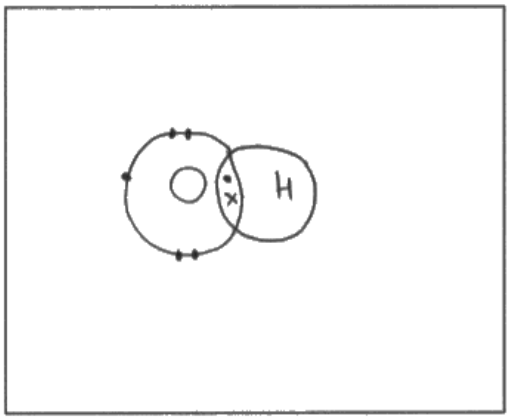
Draw dot-and-cross diagrams of these two species.

Use crosses (x) for oxygen electrons and dots (•) for hydrogen electrons.

(2)



hydroxide ion



hydroxyl radical

ResultsPlus
Examiner Comments

This is a fully correct answer and is laid out clearly.

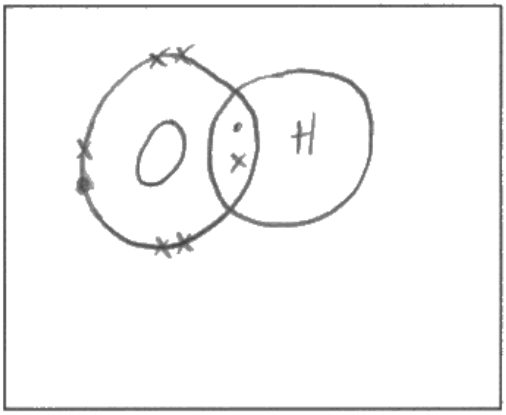
(b) Water molecules can undergo either heterolytic fission to form a hydroxide ion or homolytic fission to form a hydroxyl radical.

OH·

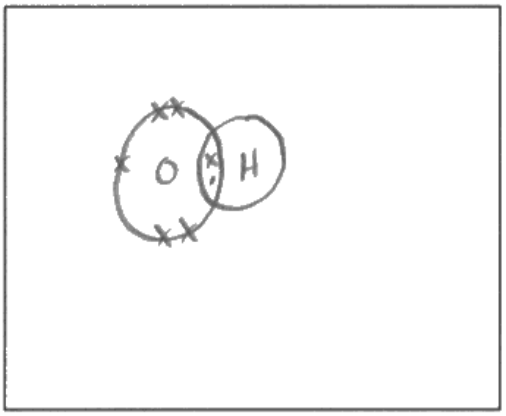
Draw dot-and-cross diagrams of these two species.

Use crosses (×) for oxygen electrons and dots (•) for hydrogen electrons.

(2)



hydroxide ion



hydroxyl radical

This response scores the mark for the correct radical. Although the electrons for the hydroxide ion are all correct, the negative charge is missing and so this does not score M1.

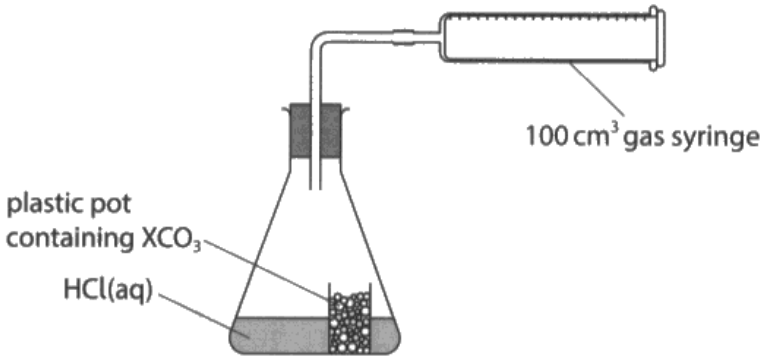
Check all answers carefully as it is easy for errors to creep in and cost valuable marks.

Question 5(a)

This question proved to be straightforward, with most candidates securing full marks clearly showing a good understanding of the calculation.

Most were also able to give their answer to the appropriate number of significant figures, although this was most frequently the mark lost by a few candidates.

5 The kinetics of the reactions of hydrochloric acid with metal carbonates were investigated using the apparatus shown.



The equation for the reaction is shown.

$$XCO_3(s) + 2HCl(aq) \rightarrow XCl_2(aq) + CO_2(g) + H_2O(l)$$

(a) One student used 0.355 g of calcium carbonate.

Calculate the minimum volume, in **cm³**, of 0.100 mol dm^{-3} hydrochloric acid that would completely react with this mass of calcium carbonate.
Give your answer to an appropriate number of significant figures.

[Calcium carbonate molar mass = 100.1 g mol^{-1})

(4)

$CaCO_3$ mr: 40.1 + 12 + 48 = 100.1

$$\text{mol} = \frac{0.355}{100.1} = 3.546 \times 10^{-3} \text{ mol}$$

$\downarrow \times 2$

7.09×10^{-3} mol of HCl

$$\text{Conc} = \frac{\text{mol}}{\text{vol}} \rightarrow \frac{\text{mol}}{\text{conc}} = \text{vol} \rightarrow \frac{7.09 \times 10^{-3}}{0.1}$$

$= 7.09 \times 10^{-2}$ dm^3

$\downarrow \times 1000$

70.929... cm^3

= 70.9 cm^3 (3sf)

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 the units were not required, the units in the answer are correct.

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

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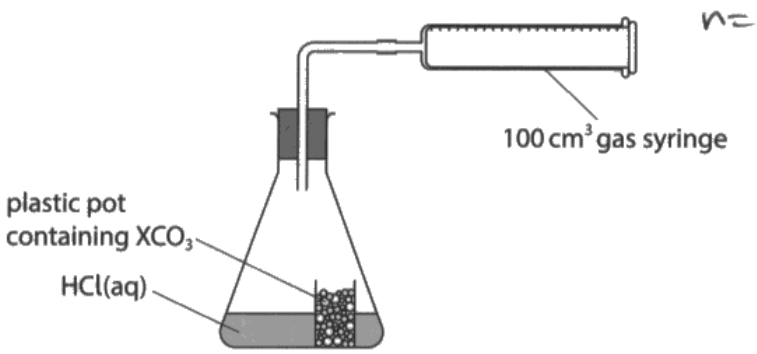

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Give your answer to an appropriate number of significant figures.

[Calcium carbonate molar mass = 100.1 g mol^{-1})

(4)

$n = c \times V$

$n(CaCO_3) = \frac{mass}{Mr} = \frac{0.355}{100.1} = 3.54645 \times 10^{-3}$

$n(HCl) = (3.54645 \times 10^{-3}) \times 2$ (1 : 2 ratio)

$= 7.0929 \times 10^{-3}$

$n = \frac{c \times V}{1000}$

$V = \frac{n}{c} = \frac{(7.0929 \times 10^{-3})}{(0.1)}$

$V = 0.070929\ dm^3$

$\times 1000$ → $V(cm^3) = 70.93\ cm^3$

÷1000 → cm → dm ← ×1000

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Examiner Comments

This candidate scored three marks out of the four marks. They followed through all of the steps correctly and all their working is correct apart from the final evaluation which was given to 4 SF. The question asks for an appropriate number of significant figures which, given the number of significant figures indicated by the data, is either 2 or 3 SF and so the final mark is not awarded.

ResultsPlus
Examiner Tip

'Read the Question Twice' to ensure you know what the question and command words are instructing you to do. If in doubt, then always give your answer to three significant figures.

Question 5(b)

This was a straightforward question with almost all candidates scoring the mark.

SA

(b) State why powdered metal carbonate reacts faster than large lumps.

(1)

Powdered Metal Carbonate provided a large surface area for the reaction to take place

ResultsPlus
Examiner Comments

A concise correct answer.

Question 5(c)(i)

Most candidates showed that they knew what to do here since their revision must have seen this sort of question before on previous versions of paper 2.

The most common errors were the incorrect conversion of pressure to Pascals or the incorrect conversion of volume when evaluating their final answer.

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.

It is advised that candidates learn the correct units of the Ideal Gas Equation and practise the conversions from data provided.

(c) A second student used 4.19×10^{-3} mol of magnesium carbonate and suggested heating up the apparatus to speed up the rate of reaction.

(i) If the use of heat means that the carbon dioxide gas is at a temperature of 74.0 °C, then the apparatus shown would **not** give a measurable result.

Justify this comment by calculating the volume of carbon dioxide gas at this temperature using the ideal gas equation.

Assume that the pressure remains at 100 kPa throughout the experiment.

