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Examiners' Report
June 2019

GCE Chemistry 9CH0 02

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Introduction

This is the third examination series in the Pearson Edexcel Level 3 Advanced GCE in Chemistry (9CH0) qualification. Paper 2 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.

Evidence from examiners suggested that candidates had sufficient time to attempt all questions, with significant blank spaces seen in only a few cases. However, a small number of scripts did exhibit very poor presentation, making it difficult at times to judge the standard of the chemistry.

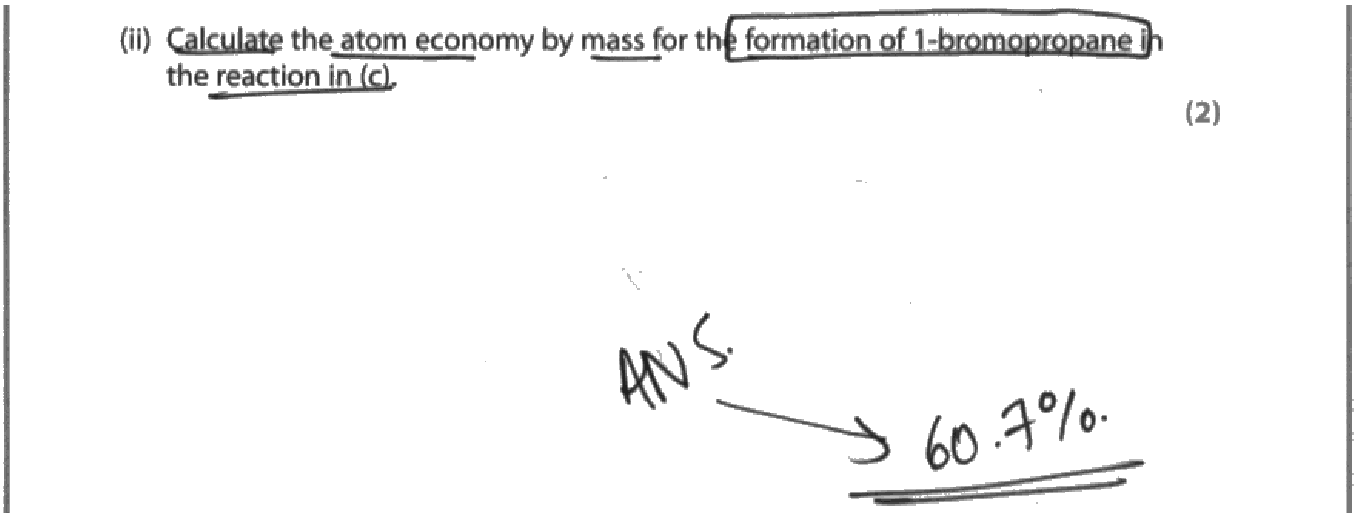
Examiners reported that they saw fewer errors linked to significant figures than in previous sessions and although slips were still evident, the use of appropriate arrows, dipoles and lone pairs seemed better within mechanisms. They also suggested that the quality of graphs had improved, especially with respect to the correct labelling of axes. Use of $pV = nRT$ was another strength, and even when mistakes occurred, working could normally be followed to allow the award of marks for transferred errors.

The mean mark for the paper was higher than in 2018, though the spread of marks was greater.

The multiple-choice questions proved straightforward in most cases, with a mean mark of 8.24. The most challenging examples were Q1(a)(ii), where only 50% of candidates realised that hexan-2-ol would give a positive iodoform test, and Q4(c)(ii), were less than 50% deduced the correct number of optical isomers was four.

Question 2 (c) (ii)

This proved to be a straightforward opening to the free-response questions and pleasingly many candidates scored both marks using a concept from early in the course. Very few examples were seen where candidates had little idea how to proceed, and the most common way to lose credit was to express the final answer as 0.603. An odd, but surprisingly common error was to see the molar mass of HBr shown as 1 + 79.9 = 89.9. Perhaps more predictably some candidates used the atomic mass of chlorine instead of bromine throughout.



(ii) Calculate the atom economy by mass for the formation of 1-bromopropane in the reaction in (c).

(2)

ANS. $\rightarrow$ 60.7%.

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Examiner Comments

One would suspect from the closeness of this response to the correct answer, that the candidate was pursuing a sensible method. Unfortunately, as the final answer is incorrect and no working is evident, it scored 0 marks.

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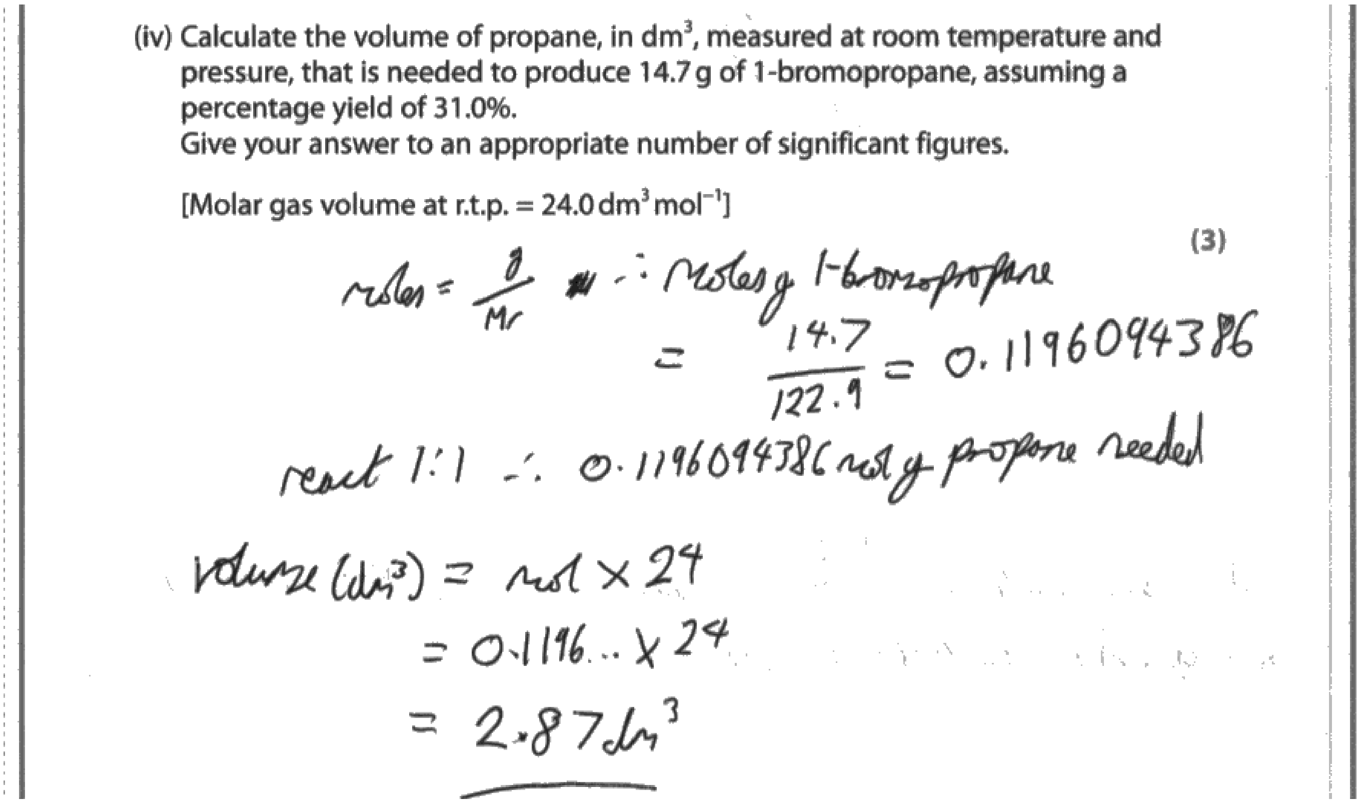
Examiner Tip

Always show all steps in your working for chemical calculations to allow access to some credit even if you get the final answer wrong.

Question 2 (c) (iv)



(iv) Calculate the volume of propane, in dm^3, measured at room temperature and pressure, that is needed to produce 14.7 g of 1-bromopropane, assuming a percentage yield of 31.0%.
Give your answer to an appropriate number of significant figures.

[Molar gas volume at r.t.p. = 24.0 dm^3 mol^{-1}]

(3)

$\text{moles} = \frac{g}{M_r}$ ∴ moles of 1-bromopropane $= \frac{14.7}{122.9} = 0.1196094386$