(4)

$pV = nRT$

$V = \frac{nRT}{p}$

$p = 100\,000$ pa

$n = 4.19 \times 10^{-3}$

$R = 8.31$

$T = 347$ K

$V = \frac{(4.19 \times 10^{-3}) \times 8.31 \times 347}{100\,000}$

$V = 1.2 \times 10^{-4}$ m^3

$\times 10^6$

$V = 120.8$ cm^3

120.8 > 100 cm^3 so the CO_2 wouldn't all fit in the gas syringe and it would burst the bung off

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Examiner Comments

This is a well laid out answer which is fully correct for all four marks. There is a final statement as to why the apparatus would not give a measurable result.

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Examiner Tip

Always lay your work out clearly to help you follow a logical pathway. A good clear layout makes it much easier for the examiner to mark and for you to be given appropriate credit.

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Justify this comment by calculating the volume of carbon dioxide gas at this temperature using the ideal gas equation.

Assume that the pressure remains at 100 kPa throughout the experiment.

(4)

$pV = nRT$

$(100 \times 1000) \times Vm^3 = (4.19 \times 10^{-3}) \times 8.31 \times 347$

$Vm^3 = 1.2082.. \times 10^{-4} = 0.1208\ cm^3$

74°C

0° = 273 K

74° = 347

Volume produced is too small to be seen in a 100 cm^3 gas syringe

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Examiner Comments

The candidate converts units of temperature and pressure appropriately and correctly calculates the volume of carbon dioxide produced. However, the subsequent conversion of volume is not correct and should be 0.1208 dm^3 or 120.8 cm^3. Three marks were awarded.

ResultsPlus
Examiner Tip

If time permits, check your numerical answers for correct conversions and units.

Question 5(c)(ii)

The overall standard of response to this question was varied.

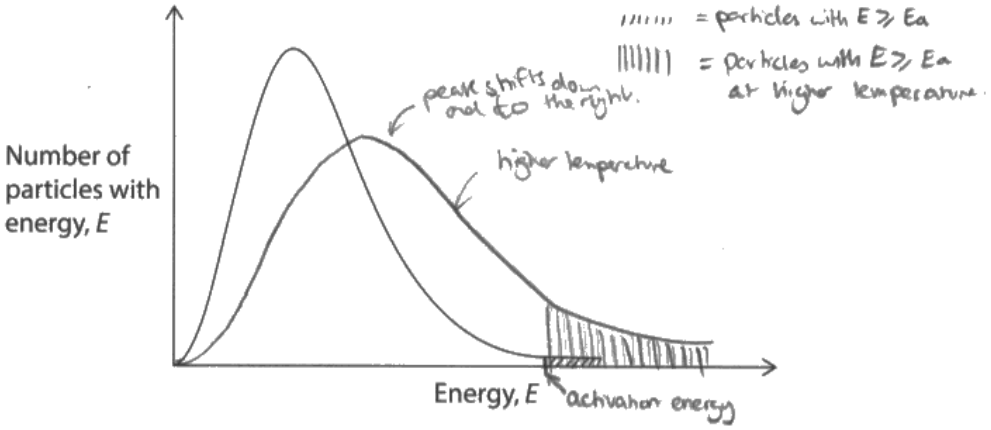
The standard of the curves drawn was commonly commented on by examiners, with frequent errors including the curve added in such a way that it crossed the first curve twice, the curve starting to go up at the end on the right and the curve either plateauing at some considerable height from the x axis or going too far and crossing the x axis. Frequently candidates missed the annotation of the activation energy.

M3 was often awarded for stating that more particles have an energy greater than or exceeding the activation energy and some candidates went further by shading the graph to illustrate the greater proportion of particles with an energy greater than or equal to E_A.

(ii) The student suggested that the Maxwell–Boltzmann distribution of molecular energies for a reaction mixture at a particular temperature is shown in a graph.

Explain, by adding another line to the graph **and** by annotating the graph, how heating the reaction mixture results in a faster reaction rate.

(3)



At a higher temperature, particles have more kinetic energy, so more particles have energy ≥ activation energy so there a more succesful collisions so there is a higher frequency of succesful collisions which results in a faster rate. At a higher temperature, there ~~are~~ is also an increased frequency of collisions due to increased E_k so higher rate.

ResultsPlus
Examiner Comments

This is an example of a response which scored all available marks.

The peak of the curve has been suitably shifted to the right and lower. The activation energy is drawn on the graph and is to the right of both peaks for M2. M3 could have been awarded from either the annotation on the graph or the explanation underneath.

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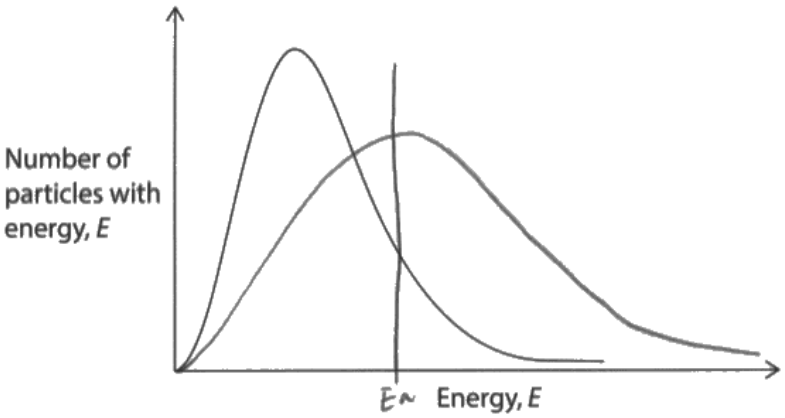
Explain, by adding another line to the graph **and** by annotating the graph, how heating the reaction mixture results in a faster reaction rate.

(3)



when heating a reaction mixture a greater proportion of particles with energy will have more than or equal to the Ea, this is because the kinetic energy of the particles will increase when heated leading to the curve in the M-B distribution shifting to the right, this means that more successful collisions occur, meaning reaction rate increases.

ResultsPlus
Examiner Comments

This is an example of a response which scored two marks. The activation energy line is drawn on the graph but needed to be to the right of both line peaks, so M2 was not scored here.

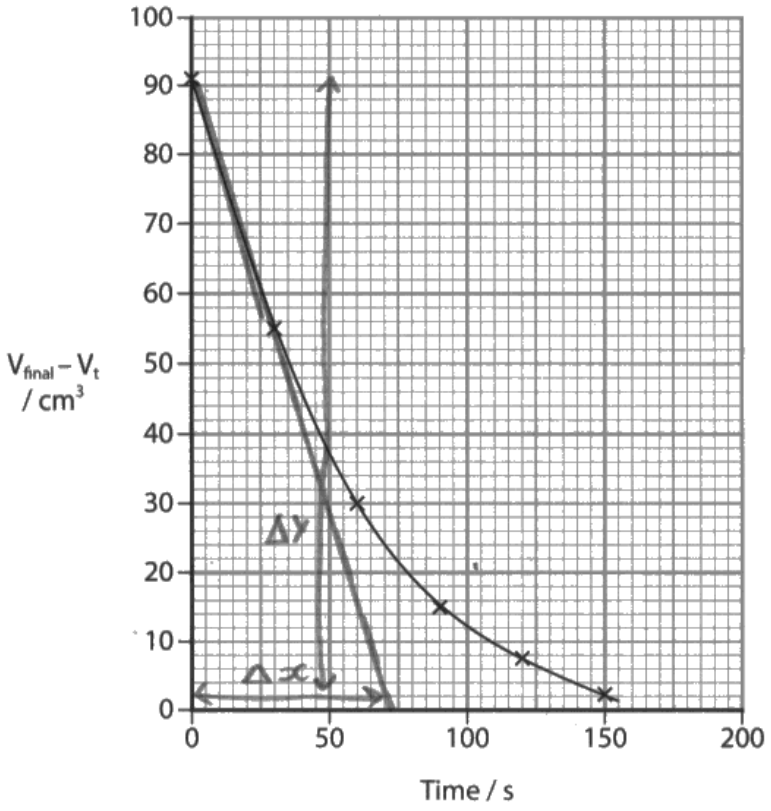
Question 5(d)

This was a well answered question, with many candidates able to score both marks for the appropriate drawing of a tangent to calculate the gradient with correct units.

Common errors include drawing an initial gradient too shallow or steep and not drawing a gradient at t=0.

Most were able to score M2 as a transferred error from the incorrect gradient, providing their units were correct.

(d) A third student, in order to obtain the rate of reaction, measured the volume of gas produced at various times and used their data to plot the graph shown.



Determine the initial rate of this reaction.
You **must** show your working on the graph.
Include units in your answer.

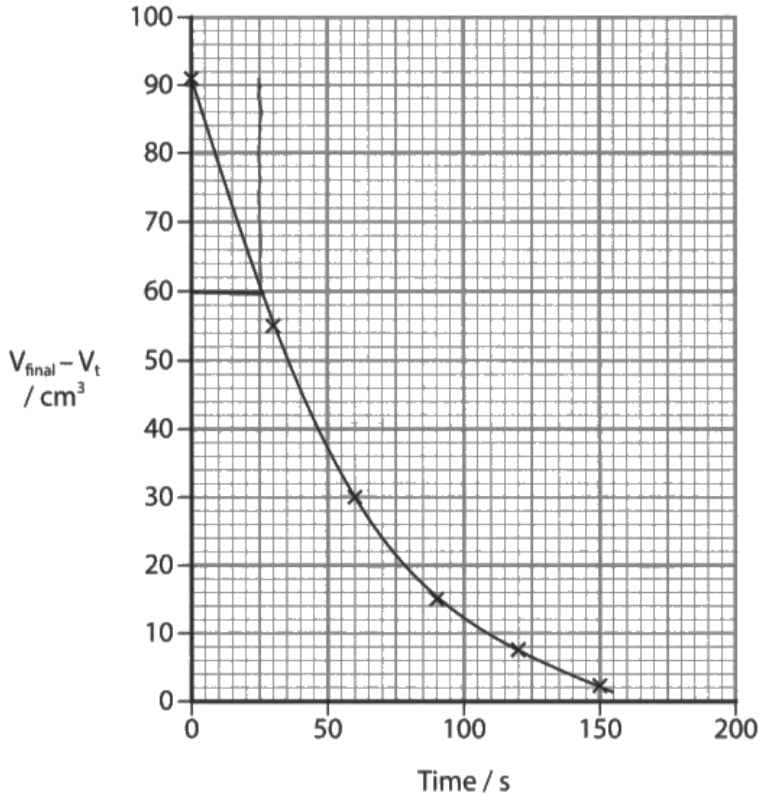
(2)

$$\text{rate} = \frac{91.0}{75} = 1.21 \text{ cm}^3 \text{ s}^{-1}$$

ResultsPlus
Examiner Comments

A fully correct response scoring both marks.

(d) A third student, in order to obtain the rate of reaction, measured the volume of gas produced at various times and used their data to plot the graph shown.



Determine the initial rate of this reaction.
You **must** show your working on the graph.
Include units in your answer.

(2)

91 - 60 = 31

25 seconds

31/25 = 1.24

1.24 cm^3 s^{-1}

ResultsPlus
Examiner Comments

Although this response does not draw a tangent at t=0, an alternative acceptable method was used to correctly calculate the gradient, with correct units for both marks.

Question 6(a)

This question attracted the full range of marks with many candidates able to give at least one of the relevant tests to distinguish the three compounds.

Many candidates gave more than one test for the benzaldehyde, usually losing credit for insufficient detail for one or more of the tests or for giving incomplete observations.

The team of examiners commented on the quality of some of the responses which scored full marks.

A few candidates thought that giving tests for two of the substances and deducing the third by elimination would be enough for full credit.

6 This question is about benzaldehyde and some related compounds.

*(a) Benzaldehyde (C_6H_5CHO) can be distinguished from phenylethanone ($C_6H_5COCH_3$) and benzoic acid (C_6H_5COOH) using **chemical** tests.

Describe a series of **chemical** tests which could be used to distinguish each of these compounds, giving the relevant tests and their positive results.

Do **not** use tests which give positive results for more than one of these compounds.

Detailed information of the laboratory equipment is not required.

(6)

Benzaldehyde will react with acidified potassium dichromate and heated under reflux. colour change will be a orange to green solution. No colour change for phenylethanone and benzoic acid as they cannot be further oxidised.

Phenylethanone will react with alkaline iodine solution to form a pale yellow precipitate. No precipitate forms for benzaldehyde and benzoic acid.
pale yellow precipitate forms due to CH_3CO group which forms CHI_3.

Benzoic acid will react with any metal carbonate, for example Magnesium carbonate. Bubble the gas evolved through lime water and the solution will turn cloudy. This is because carbon dioxide gas is produced.
No change in colour of limewater for benzaldehyde and phenylethanone as no carbon dioxide produced.

ResultsPlus
Examiner Comments

This is an excellent response which succinctly describes the three tests with detailed observations for all six marks.

ResultsPlus
Examiner Tip

When giving chemical tests, always give the full observations for a positive result, just as would be expected when completing a core practical for the Practical Endorsement.

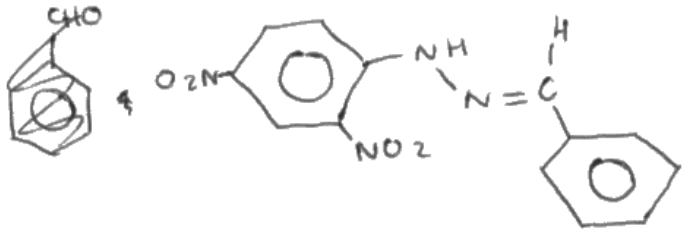
Question 6(b)(ii)

This question was answered correctly for most candidates.

The most common errors were the omission of an NO_2 group or a second nitrogen atom joined by a double bond to the benzene ring.

(ii) Draw the structure of the organic product of the reaction of 2,4-DNPH with benzaldehyde.

(1)



ResultsPlus
Examiner Comments

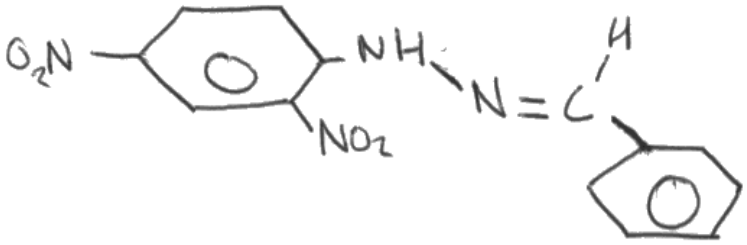
A fully correct structure for the one mark.

ResultsPlus
Examiner Tip

Take time to read the question as this often provides sufficient information to allow you to deduce the structure of the organic product.

(ii) Draw the structure of the organic product of the reaction of 2,4-DNPH with benzaldehyde.

(1)



ResultsPlus
Examiner Comments

This response was awarded the mark as the connectivity of the N-N bond was viewed as a neutral mistake given the complexity of the structure and the one mark available.

Question 7(a)

This question attracted the full range of marks with many candidates scoring at least five marks out of the available seven.

Most were able to identify the (nucleophilic) substitution for producing the amine from the halogenoalkane and also for the reduction of the nitrile.

A large proportion were also able to identify the reduction of the nitrile having a higher atom economy.

Candidates generally struggled with the balanced equation and included the reactants above the arrow. Reactants always appear on the left and products on the right hand side, leaving the arrow for conditions and catalysts.

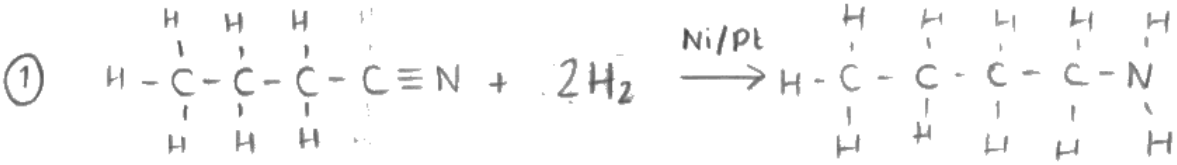
7 This question is about amines.

(a) Aliphatic amines may be prepared from halogenoalkanes or from nitriles.

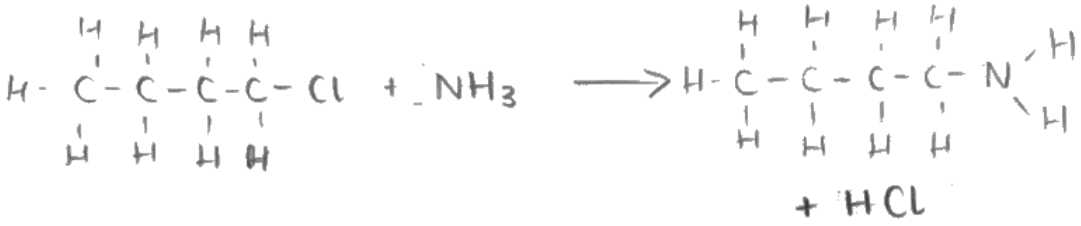
Assess these two methods for the preparation of butylamine.
Consider the reagents, the conditions needed, atom economy and the type of reaction.
Include equations.