react 1:1 ∴ 0.1196094386 mol of propane needed

$\text{volume (dm}^3) = \text{mol} \times 24$

$= 0.1196... \times 24$

$= \underline{2.87 \text{ dm}^3}$

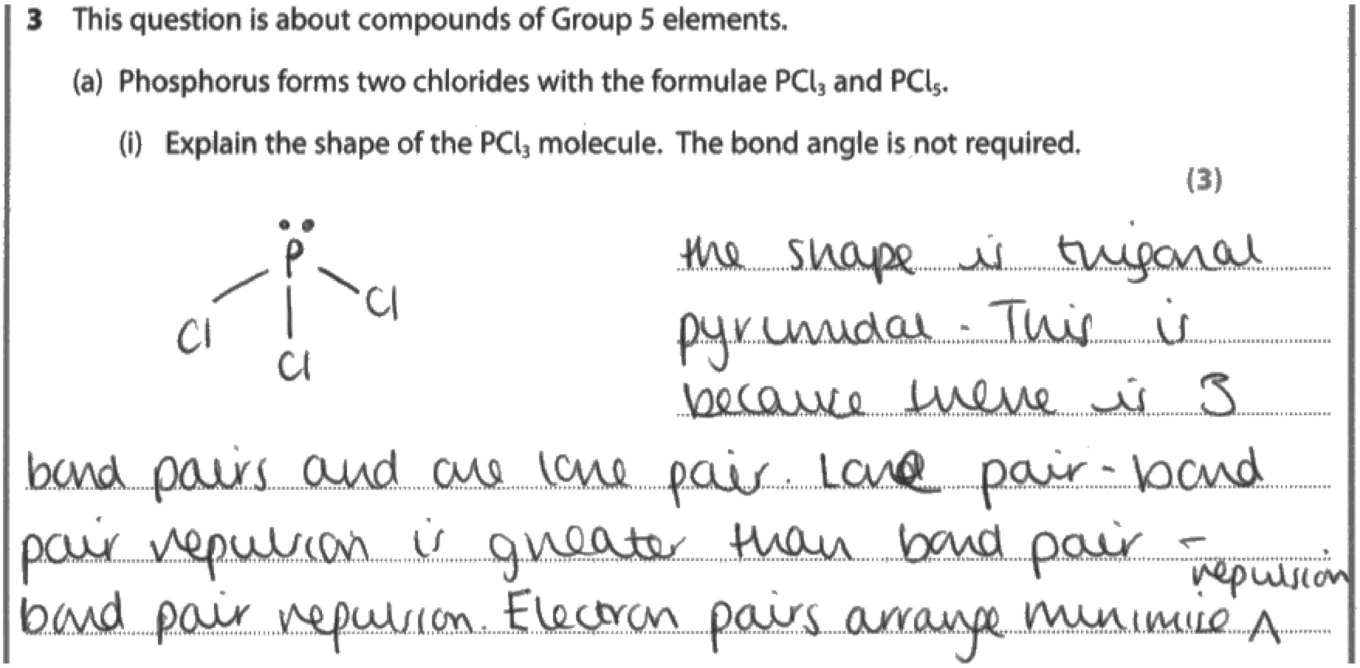
ResultsPlus
Examiner Comments

This candidate has clearly laid out their working, so the examiner can see what they are trying to achieve. Unfortunately they have not considered the fact that the reaction only has a 31% yield, so scores 2 marks, rather than 3.

ResultsPlus
Examiner Tip

Remember, when calculating the amounts needed for a reaction, a yield of less than 100% will always need you to use more reactant to compensate for the loss of product.

Question 3 (a) (i)



3 This question is about compounds of Group 5 elements.

(a) Phosphorus forms two chlorides with the formulae PCl_3 and PCl_5.

(i) Explain the shape of the PCl_3 molecule. The bond angle is not required.

(3)

the shape is trigonal pyramidal. This is because there is 3 bond pairs and one lone pair. Lone pair-bond pair repulsion is greater than bond pair-bond pair repulsion. Electron pairs arrange minimise repulsion

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Examiner Comments

This example scores all 3 marks. Although the diagram isn't 3-dimensional, the correct shape is described. The correct number of bond and lone pairs of electrons are stated, and then linked to idea of minimising repulsion between them.

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Examiner Tip

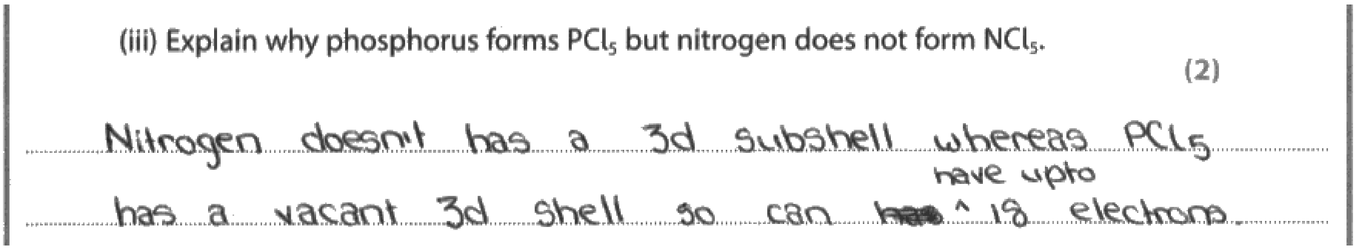
If you are unsure about the number of bond and lone pairs of electrons in a molecule, draw a dot-and-cross diagram to help.

Question 3 (a) (ii)

Drawing the 3-dimensional shape of a molecule is a skill many candidates should practice. Although the majority could name the shapes, the diagrams varied in quality, with many examples failing to resemble any of the shapes identified on the specification. The best answers showed three chlorine atoms in the central plane, with the use of one hatch and one wedge to stress the idea of three dimensions. Not all candidates who managed this could label the angles appropriately. The most common error was to label the angle between the central plane and the one of the vertical chlorine atoms as 120°.

Question 3 (a) (iii)

This proved to be the most challenging question on the paper with most candidates attempting to justify the difference in terms of the relative size of the central atoms, rather than by considering the electrons available. Others thought that phosphorus would be able to form a greater number of bonds due to its greater nuclear charge. The best answers simply considered the idea that phosphorus can accommodate 18 electrons in its outer shell, but nitrogen's outer shell can only hold 8 electrons.



(iii) Explain why phosphorus forms PCl_5 but nitrogen does not form NCl_5.

(2)

Nitrogen doesn't has a 3d subshell whereas PCl_5 has a vacant 3d shell so can ~~has~~ have upto 18 electrons.

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Examiner Comments

Here, by considering the lack of availability of d subshell in nitrogen, and the implication that phosphorus can hold up to 18 electrons (in its outer shell), the candidate just manages to score both marks.

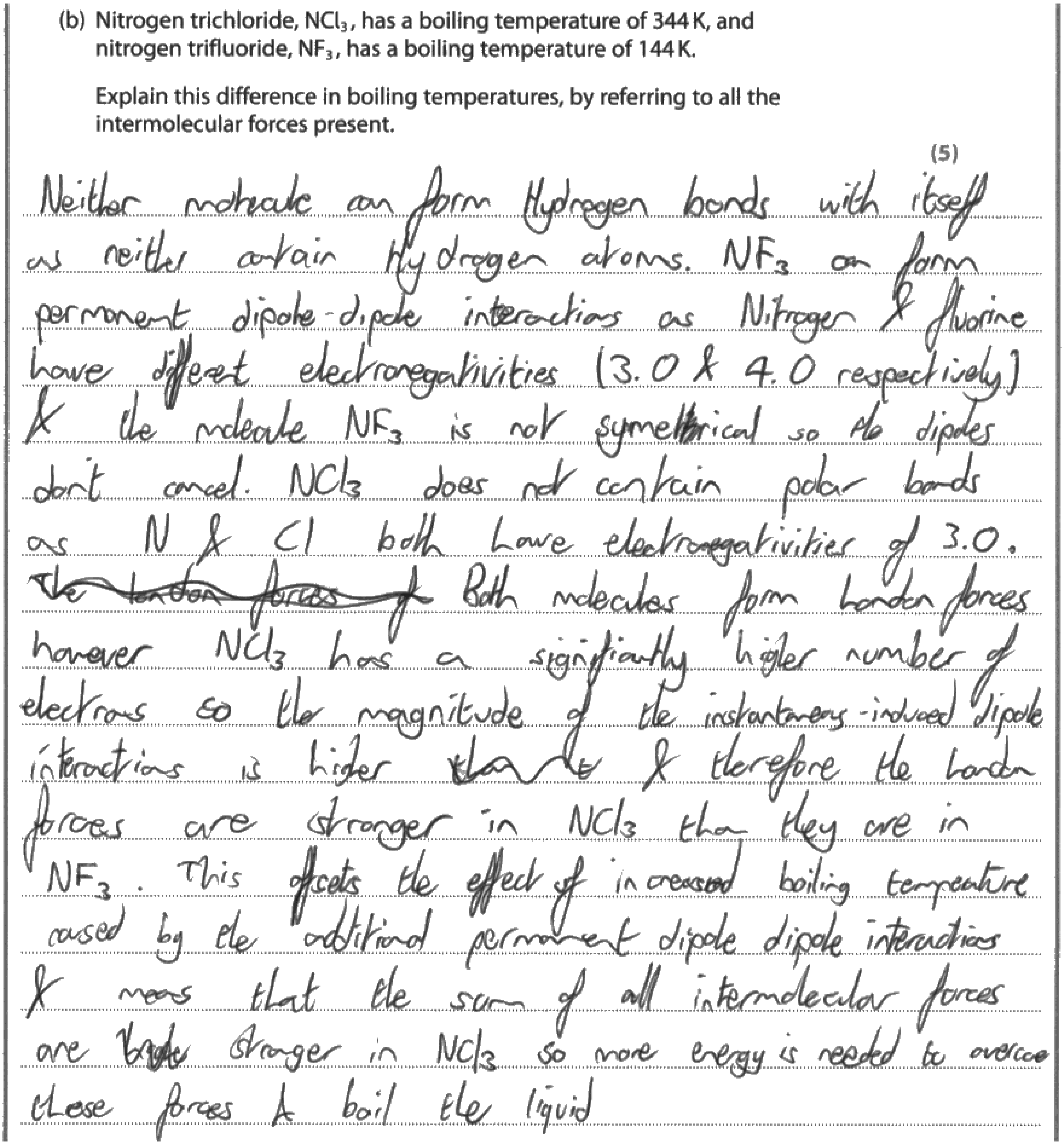
ResultsPlus
Examiner Tip

Remember to consider electrons when deciding the number of bonds an atom can form.

Question 3 (b)

This question produced a wide range of marks, with a degree of discrimination between candidates. There were a lot of good answers linking London forces to the number of electrons and subsequent energy needed to break these forces. Only a few that clearly stated that covalent or ionic bonds were broken.

A number of candidates believe that London forces are the weakest regardless of the context and do not realise that it is possible for them to be greater than other intermolecular forces in molecules. This led to several candidates trying to explain why dipole-dipole forces were weaker in nitrogen trifluoride and losing the associated marks. Some candidates missed out on marks through their use of imprecise chemical terminology, most commonly with **chloride ions** being referred to as having more electrons.



(b) Nitrogen trichloride, NCl_3, has a boiling temperature of 344 K, and nitrogen trifluoride, NF_3, has a boiling temperature of 144 K.

Explain this difference in boiling temperatures, by referring to all the intermolecular forces present.

(5)

Neither molecule can form Hydrogen bonds with itself as neither contain Hydrogen atoms. NF_3 can form permanent dipole-dipole interactions as Nitrogen & fluorine have different electronegativities (3.0 & 4.0 respectively) & the molecule NF_3 is not symmetrical so the dipoles don't cancel. NCl_3 does not contain polar bonds as N & Cl both have electronegativities of 3.0. ~~The London forces of~~ Both molecules form London forces however NCl_3 has a significantly higher number of electrons so the magnitude of the instantaneous-induced dipole interactions is higher ~~than the~~ & therefore the London forces are stronger in NCl_3 than they are in NF_3. This offsets the effect of increased boiling temperature caused by the additional permanent dipole dipole interactions & means that the sum of all intermolecular forces are ~~both~~ stronger in NCl_3 so more energy is needed to overcome these forces to boil the liquid

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Examiner Comments

This example sticks closely to the guidance given in the stem. All intermolecular forces are considered, including ruling out the presence of hydrogen bonds. The candidate seems to have the difference in boiling temperature in mind at all times, but unlike some responses, does not attempt to deviate from their understanding of permanent dipole-permanent dipole interactions in an attempt to maintain the misconception that these forces will always be more significant than London forces.

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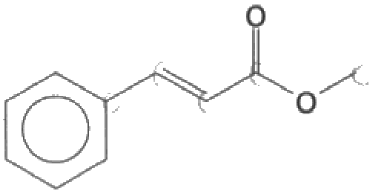
Examiner Tip

Remember that London forces **can be** the most significant intermolecular forces, especially when comparing molecules of different molar masses.

Question 4 (a)

This calculation was accessible to the majority of candidates, and most were able to score 2 marks. Those who didn't were still able to score 1 for deducing the molar mass of methyl cinnamate. A few candidates persist in the idea that answers in multi-step calculations should be rounded to 2 or 3 significant figures at each step. However, in some cases this can make a significant difference to the final answer, so candidates should remember that this rounding should be left until the final answer.

4 Methyl cinnamate, $C_{10}H_{10}O_2$, is a white crystalline solid used in the perfume industry.



methyl cinnamate

C

(a) Calculate the mass of carbon in 2.34 g of methyl cinnamate.

(2)

moles $= \frac{2.34}{162} = 0.014$ moles

mass Carbon = ~~0.014 × 12~~

= ~~0.173 g~~

0.014 × 120 = 1.68 g

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Examiner Comments

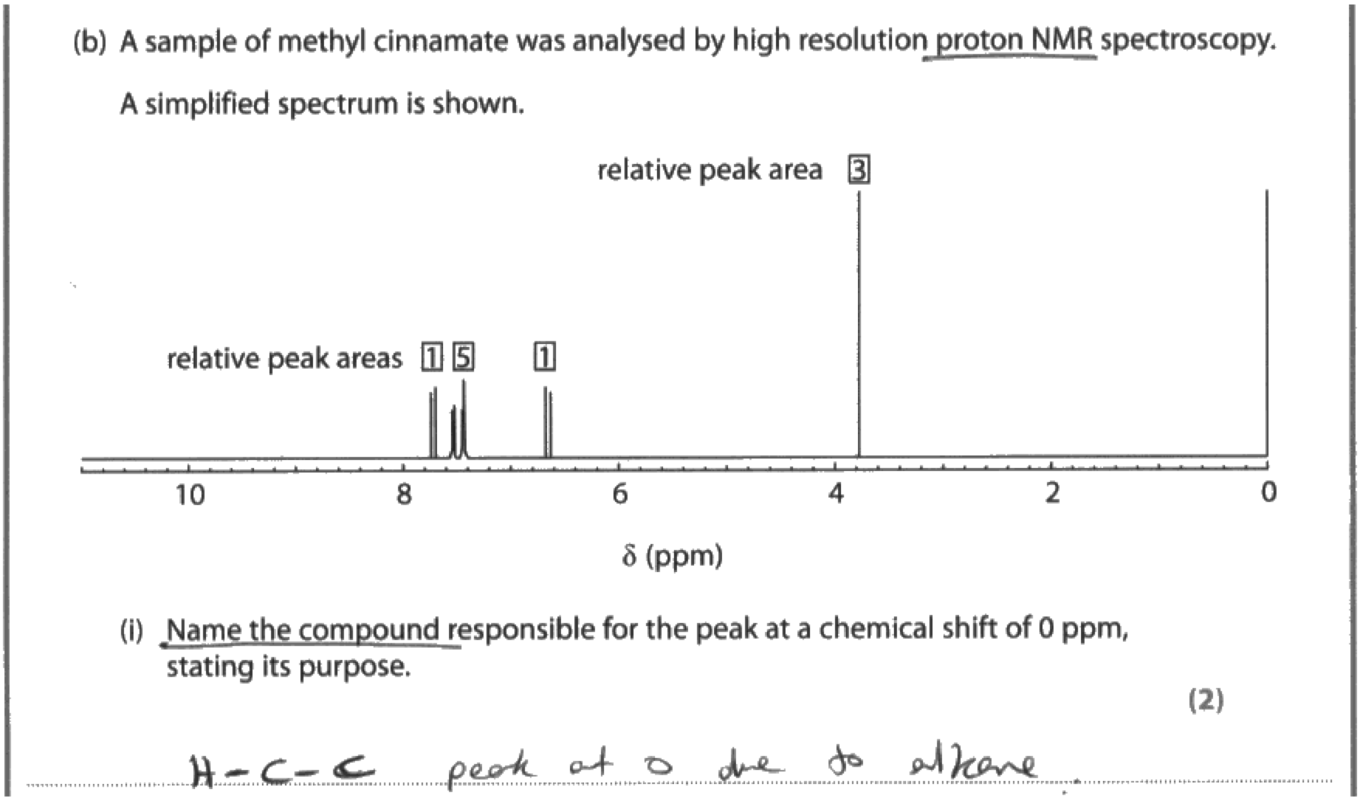
In this case the candidate scored 1 mark. They have calculated the amount of methyl cinnamate correctly. It looks as though they had unrounded the value from their calculator in their first attempt when they multiplied by 12 rather than 120. Unfortunately, in their second attempt they carried forward the rounded value into the last step, getting 1.68 g rather than 1.73 g.

ResultsPlus
Examiner Tip

You can write down correctly rounded values in your working of multi-step calculations, but it is best practice to use the unrounded values in your calculator as you process each step, only rounding at the final step.

Question 4 (b) (i)

Whilst many candidates knew the role of TMS as a reference compound, a surprising number could not name it accurately. ‘Silicate’, ‘saline’, ‘silicone’ were amongst a variety of misspellings seen by examiners. References to the 12 equivalent hydrogen environments were often included, but students should remember to use the command words to help guide their answer. Here the stem required the purpose of TMS to be **stated**, not to **explain** why it was suitable.



(b) A sample of methyl cinnamate was analysed by high resolution proton NMR spectroscopy.

A simplified spectrum is shown.

(i) Name the compound responsible for the peak at a chemical shift of 0 ppm, stating its purpose.

(2)

H–C–C peak at 0 due to alkane

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Examiner Comments

Apart from misspellings of tetramethylsilane, the most common misconception was of the kind shown by this answer. Here the candidate has used the data booklet and picked the hydrogen environment closest to the shift of 0 ppm. Had they focused on the word ‘compound’ in the stem, they may have realised that their generic response of ‘alkane’ was inappropriate.

ResultsPlus
Examiner Tip

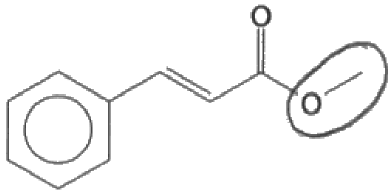
Remember that incorrect spellings can mean marks are not awarded, if they lead to confusion with another possible substance.

Question 4 (b) (ii)

Many candidates were able to identify the methyl group on the far right of the structure, interpreting the skeletal format successfully. The justification allowed a degree of discrimination and some candidates missed out on full credit because of a lack of clarity. For instance, some responses, despite the stem using the terminology ‘relative peak area’, talked solely about peak height. Others were imprecise when discussing the splitting, suggesting it was caused by the fact that ‘there are no hydrogens attached’ or ‘because of the n+1 rule’. In each case, a little more detail could have scored the mark.

(ii) Identify the proton environment that causes the peak at a chemical shift of 3.8 ppm by circling it on the diagram shown. Fully justify your answer.

(3)



3·8 ppm corrosponds to the known value of an ester linkage NMR sample and there is ~~only one~~ a singlet present at 3·8 ppm on the spectrum, meaning that the carbon has no adjacent carbons.

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Examiner Comments

Here the correct group is circled scoring the first mark. However, there is no reference to the peak area and the three methyl hydrogen atoms and the singlet is linked to no adjacent **carbon** atoms. Although the methyl group does not have any adjacent carbon atoms, this is not the reason for the lack of splitting, so cannot score.

ResultsPlus
Examiner Tip

Remember it is **hydrogen** atoms on an **adjacent** carbon atoms that cause splitting in ^{1}H NMR. There is no splitting in ^{13}C NMR.

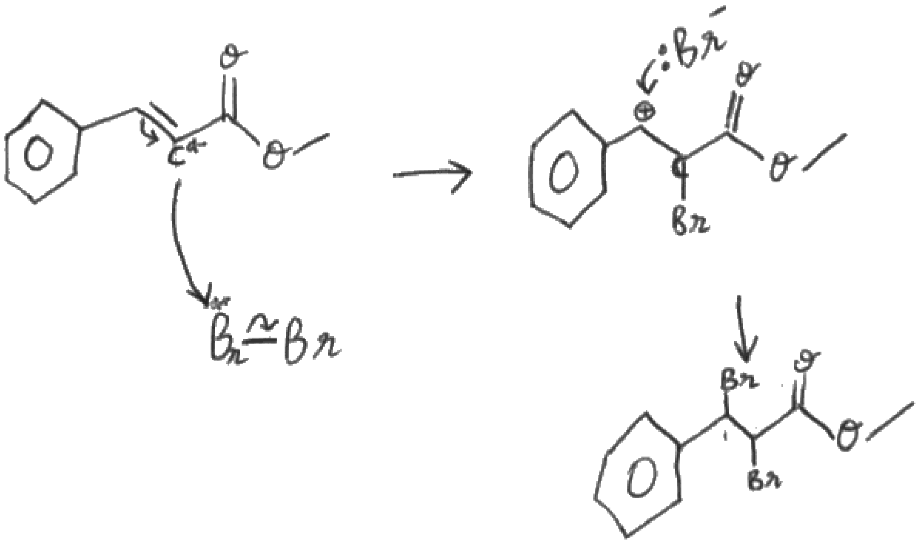
Question 4 (c) (i)

The electrophilic mechanism seemed to pose few problems for many candidates, even with the unusual context and skeletal format. Clearly this is well understood from year one of the course. The imprecise use of arrows and omission of diploes or lone pairs were inevitably seen, but the examination team felt such slips were less frequent than in previous series. A small number of candidates, generally those that found the paper as a whole challenging, attempted to show a substitution reaction of the ring. A minority understood the reaction resulted in the loss of the C=C bond, but mistakenly added both bromine atoms to the same carbon.