(7)

Reducing Nitriles

(1) 

Nucleophilic Substitution with haloalkanes

(2) 

(1)

For reducing nitriles catalytic hydrogenation is used
the butane nitrile
with H_2, a nickel or platinum catalyst and a high temperature and pressure.

The atom economy is 100 %

For preparing butylamine from a halogenoalkane excess NH_3 ethanolic , is added to chlorobutane and its heated in a sealed container.

The atom economy is $\frac{73}{109.5}$ = 60 %

This is an example of an excellent response which scores all seven available marks.

It is well laid out and develops logical progression through the answer making it very simple to identify all the marking points.

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

Question 7(b)(i)

This proved to be a challenging question for many, with very few candidates securing full marks.

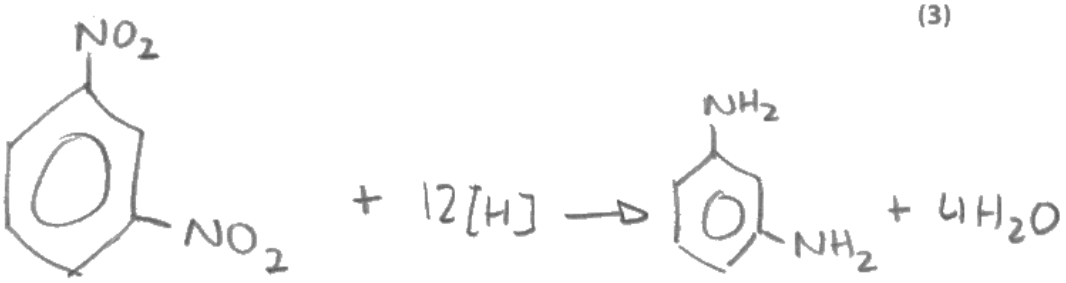
Most were able to give the correct organic species in the equation, although correctly balancing the equation was more rarely seen.

Often candidates missed the reaction conditions and only gave reagents, so not scoring M3.

(b) Preparation of the aromatic amine, benzene-1,3-diamine, requires different conditions.

(i) Write an equation for the preparation of benzene-1,3-diamine from the corresponding dinitro-compound and include necessary conditions.

(3)



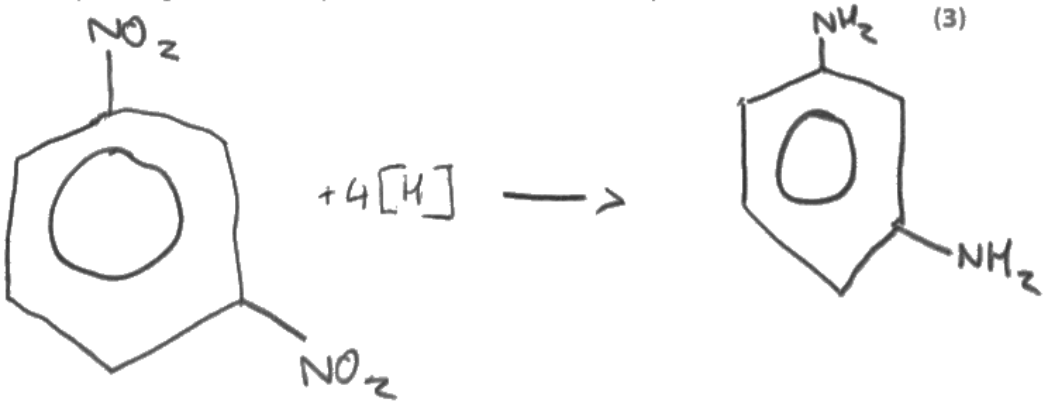
Conditions Tin , HCl , heat

ResultsPlus
Examiner Comments

This response scores all three marks. The additional guidance allowed the use of just 'heat' or 'reflux' and HCl was an acceptable alternative to HCl, although the use of dilute HCl would not have been awarded.

(b) Preparation of the aromatic amine, benzene-1,3-diamine, requires different conditions.

(i) Write an equation for the preparation of benzene-1,3-diamine from the corresponding dinitro-compound and include necessary conditions. (3)



Conditions Sn (Tin) catalyst, concentrated hydrochloric acid, reflux.

This response scores M1 and M3 only. The equation is missing 4 water molecules on the product side and so M2 was not awarded.

When asked to write an equation, always check that your equation is balanced.

Question 7(b)(ii)

This was one of the most challenging questions on this paper and candidates struggled with the reasoning behind the difference in basicity.

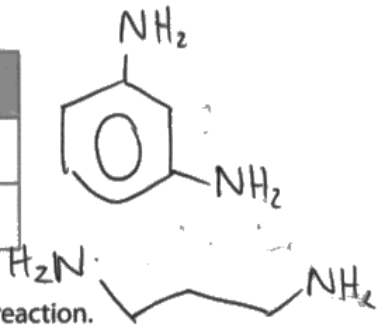
Very few used the pK_b data as requested and for those who did, many thought that a higher pK_b meant a stronger base.

There were some excellent answers scoring all available marks which was pleasing to see.

(ii) Explain the factors affecting the basicity of benzene-1,3-diamine and propane-1,3-diamine.

Include reference to information given in the table.

Substance	pK_{b1}
benzene-1,3-diamine	8.89
propane-1,3-diamine	3.83



K_{b1} is the equilibrium constant for the first protonation reaction.

The equation is shown.

$$RNH_2 + H_2O \rightleftharpoons RNH_3^+ + OH^-$$

(4)

$pKb = -\log_{10}(Kb)$

higher Kb ⇒ more basic ⇒ lower pKb.

propane-1,3-diamine (B) is more basic than benzene-1,3-diamine (A) as it has a lone pair of electrons on the nitrogen atom in (A) can overlap with the delocalised electron density of the benzene ring and delocalise into it, which increases the electron density of the ring but makes the lone pair less available to accept a proton (from water) and as a base.

(B) is more basic because the alkyl groups bonded to the nitrogens is electron releasing and has an inductive effect, so increases the electron density on the nitrogens and makes the lone pairs more available to accept a proton (make a dative covalent bond) from water.

ResultsPlus
Examiner Comments

This was an example of an excellent response, covering all marking points.

The answer is laid out clearly and there is a logical development of the reasons as to why the propane-1,3-diamine is more basic, using the values in the table as requested.

Question 7(c)

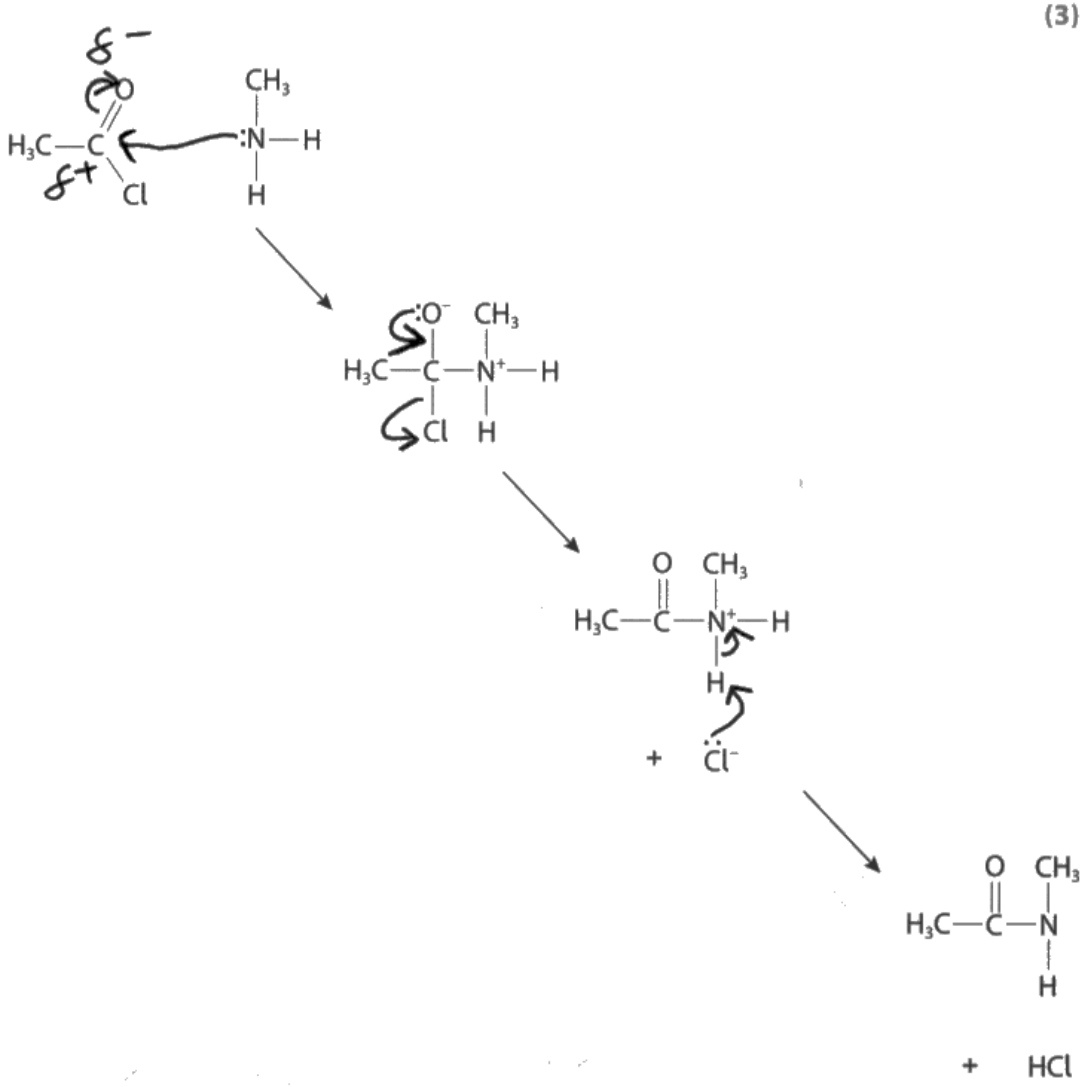
This question was generally well answered showing a good understanding of curly arrows in mechanisms.

Common errors included arrows not clearly originating from a lone pair of electrons or going to an ambiguous area.

(c) Methylamine reacts with ethanoyl chloride to produce an amide.
An incomplete outline of the mechanism is shown.

Add curly arrows to show the movement of the electrons in the mechanism.

(3)



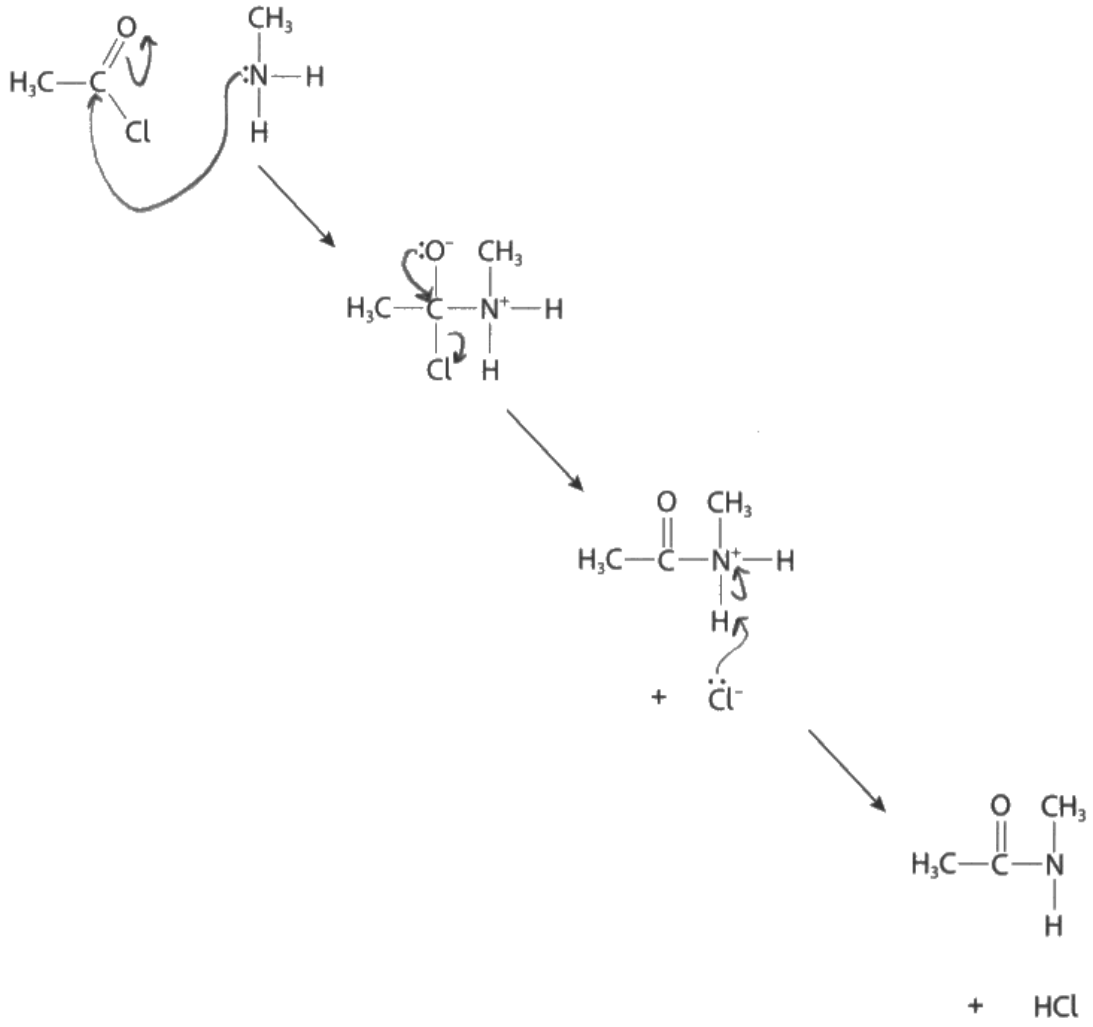
ResultsPlus
Examiner Comments

An example of a perfectly correct response with the six curly arrows clearly starting and ending in the correct positions.

(c) Methylamine reacts with ethanoyl chloride to produce an amide.
An incomplete outline of the mechanism is shown.

Add curly arrows to show the movement of the electrons in the mechanism.

(3)



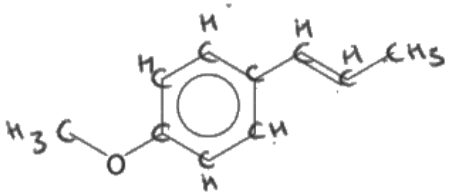
This response would have scored for all six curly arrows being correct, but the third curly arrow clearly points towards the carbon of the C-O bond and not to the bond itself. This response was awarded two marks.

Take care with curly arrow notation for mechanisms and ensure that it is clear where the arrow originates from and to where it is directed.

Question 8(a)

This was generally well answered with many correct responses seen.

8 The flavour of aniseed and liquorice is mainly due to anethole, which has the structure shown.



(a) Give the molecular formula of anethole.

(1)

$C_{10}H_{12}O$

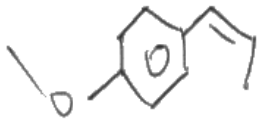
An example of a correct response.

Question 8(b)

Many candidates scored the mark here, although there were many answers simply flipping the molecule over as if reflecting it in a mirror to produce what they thought was a different optical isomer.

(b) Draw the stereoisomer of anethole.

(1)



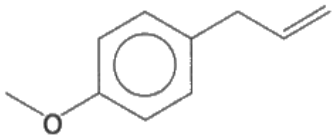
An example of a correct response.

Question 8(c)

It was not expected that less than half of the candidates would score this mark.

Commonly candidates referred to having the same group 'on the same side' or extraneously referred to restricted rotation around the C=C double bond. Some candidates referred to chiral carbons or the position of the C=C double bond.

(c) A structural isomer of anethole is estragole, which has the structure shown.



Give a reason why anethole shows stereoisomerism but estragole does **not**.

(1)

2 different groups on each C in C=C in anethole but one C in C=C in estragole has 2 Hs.

ResultsPlus
Examiner Comments

This is an example of a response that would score either by referring to one of the carbons in the C=C in estragole is attached to two hydrogens, or in anethole each carbon in the C=C has two different groups.

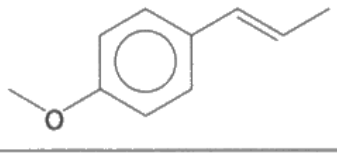
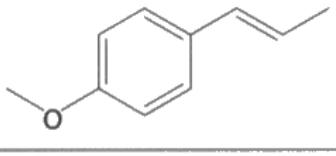
Question 8(e)(i)

Candidates found this question to be very challenging, with very few fully correct responses seen.