(c) Methyl cinnamate undergoes an addition reaction in the dark with bromine.

(i) Draw the mechanism for the reaction between methyl cinnamate and bromine, Br_2.
Include curly arrows, and relevant lone pairs and dipoles.

(4)



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Examiner Comments

This example shows how imprecise use of curly arrows impacts the mark given for a mechanism. Although an arrow is evident on the C=C bond it does not go to the ∂^+ bromine atom. The arrow that does head toward the bromine atom starts incorrectly from one of the carbon atoms in the C=C bond. The bromine molecule has the ∂^- missing and the arrow should go from the bond to the ∂^-bromine atom. However, the final two marks are awarded as shown by the mark scheme.

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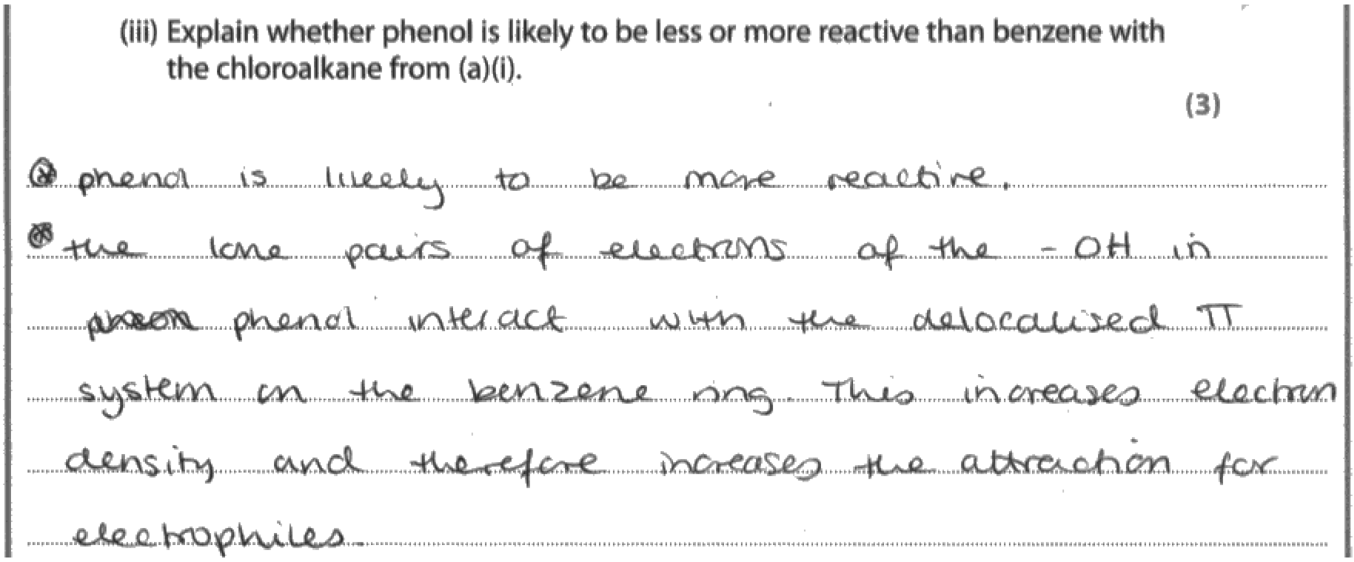
Examiner Tip

To minimise mistakes, as well as making sure you can remember mechanisms, practice explaining what is happening in terms of movement of electrons. As each double-headed arrow represents the movement of an electron pair, this will help you work out mechanisms, rather than just recall them.

Question 5 (a) (iii)



(iii) Explain whether phenol is likely to be less or more reactive than benzene with the chloroalkane from (a)(i).

(3)

⊗ phenol is likely to be more reactive.

⊗ the lone pairs of electrons of the -OH in phenol interact with the delocalised π system on the benzene ring. This increases electron density and therefore increases the attraction for electrophiles.

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Examiner Comments

This example does not score the first mark as it is not clear that the lone pair is from the **oxygen atom**. The last sentence means that both the other marks are given, as the reference to electron density is clearly linked to the ring.

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Examiner Tip

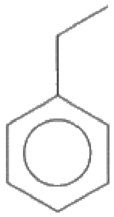
When discussing lone pairs in organic chemistry, make sure you make it clear which atom in a molecule or ion has the lone pair. For instance the nitrogen atom in NH_3 has the lone pair and the carbon atom in CN^- has the lone pair.

Question 5 (a) (i) - (ii)

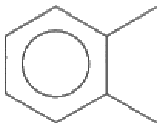
As with Q4(c)(i), examiners in the main were pleased to note that the basics of the electrophilic substitution mechanism is well taught and understood. The displayed formula in Q5(a)(i) was almost universally correct. Most candidates understood the basics of the mechanism, so picked up credit. The most frequent errors were:

- Use of $C_2H_5^+$ in the reaction with the benzene, leading to a lack of clarity as to which carbon was involved in the step.
- Showing the CH_3 group, rather than the CH_2 group attached directly to the ring.
- The central positive charge shown outside of the ‘horseshoe’.
- The open part of the ‘horseshoe’ not face the carbon in the ring to which the ethyl group was attached.
- Omission of an equation to show the reformation of the catalyst.

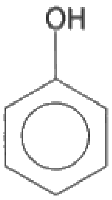
5 This question is about the arenes, ethylbenzene, xylene, and phenol, which can be identified in wine samples using gas chromatography.



ethylbenzene



xylene

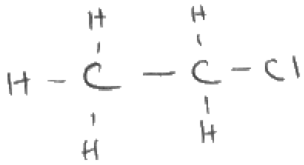


phenol

(a) Ethylbenzene can be formed by the reaction of a chloroalkane with benzene, catalysed by aluminium chloride, $AlCl_3$.

(i) Draw the **displayed** formula of the chloroalkane required for this reaction.

(1)

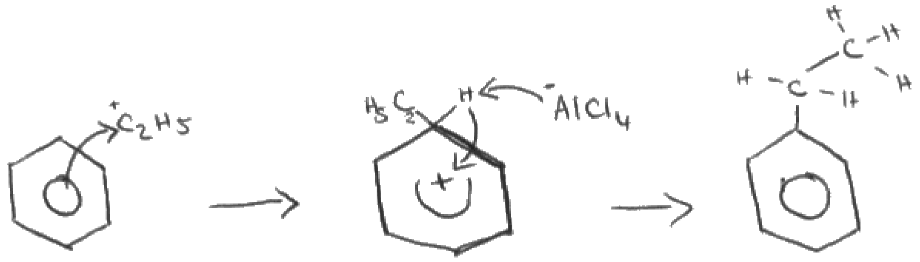


(ii) Draw the mechanism for this reaction.
Include equations showing the role of the catalyst and how it is regenerated.

(5)

Catalyst formed $C_2H_5Cl + AlCl_3 \rightarrow {}^{+}C_2H_5 + {}^{-}AlCl_4$

Mechanism



~~ref~~ regeneration of catalyst

$${}^{-}AlCl_4 + H^{+} \longrightarrow AlCl_3 + HCl$$

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Examiner Comments

This shows a fairly typical response in the mid-range, where the basic principles are evident, but a lack of detail prevents the award of all marks.

The use of $C_2H_5^+$ is acceptable in the equation but in the first step of the mechanism in it is not clear which carbon will bond to the ring, so the mark cannot be given. The intermediate is correct, however the arrow from the hydrogen atom should come from the bond from the hydrogen to the ring as it shows the electrons from the C-H bond reforming the delocalised region of the ring.