The best responses discussed how the orbitals overlap in the context of sigma and pi bonds and supported their explanations with a relevant diagram.

Commonly, candidates referred to sigma bonds overlapping rather than orbitals, or similarly were confused between Pi orbitals overlapping instead of **P orbitals** overlapping sideways.

(e) The structure of anethole can be drawn with a delocalised model of the benzene ring or with the Kekulé benzene ring structure as shown.

delocalised model	Kekulé structure
	

(i) Describe how the orbitals of carbon atoms overlap to form the σ-bonds and the π-bonds in the delocalised model of the benzene ring.
You may include a labelled diagram in your answer.

(3)

The delocalised π ring is above and below the plane of ring.

The carbon atoms for 3 sigma bonds - one with a hydrogen atom and ~~one~~ two with carbon atoms. These orbitals overlap head on to form sigma bond. The last electron of each carbon atom is in P orbital, these P orbitals over lap sideways to form delocalised π ring. That is very stable

ResultsPlus
Examiner Comments

This response scores all three available marks and clearly refers to the head on overlap of orbitals to form sigma bonds and the sideways overlap of P orbitals forming a delocalised pi ring.

ResultsPlus
Examiner Tip

When encountering a multiple mark question try to 'scaffold' your response, for example by explaining how a sigma bond forms, how a pi bond forms and finally, how this relates to the delocalised pi electron ring system.

Question 8(e)(ii)

Candidates found this question to be one of the most challenging on the paper.

For the thermodynamic measurements many lost both marks through vaguely referring to energy changes or bond energies, without referring to enthalpy changes of hydrogenation.

Some candidates did not score M1 as they stated that the enthalpy of hydrogenation is lower or less for the delocalised model. Centres and their candidates are reminded that when exothermic enthalpy changes are being considered that a description of the value being less/smaller/lower does not score. These terms are ambiguous when dealing with negative numbers.

For the physical measurements, a good number of candidates referred to 'the bond lengths in benzene' all being the same, without stipulating that they were referring to the carbon-carbon bond lengths.

Commonly candidates discussed chemical evidence such as resistance to bromination or lack of the 1,2-dibromo isomers which was not asked for in the question.

(ii) Explain why the delocalised model of the benzene ring is the preferred representation rather than the Kekulé cyclic triene.
Refer to **one** physical and **one** thermodynamic measurement in your answer.

(4)

In the hydrogenation of benzene, the expected ~~value~~ enthalpy change should be roughly 3x that of the hydrogenation of cyclohexene (-120 kJ mol^{-1}) (so around -320 kJ mol^{-1}) if the kekule model is correct. However, the actual enthalpy change is much less exothermic (-208 kJ mol^{-1}) suggesting the benzene ring is more stable supporting the delocalised model. Furthermore, using x-ray diffraction to get an electron density map of benzene shows all bonds are the same length, disproving the kekule model which would suggest that the 3 C=C bond bonds present would be shorter than the other 3 C-C bonds.

ResultsPlus
Examiner Comments

This response scores all four marks and is clearly structured and well answered. Although the candidate states that all bonds are the same length, this is clarified by the final statement that the 3 C=C bonds present would be shorter than the other three C-C bonds.

(ii) Explain why the delocalised model of the benzene ring is the preferred representation rather than the Kekulé cyclic triene.
Refer to **one** physical and **one** thermodynamic measurement in your answer.

(4)

The kekule structure has 3 double bonds yet is unable to ~~for~~ decolourise bromine water since it does substitution (bromination) reaction instead of addition. If cyclohexene has a ΔH of 120 kjmol^{-1} the expected ΔH of ~~he~~ triene is 360 kjmol^{-1}, however it is 208 kjmol^{-1} due to the e$^-$ distribution above and below in π bond. So it cannot be the kekule structure.

ResultsPlus
Examiner Comments

Unfortunately this response does not score any marks. The chemical reactivity of the delocalised model of benzene compared to the cyclic triene was not asked for in the question so does not score.

The values for the hydrogenation are correct but are not stated as hydrogenation in the response and are missing the negative sign.

ResultsPlus
Examiner Tip

Carefully read the question and structure your response accordingly, ensuring you refer to one physical and one thermodynamic measurement when explaining.

Question 8(f)

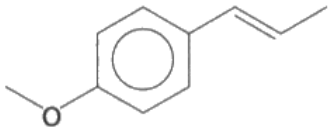
Most candidates were able to identify that the anethole is more soluble in ethanol than in water and so scored the two marks.

For M3, explaining why this was the case in terms of molecular structures and intermolecular forces was seen less often. A comparison between the factors affecting solubility of anethole in the two different solvents was required.

(f) Anethole is also present in some alcoholic drinks such as the Greek liquor, ouzo.

The anethole is responsible for the so-called 'ouzo effect'. This effect is the transparent ouzo liquor turning milky when water is added.
The addition of water causes the anethole to form oily droplets which result in a stable milky emulsion.

Deduce the solubility of anethole in ethanol and in water from the 'ouzo effect'.
Justify your answer with reference to the anethole structure shown, but detailed descriptions of intermolecular forces are not required.



anethole

(3)

Anethole is insoluble in water, but soluble in ethanol. This is because anethole can form one hydrogen bond with water (due to the lone pair of electrons on the oxygen) however this isn't strong enough to break the collectively strong london forces of anethde. Anethole forms many london forces with ethanol which is stronger than its london forces causing it to dissolve.

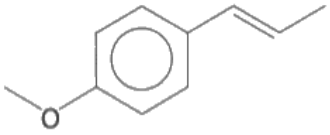
ResultsPlus
Examiner Comments

A well structured response that scored all three marks.

(f) Anethole is also present in some alcoholic drinks such as the Greek liquor, ouzo.

The anethole is responsible for the so-called 'ouzo effect'. This effect is the transparent ouzo liquor turning milky when water is added.
The addition of water causes the anethole to form oily droplets which result in a stable milky emulsion.

Deduce the solubility of anethole in ethanol and in water from the 'ouzo effect'. Justify your answer with reference to the anethole structure shown, but detailed descriptions of intermolecular forces are not required.



anethole

(3)

Anethole is more soluble in ethanol than water. As they can both form permanent dipole bonds with each other which is equal to the bonds within each molecule

ResultsPlus
Examiner Comments

This response scores M1 and M2 for the first sentence stating that the anethole is more soluble in ethanol than in water.

Question 9(a)(iii)

This proved to be a challenging question for candidates, with a number of responses left blank.

Many candidates were able to work out the answer but often provided wordy or difficult-to-follow explanations, sometimes omitting units or reasons.

Most of the candidates scoring full marks did so by assuming a rate equation with order 2, substituting units and then cancelling until they obtained the correct answer. Others used the given units of rate constant to deduce that two concentrations were involved, hence second order.

(iii) The rate constant for the reaction of 1-bromopropane with aqueous potassium hydroxide has the units of $dm^3 mol^{-1} s^{-1}$.

Explain why it can be deduced that the reaction is second order overall.
Assume that the units of the rate of reaction are $mol\,dm^{-3} s^{-1}$.

(2)

rate = k × [x] x being the conc of the other reactants and orders.

$\frac{mol\,dm^{-3} s^{-1}}{mol^{-1} dm^3 s^{-1}} = [x]$

$[x] = mol^2 dm^{-6}$.

There must be second order as the units for conc are $mol\,dm^{-3}$ and to give a k of $dm^3 mol^{-1} s^{-1}$ through substitution equation.
Of reaction, the units of the concentrations is $mol^2 dm^{-6}$ which is $(mol\,dm^{-3})^2$ which is 2nd order

A fully correct response which is clearly explained.

Question 9(a)(i-ii)

Most candidates scored two marks for Q09(a)(i).

This type of calculation based on graph plotting has been seen before in previous papers, so many candidates knew what to do.

It was disappointing to see a number of candidates who were unable to make the best use of the graph paper and failed to ensure that plotted points covered at least half of the graph paper, which lost M2. Also, there were still further candidates who plotted negative values becoming decreasingly negative down the page and those who plotted lnk on the x-axis and 1/T on the y-axis, so losing M2.

Gradients were often determined correctly, scoring M3. Despite clear instructions given in the question, often the units were lacking for the gradient which lost M4.

It was pleasing to see very few occurences of negative activation energies.