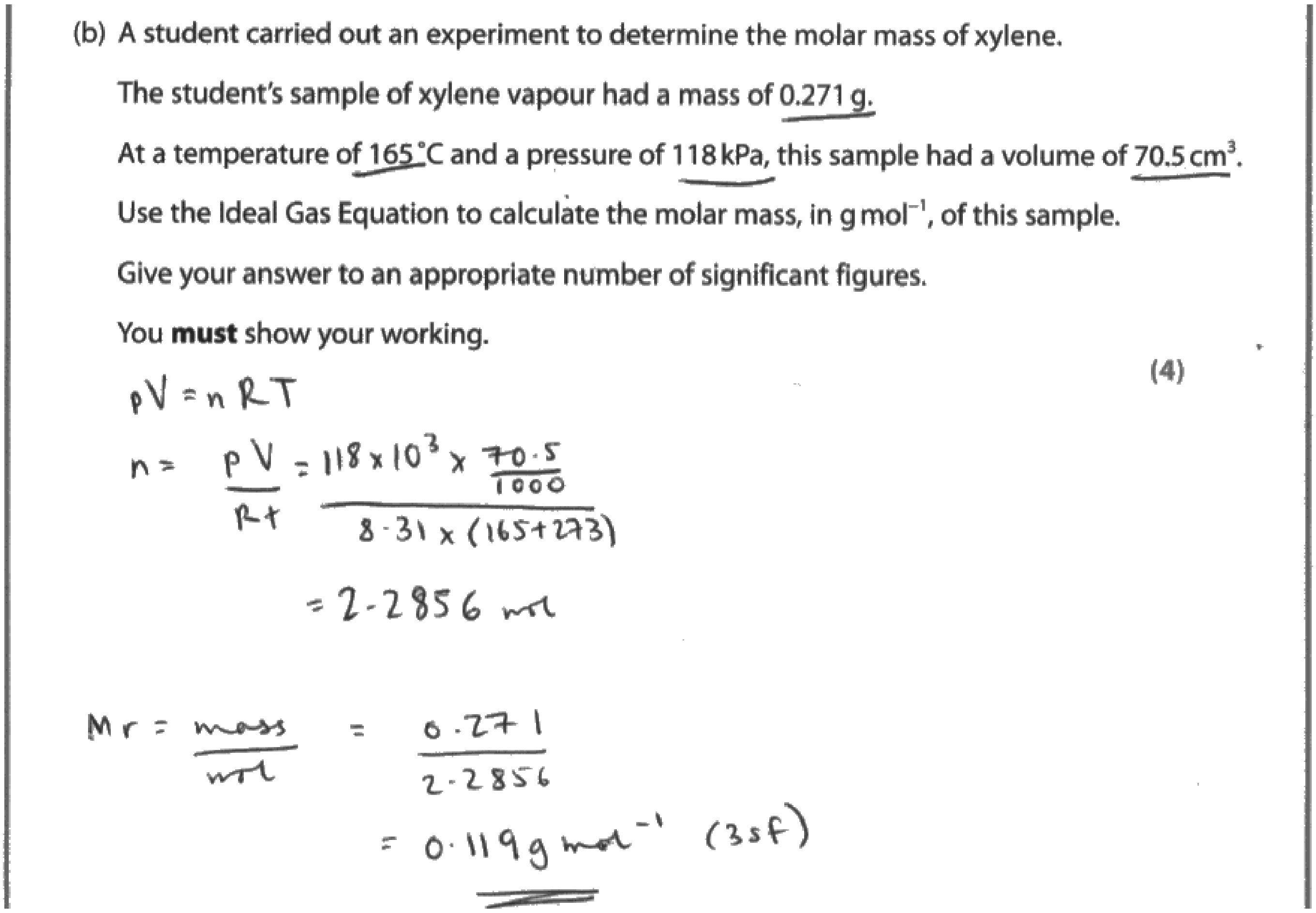
ResultsPlus
Examiner Tip

Remember a double-headed arrow represents two electrons moving, so should start where 2 electrons are evident. This could be a bond pair or a lone pair.

Question 5 (b)

Only a very small number of candidates could not recall the Ideal Gas Equation and many candidates went on to gain significant credit. The most common errors were the incorrect conversion of volume to m^3 and forgetting to convert temperature to K. Transferred error marks were available so each of these errors in isolation only lost 1 mark. It was surprising to see few candidates who made the volume error, and hence often get a numerical answer of 0.119. It would have been beneficial for candidates to have gone back and looked for a mistake as their value was clearly incorrect.

Inappropriate significant figures were most evident on this question. Even though all the data used was quoted to 3 significant figures, a number gave a final answer of 118.6 or 118.57.



(b) A student carried out an experiment to determine the molar mass of xylene.

The student's sample of xylene vapour had a mass of 0.271 g.

At a temperature of 165 °C and a pressure of 118 kPa, this sample had a volume of $70.5\ cm^3$.

Use the Ideal Gas Equation to calculate the molar mass, in $g\ mol^{-1}$, of this sample.

Give your answer to an appropriate number of significant figures.

You **must** show your working.

(4)

$pV = nRT$

$n = \frac{pV}{Rt} = \frac{118 \times 10^3 \times \frac{70.5}{1000}}{8.31 \times (165+273)}$

$= 2.2856$ mol

$Mr = \frac{\text{mass}}{\text{mol}} = \frac{0.271}{2.2856}$

$= 0.119\ g\ mol^{-1}$ (3sf)

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Examiner Comments

Converting cm^3 to dm^3, rather than m^3 is shown here, resulting in a final answer out by a factor of a thousand. Despite the unlikely molar mass, transferred error means a score of 3 marks was given.

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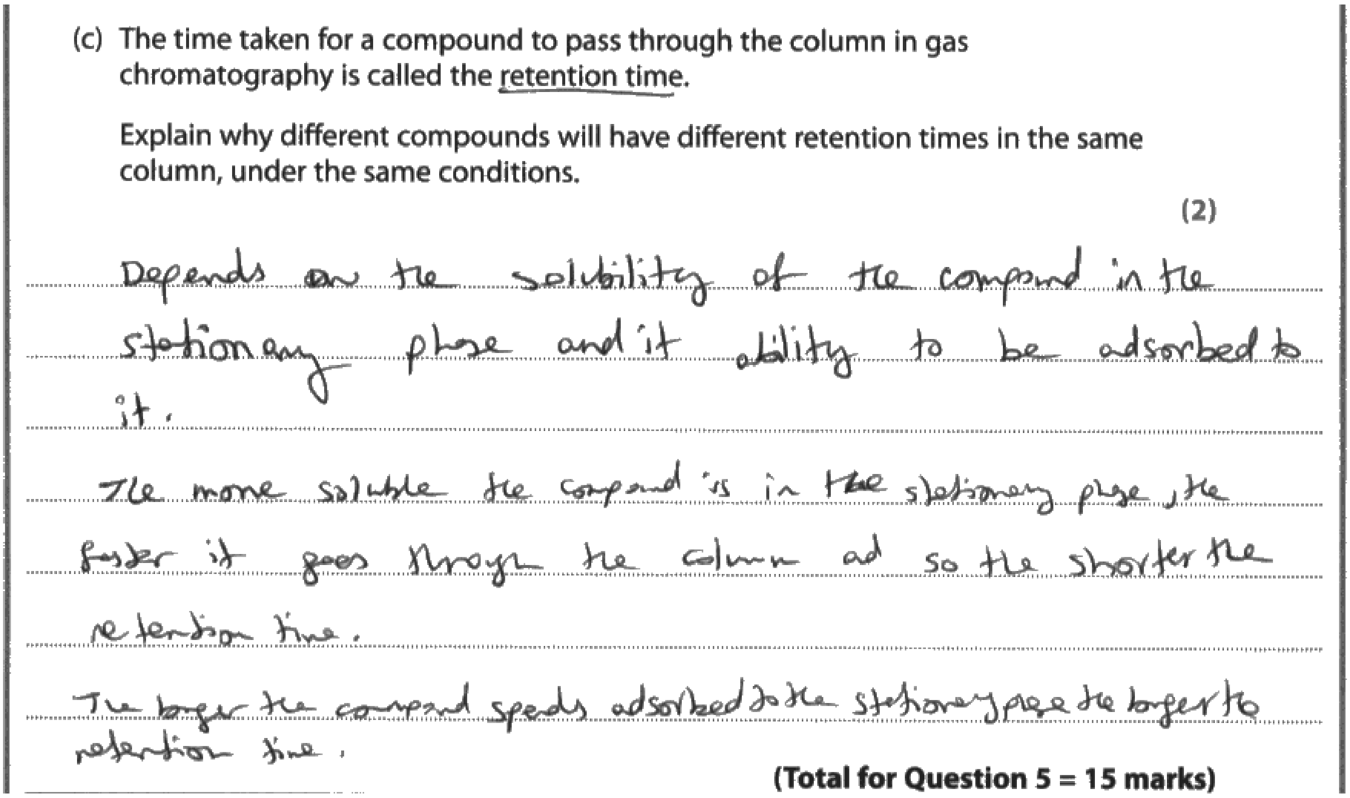
Examiner Tip

When carrying out any chemical calculation, always check to see if the magnitude of the numerical answer makes sense in the context of the question.

Question 5 (c)

Perhaps because candidates are unlikely to have direct experience of gas chromatography answers often lacked detail. The best answers made clear reference to the affinity with the stationary phase, though a surprising number didn't make the link between the strength of affinity and the resultant impact on retention, just stating that 'different affinities lead to different retention times'. Weaker answers concentrated solely on the mobile phase or on the very simplistic model that heavier molecules take longer to move. Such answers did not gain credit.



(c) The time taken for a compound to pass through the column in gas chromatography is called the retention time.

Explain why different compounds will have different retention times in the same column, under the same conditions.

(2)

Depends on the solubility of the compound in the stationary phase and it ability to be adsorbed to it.

The more soluble the compound is in the stationary phase, the faster it goes through the column and so the shorter the retention time.

The longer the compound spends adsorbed to the stationary phase the longer the retention time.

(Total for Question 5 = 15 marks)

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Examiner Comments

As the stationary phase in GC can be a liquid held on a solid support, discussing the solubility in the stationary phase is an acceptable approach. This example only scores 1 mark, because although both the solubility in the stationary phase and adsorption to the stationary phase are evident in the explanation, the statement linking greater solubility in the stationary to a shorter retention time is contradictory.

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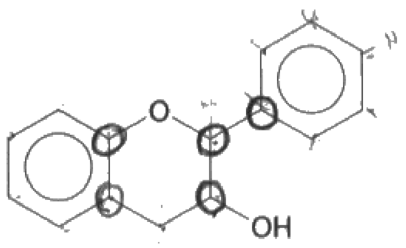
Examiner Tip

Make sure you revise both gas and high performance liquid chromatography, as well as the chromatography experiments you may have done in the laboratory.

Question 6 (a)

6 The compound flavan-3-ol is found in tea, fruit and wine.



C15
H 176
2 O

(a) Clearly label all the chiral carbon atoms in flavan-3-ol.

O = chiral carbon present

(1)

ResultsPlus
Examiner Comments

Although the 2 correct chiral centres are shown, additional incorrect ones are also circled, so the mark was not given.