9 Halogenoalkanes are hydrolysed to form alcohols.

(a) The rate constant for the reaction of 1-bromopropane with aqueous sodium hydroxide was determined at five temperatures.
Some of the results are given in the table.

Temperature (T) / K	1/Temperature ($1/T$) / K^{-1}	Rate constant (k) / $dm^3\,mol^{-1}\,s^{-1}$	ln k
298	3.36×10^{-3}	1.36×10^{-4}	−8.9
304	3.29×10^{-3}		−8.4
308	3.25×10^{-3}	3.04×10^{-4}	−8.1
318	3.14×10^{-3}	6.76×10^{-4}	−7.3
328	3.06×10^{-3}	1.23×10^{-3}	−6.7

(i) Complete the table of data.

(2)

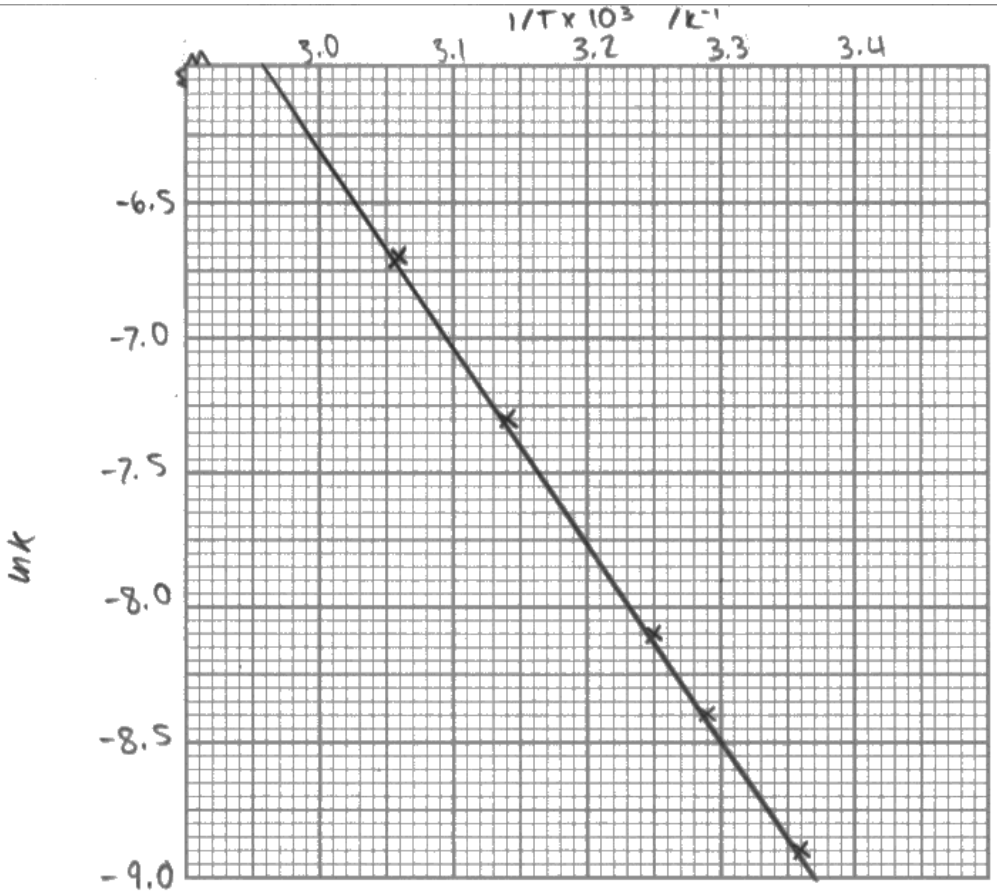
(ii) Plot a graph of ln k against $1/T$ and use it to determine the activation energy, E_a, for this reaction in $kJ\,mol^{-1}$.

You must show your working on the graph and include the value of the gradient of the line and its units.

The Arrhenius equation can be expressed as

$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant}$$

(5)



gradient = $-\frac{Ea}{R}$

$\frac{\Delta y}{\Delta x} = \frac{-8.9 - -6.7}{3.36 \times 10^{-3} - 3.06 \times 10^{-3}}$

$= -7333.3$ K

$-Ea$ = gradient x R

$= -7333.3 \times 8.31$

$= -60940$

$Ea = +60940$ J mol^{-1}

$= +60.94$ kJ mol^{-1}

Gradient -7333.3 K

Activation energy 60.94 kJ mol^{-1}

ResultsPlus
Examiner Comments

Q09(a)(i) scores one mark as only the value for temperature is given.

Q09(a)(ii) scores all five marks.

9 Halogenoalkanes are hydrolysed to form alcohols.

(a) The rate constant for the reaction of 1-bromopropane with aqueous sodium hydroxide was determined at five temperatures.
Some of the results are given in the table.

Temperature (T) / K	1/Temperature ($1/T$) / K^{-1}	Rate constant (k) / $dm^3\,mol^{-1}\,s^{-1}$	ln k
298	3.36×10^{-3}	1.36×10^{-4}	–8.9
304	3.29×10^{-3}	2.25×10^{-4}	–8.4
308	3.25×10^{-3}	3.04×10^{-4}	–8.1
318	3.14×10^{-3}	6.76×10^{-4}	–7.3
328	3.06×10^{-3}	1.23×10^{-3}	–6.7

(i) Complete the table of data.

(2)

(ii) Plot a graph of ln k against $1/T$ and use it to determine the activation energy, E_a, for this reaction in $kJ\,mol^{-1}$.

You must show your working on the graph and include the value of the gradient of the line and its units.

The Arrhenius equation can be expressed as

$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant}$$

(5)

$\frac{\Delta y}{\Delta x} = \frac{-2.65}{0.36 \times 10^{-3}} = -7361.1\ K$

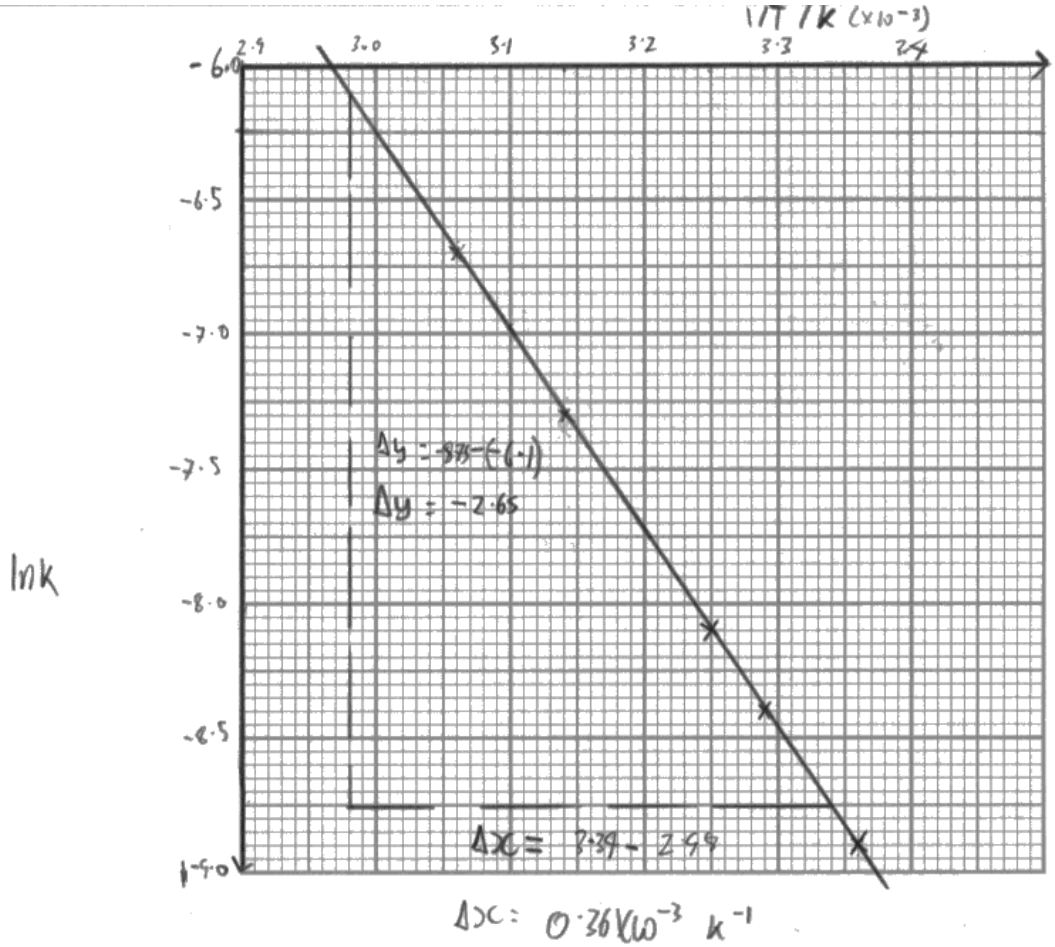
$\frac{-E_a}{R}$ = grad

$E_a = -R \times -7361.1\ K$

$E_a = -8.31 \times -7361.1$

$E_a = +61170\ J\,mol^{-1}$

$E_a = +61.2\ kJ\,mol^{-1}$



Gradient ..... -7361 k .....