ResultsPlus
Examiner Tip

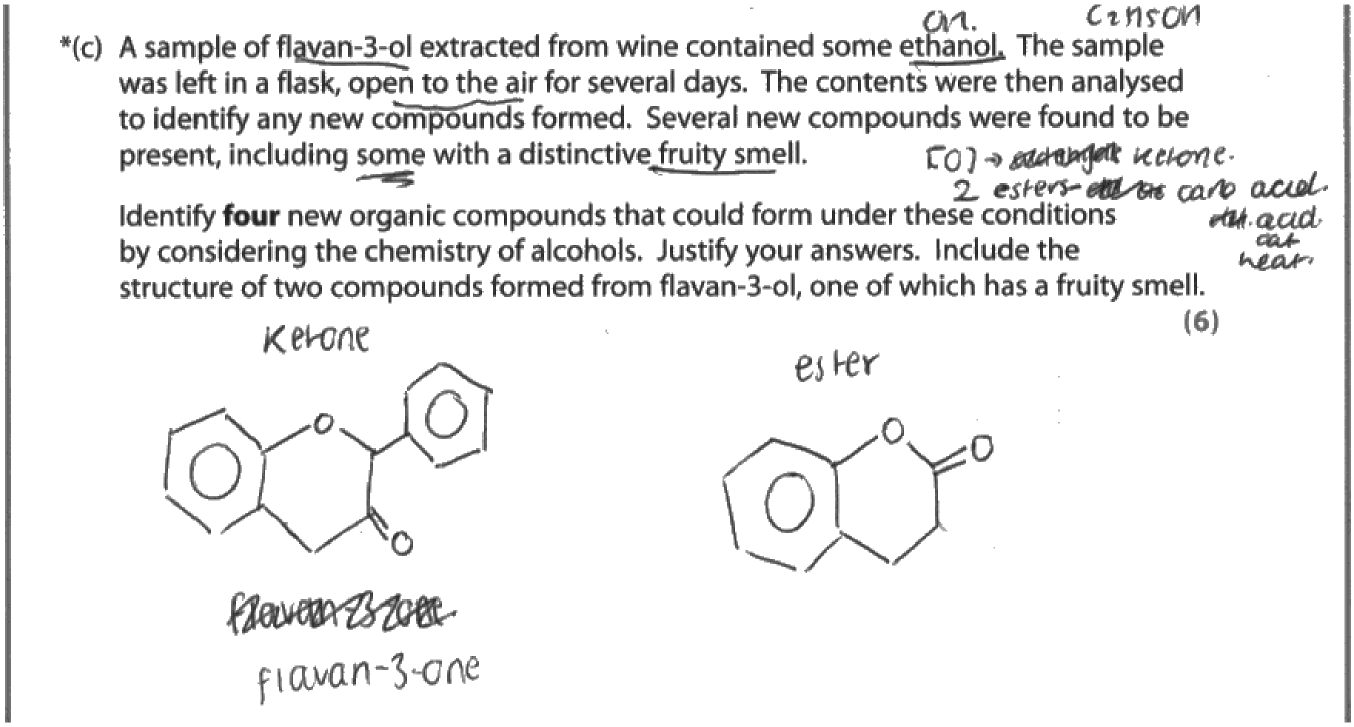
When attempting to identify chiral centres in a skeletal formula, it may be helpful to annotate the diagram to show any hydrogen atoms, to help deduce whether or not four different groups are attached.

Question 6 (b)

This task seemed low demand in the sense that candidates had to just identify the number and type of each atom and hence, write the molecular formula. However, as with Q6 (a), it provided clear discrimination at the A grade boundary. Each element was subject to miscounting, though not surprisingly mistakes in the number of hydrogen atoms were most common. Candidates can easily practice this skill in conjunction with translating skeletal formulae into displayed formulae.

Question 6 (c)

Examiners felt that this was the most discriminatory question on the paper with the full range of marks seen regularly. Weaker candidates tended to either discuss reactions of alcohols in entirely generic terms or scored 1 or 2 marks for discussion of oxidation of the ethanol to either ethanal or ethanoic acid. In the mid-range, oxidation of the flavan-3-ol was more evident, though sometimes the product was described as an aldehyde. Others didn't realise the -OH group in flavan-3-ol was secondary and insisted it could be oxidised to a carboxylic acid. The use of the term 'fruity smell' keyed many candidates into the notion that esters would form, though ethyl ethanoate was seen less frequently than the ester formed from ethanoic acid and flavan-3-ol. Fortunately, most candidates resisted the urge to include significant amounts of additional, potentially incorrect, chemistry. Hence, mistakes tended to prevent the award of marks linked to indicative points rather than lines of reasoning.



OH. C_2H_5OH

*(c) A sample of flavan-3-ol extracted from wine contained some ethanol. The sample was left in a flask, open to the air for several days. The contents were then analysed to identify any new compounds formed. Several new compounds were found to be present, including some with a distinctive fruity smell.

[O] → [illegible] ketone.
2 esters- [illegible] carb acid.
~~eth~~. acid
cat
heat.

Identify **four** new organic compounds that could form under these conditions by considering the chemistry of alcohols. Justify your answers. Include the structure of two compounds formed from flavan-3-ol, one of which has a fruity smell.

(6)

Ketone

ester

[illegible]
flavan-3-one

The flavan-3-ol is ~~an~~ secondary alcohol, this means that it can be oxidised to the ketone flavan-3-one ~~upon oxidation~~. This oxidation is possible due to the flask being left open to the air, over a long period of time.
~~An ester, which causes the sweet smell, may also be formed. This is possible~~ A carboxylic acid, formed from the ethanol, may also form. This is because when oxidised a primary alcohol will form an aldehyde and then a carboxylic acid. This oxidation may also be due to the open air flask. and ethanoic acid can be formed.

An ester, which causes the sweet smell may also be formed. This could be due to combination of the flavan-3-ol and carboxylic acid formed from ethanol. In the process, an acid catalyst is required, this may be available from H^+ produced by the breakdown of parts of ethanol or flavan-3-ol. when ~~it brakes~~ they are used to make ~~Another ester may be produced with the~~ other organic compounds.

ResultsPlus

Examiner Comments

Here, four of the indicative points are evident. The structure of the ketone is correctly shown (IP4), and the opening paragraph of page 2 refers to its formation from the oxidation of flavan-3-ol (IP1). The second paragraph starts off generically, but right at the end specifically mentions the formation of ethanoic acid (IP2). Although on page 1 the structure of the 'ester' is incorrect, paragraph 3 of page 2 describes its formation from flavan-3-ol and 'the carboxylic acid formed from ethanol' previously identified as ethanoic acid (IP5).

Four indicative points scores 3 marks, plus an additional mark for reasoning, giving a total in this case of 4 marks.

ResultsPlus

Examiner Tip

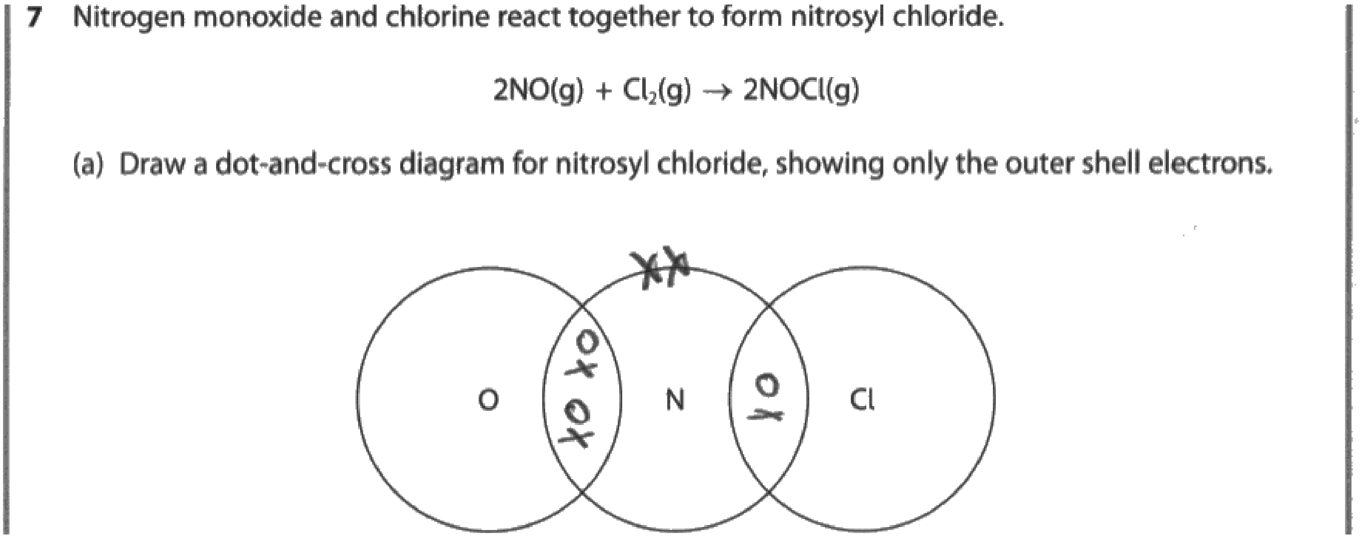
It's helpful to use generic recall of reactions such as primary alcohols oxidising to form aldehydes and carboxylic acids when revising. However, in an exam situation you will nearly always have to apply this knowledge to the compounds in a question, so your final answers should always be specific.

Question 7 (a)

Most candidates could draw the correct dot-and-cross diagram. When full credit was not scored it was generally because:

- The lone pair on the central nitrogen was omitted.
- Only electrons around the central nitrogen were shown.
- Oxygen was shown with 10 electrons in its outer shell.
- A single bond was shown between the nitrogen and oxygen atoms.

A minority of candidates show electrons singly rather than in pairs. Whilst this still would be credited if the numbers were correct, it must make it more difficult for them to check their work, opening up the potential for a slip, and hence a lost mark.



7 Nitrogen monoxide and chlorine react together to form nitrosyl chloride.

$$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$$

(a) Draw a dot-and-cross diagram for nitrosyl chloride, showing only the outer shell electrons.

ResultsPlus
Examiner Comments

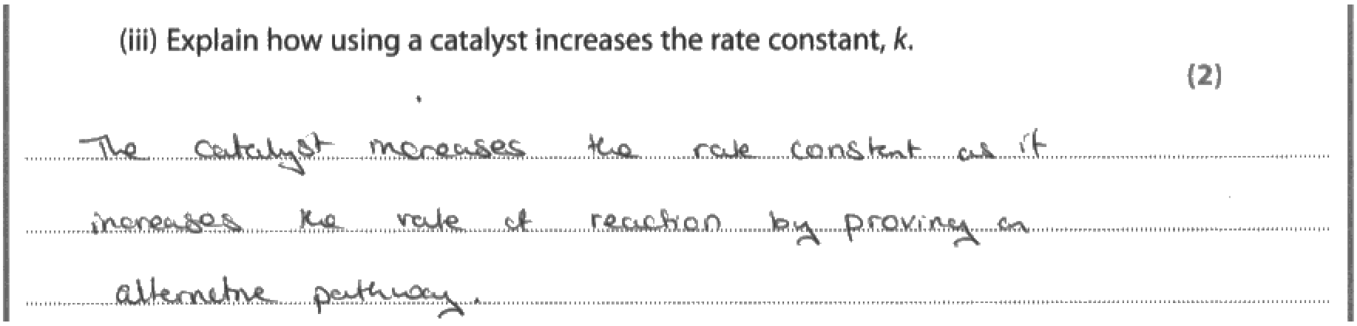
This incomplete answer could only score 1 mark, as the outer shells of both the chlorine and oxygen atoms were incomplete.

ResultsPlus
Examiner Tip

Remember to check the number of electrons in all outer shells of dot-and-cross diagrams.

Question 7 (b) (iii)

Candidates tended to focus on the rate constant in this question and as a result spent time trying to justify their answer in terms of the rate equation rather than the role of the catalyst. Those who did discuss the catalyst often gave incomplete answers that tended to ignore either the idea of an alternative pathway or the lower activation energy.



(iii) Explain how using a catalyst increases the rate constant, *k*.

(2)

The catalyst increases the rate constant as it increases the rate of reaction by proving an alternative pathway.

ResultsPlus
Examiner Comments

Although this answer does discuss the catalyst they have not linked the 'alternative pathway' to a lower activation so cannot score any marks.

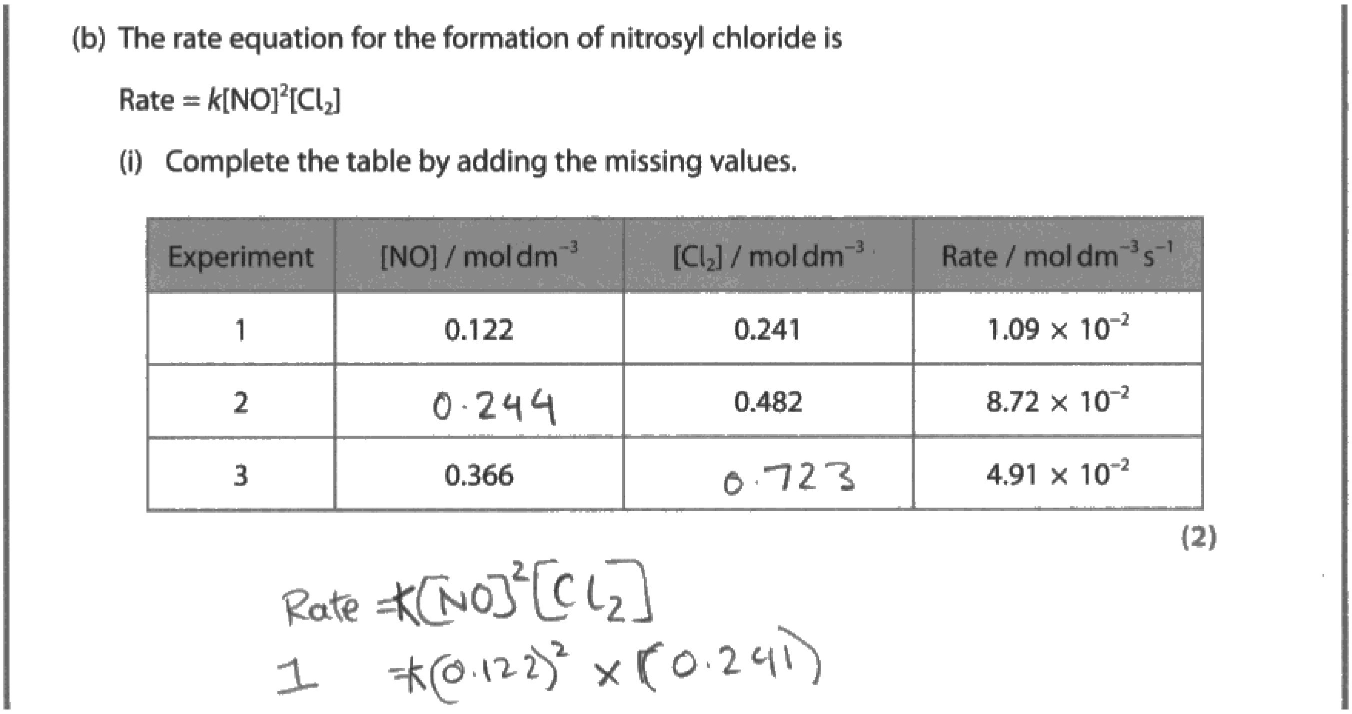
ResultsPlus
Examiner Tip

When revising try to consider how simple ideas can be framed in a variety of contexts. This will help you prepare for the eventuality of a common type of question being asked in a different, less usual context.

Question 7 (b) (i) - (ii)

Looking at the evidence seen in scripts most candidates attempted to answer Q7(b)(i) by comparing the experimental data. Most were able to deduce the concentration of NO in experiment 1. The concentration of Cl_2 in experiment 3 proved more challenging and sometimes those who successfully processed the experimental data quoted their value to 4 significant figures, which was not allowed. A small number of candidates thought carefully about their approach, and checked their answers using their calculated value for *k*.As a result, they tended to score both marks.

Calculations in Q7 (b)(ii) were of a high standard, though some candidates found it difficult to deduce the correct units even though examiners could see they had attempted to work out their answer, rather than rely on memory.



(b) The rate equation for the formation of nitrosyl chloride is

Rate = $k[NO]^2[Cl_2]$

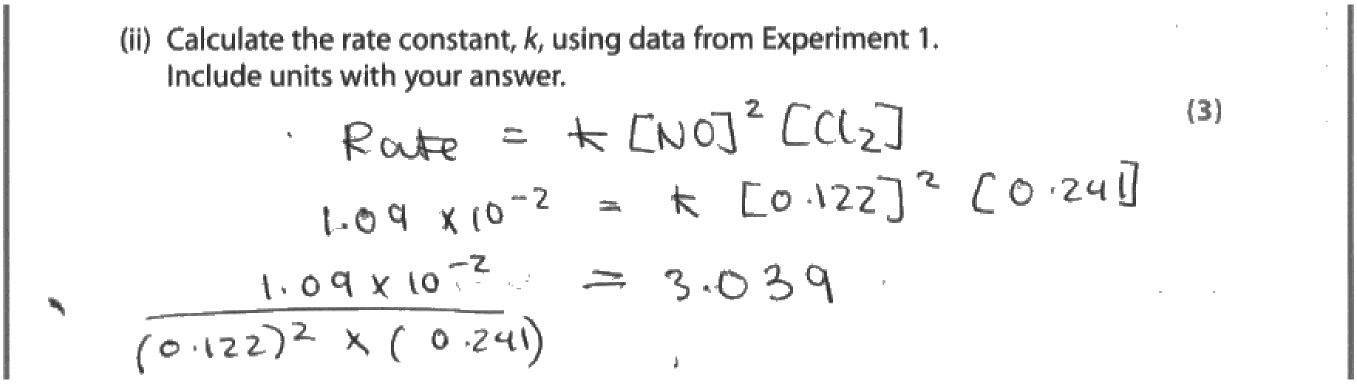
(i) Complete the table by adding the missing values.

Experiment	[NO] / mol dm^{-3}	[Cl_2] / mol dm^{-3}	Rate / mol dm^{-3} s^{-1}
1	0.122	0.241	1.09×10^{-2}
2	0.244	0.482	8.72×10^{-2}
3	0.366	0.723	4.91×10^{-2}

(2)

$$\text{Rate} = k[NO]^2[Cl_2]$$

$$1 \quad = k(0.122)^2 \times (0.241)$$



(ii) Calculate the rate constant, *k*, using data from Experiment 1.
Include units with your answer.

(3)

$$\text{Rate} = k[NO]^2[Cl_2]$$

$$1.09 \times 10^{-2} = k[0.122]^2[0.241]$$

$$\frac{1.09 \times 10^{-2}}{(0.122)^2 \times (0.241)} = 3.039$$

ResultsPlus
Examiner Comments

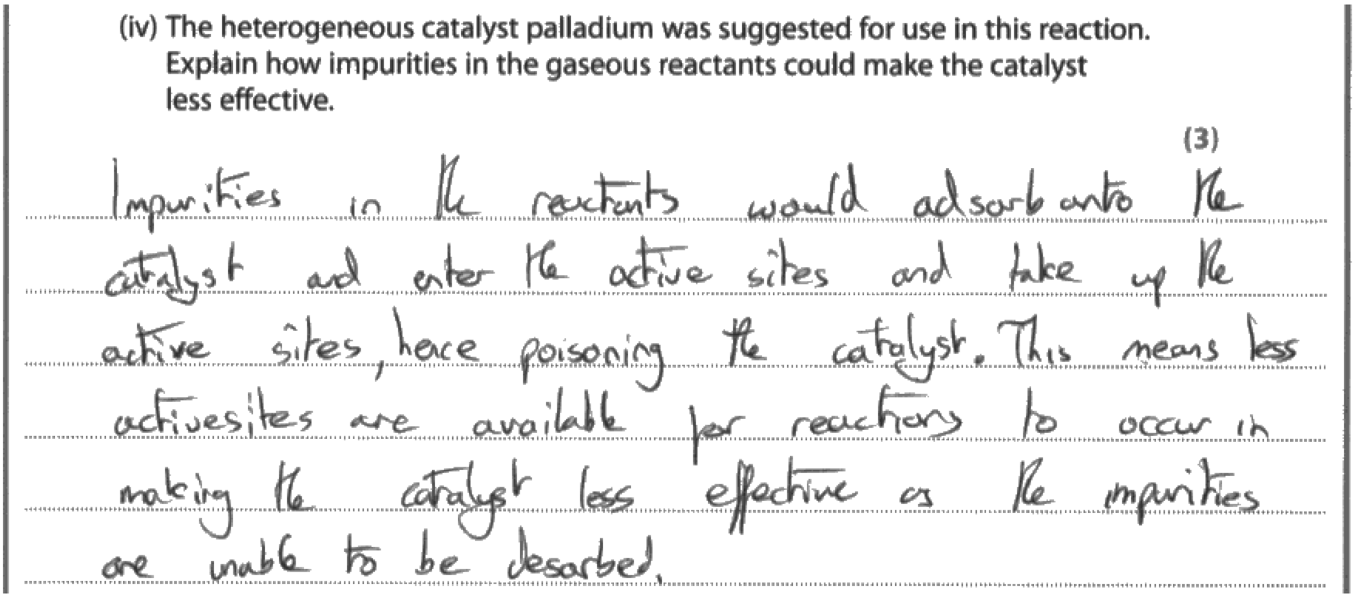
In Q7 (b)(i) the candidate has not been able to factor in the effect of two variables together, so misses out on the second mark. The calculation in Q7(b)(ii) is correct but despite the stem, no attempt has been made to work out the units for *k* so only 2 marks are given.