Activation energy ..... +61·2 kJmol⁻¹ .....

ResultsPlus
Examiner Comments

Q09(a)(i) scores both marks.

Q09(a)(ii) scores four marks as the units on the x-axis are incorrect so losing M1.

ResultsPlus
Examiner Tip

Units are easily missed or given incorrectly, but their omission, when necessary, will result in a mark being lost.

Question 9(b)

This question was generally well answered.

Q09(b)(i) - A sizeable minority gave a mechanism for S_N2 despite the clear instructions given in the question.

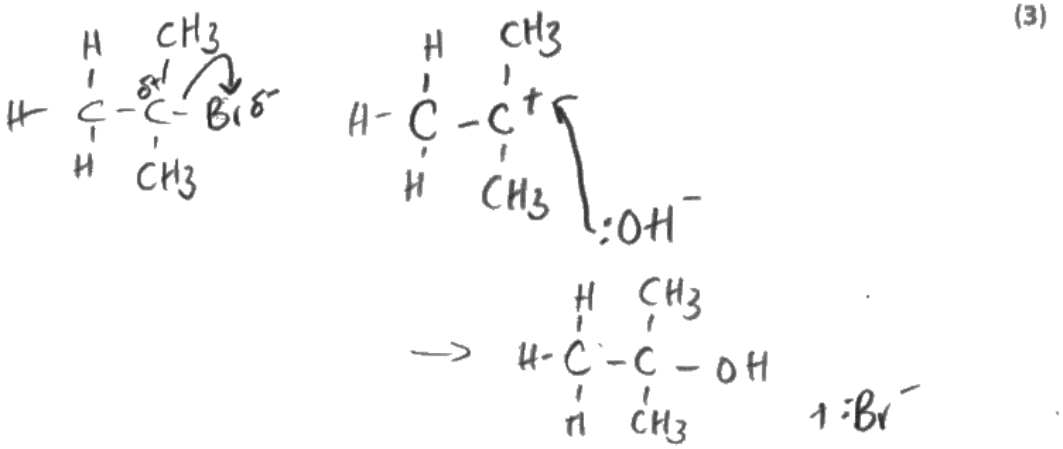
For those correctly drawing the S_N1 mechanism, many scored at least two marks but common incorrect responses were omitting the bromide ion or the negative charge or the lone pair of electron on the hydroxide ion, so losing a mark.

Q09(b)(ii) - Many stated that the rate determining step did not involve hydroxide ions without stating that the rate determining step was the first step.

(b) The rate of reaction for the hydrolysis of 2-bromo-2-methylpropane by aqueous hydroxide ions is independent of the concentration of hydroxide ions.

(i) Draw the S_N1 reaction mechanism for this hydrolysis.
Include curly arrows and any relevant dipoles and lone pairs of electrons.

(3)



(ii) State how your mechanism is consistent with the rate of reaction being independent of hydroxide ion concentration.

(1)

The slowest step (rate determining step) / first step contains only one species - the ~~bromo~~ halogenoalkane and no hydroxide ions.

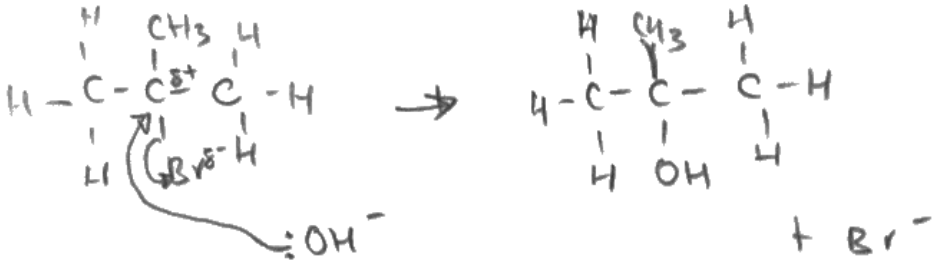
ResultsPlus
Examiner Comments

A fully correct answer worth all available marks.

(b) The rate of reaction for the hydrolysis of 2-bromo-2-methylpropane by aqueous hydroxide ions is independent of the concentration of hydroxide ions.

(i) Draw the S_N1 reaction mechanism for this hydrolysis.
Include curly arrows and any relevant dipoles and lone pairs of electrons.

(3)



(ii) State how your mechanism is consistent with the rate of reaction being independent of hydroxide ion concentration.

(1)

ResultsPlus
Examiner Comments

This response gives the S_N2 mechanism so only scores M1.

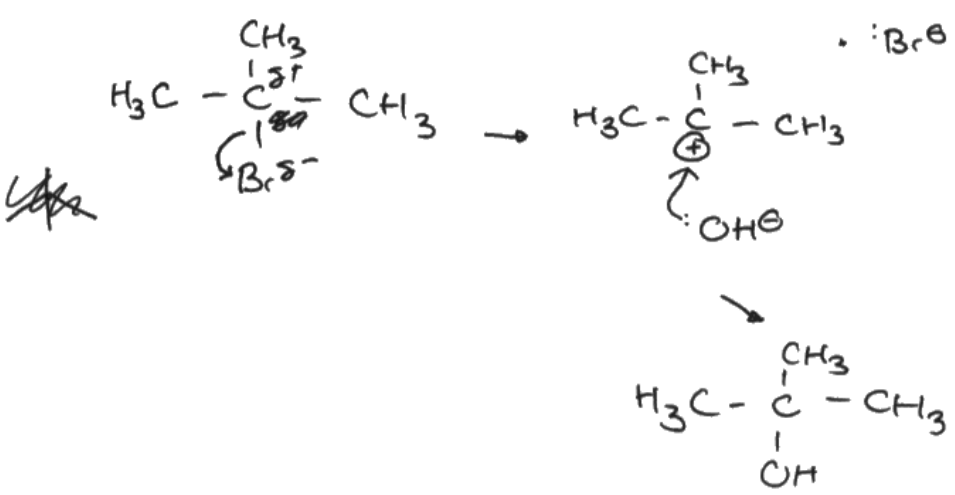
ResultsPlus
Examiner Tip

Read the question carefully and highlight the command words to ensure that you answer the question given.

(b) The rate of reaction for the hydrolysis of 2-bromo-2-methylpropane by aqueous hydroxide ions is independent of the concentration of hydroxide ions.

(i) Draw the S_N1 reaction mechanism for this hydrolysis.
Include curly arrows and any relevant dipoles and lone pairs of electrons.

(3)



(ii) State how your mechanism is consistent with the rate of reaction being independent of hydroxide ion concentration.

(1)

The rate determining step is the ~~breaking~~ removal of the bromine and the formation of the carbocation

ResultsPlus
Examiner Comments

Q09(b)(i) is fully correct for three marks.

In this response, the candidate has correctly stated that the slow step is the formation of the carbocation but not linked this to why the rate of reaction is independent of the hydroxide ion concentration so does not score this mark.

Paper Summary

Based on their performance on this paper, candidates should:

- When drawing a graph make sure that the scale will ensure that the plotted points will cover at least half of the graph paper and that both axis are suitably labelled with appropriate units.
- Double or even triple check your calculations to make sure that all the values are correct. Always give answers to the appropriate number of significant figures.
- Take care to layout calculations in a clearly labelled and methodical manner, especially when encountering unfamiliar calculations.
- Practise, practise and practise to ensure that you can do key things like calculating an activation energy.
- Pay attention to the format or introduction to a question because a part which follows on may provide necessary guidance in an earlier part which helps you to answer a subsequent question effectively.
- Always remember RTQ^2 - Read The Question Twice - before starting to answer and also when you have finished to make sure that you have addressed what is required in the question.
- Ensure that practical work is part of your revision, including, but not limited to, the Core Practicals. In particular, learn the different chemical tests, including reagents and conditions, together with the expected full observation.
- Ensure that you invest time on the Year 12 subject matter when preparing for the exam as well as the Year 13 material.

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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