ResultsPlus
Examiner Tip

Practice working out units for *k* in rate equations with a range of overall orders.

Question 7 (b) (iv)

The overall outcomes in this question pleased many examiners, though it was common to see candidates spend time discussing how heterogeneous catalysts work, before embarking on answering the question set. Lots of responses accessed the first two marks, often in terms of the impurity adsorbing onto the catalyst surface, followed by the subsequent reduction in surface area for the reactants. The ideas that the impurities form strong bonds to the surface or do not desorb from the surface were less widely noted. The use of the term ‘a**b**sorption’ which in this past has been seen often and is not allowed was rare.



(iv) The heterogeneous catalyst palladium was suggested for use in this reaction.
Explain how impurities in the gaseous reactants could make the catalyst less effective.

(3)

Impurities in the reactants would adsorb onto the catalyst and enter the active sites and take up the active sites, hence poisoning the catalyst. This means less activesites are available for reactions to occur in making the catalyst less effective as the impurities are unable to be desorbed.

ResultsPlus
Examiner Comments

This is a nice illustration of a response given 3 marks. The candidate has not wasted time discussing how the catalyst works in the absence of impurities, but has focused on exactly the requirement asked in the stem.

ResultsPlus
Examiner Tip

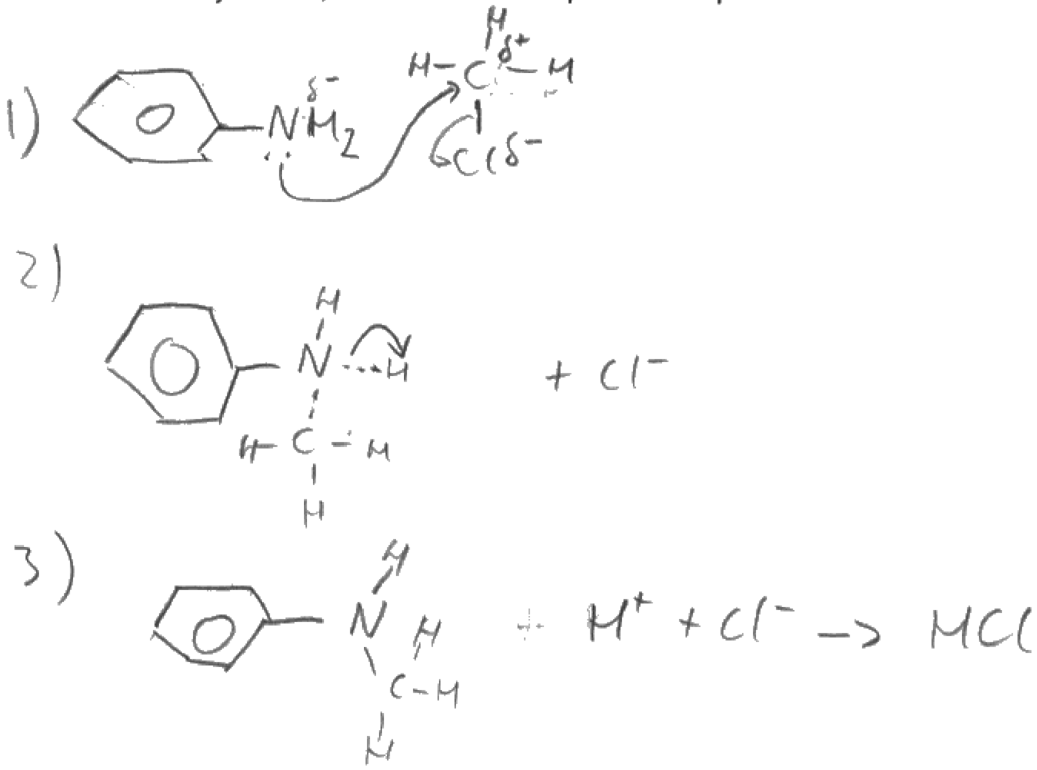
Read the stem carefully to help you avoid the temptation to waste time writing down everything you can remember about a concept, rather than just answering what has been asked.

Question 8 (a) (ii)

Of the three mechanisms on the paper, this was the most effective discriminator. Some candidates had clearly not remembered the reaction of ammonia with halogenoalkanes, so found it difficult to know where to start. Others either did not look at the structural formulae or could not interpret them so showed the halogenoalkane attacking the ring. Many of the more able candidates could link their knowledge from year 1 of the course to this mechanism, so scores of 3 or 4 marks were commonplace in this region. The previous comments on precision of arrow placement, as well as the importance of including relevant lone pairs apply here as well as Q5 (a)(ii) and Q4 (c)(i).

(ii) Draw the mechanism for the reaction in Step **1**.
Include curly arrows, and relevant lone pairs and dipoles.

(4)



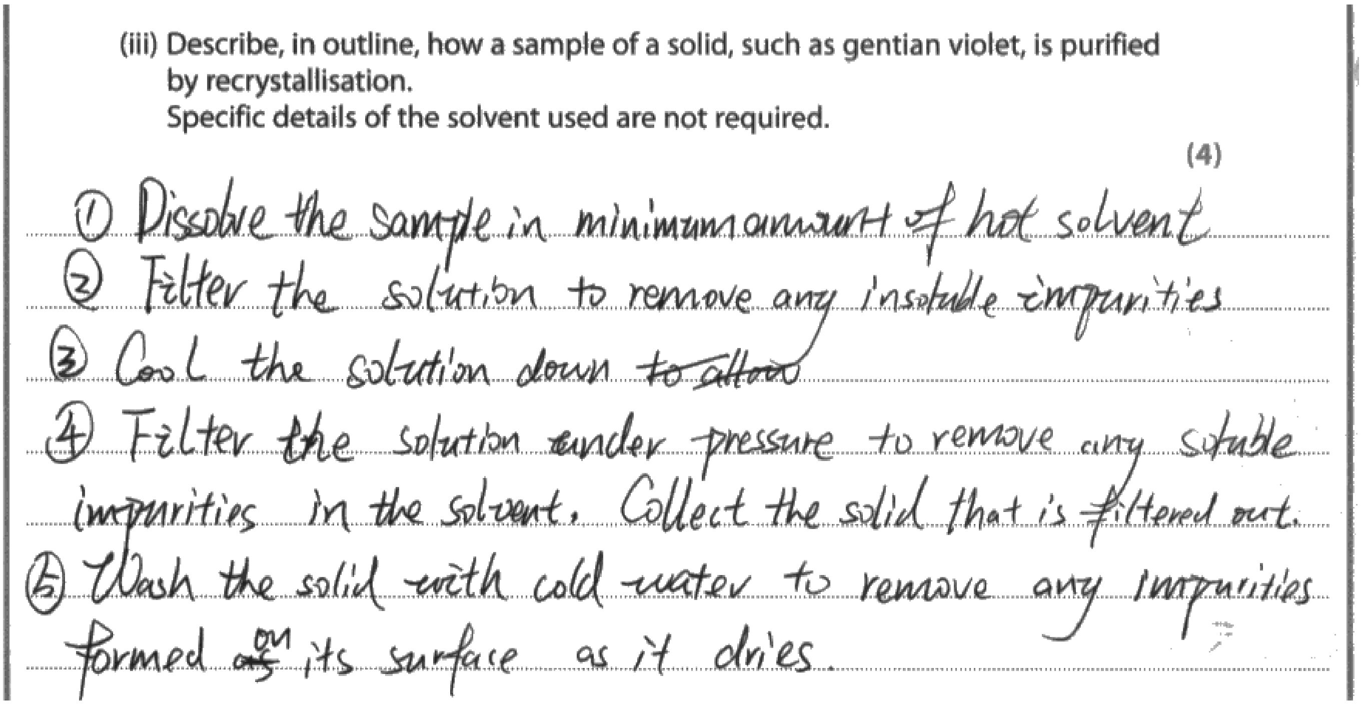
ResultsPlus
Examiner Comments

This candidate understands the initial interaction between the amine and the halogenoalkane and scores the first two marks. From then on no further credit was given as the intermediate is missing the positive charge on the nitrogen, and the N-H bond pair is moving in the wrong direction.

ResultsPlus
Examiner Tip

Practice applying all the mechanisms you learn on unfamiliar molecules, as well as the examples you see in your notes or textbooks.

Question 8 (a) (iii)



(iii) Describe, in outline, how a sample of a solid, such as gentian violet, is purified by recrystallisation.
Specific details of the solvent used are not required.

(4)

① Dissolve the sample in minimum amount of hot solvent
② Filter the solution to remove any insoluble impurities
③ Cool the solution down ~~to allow~~
④ Filter the solution under pressure to remove any soluble impurities in the solvent. Collect the solid that is filtered out.
⑤ Wash the solid with cold water to remove any impurities formed ~~of~~ on its surface as it dries.

ResultsPlus
Examiner Comments

This is a sensible approach to this type of question as the numbering helps the candidate order each step logically.The only piece of detail missing is a technique to dry the crystals, so 3 marks were given.

ResultsPlus
Examiner Tip

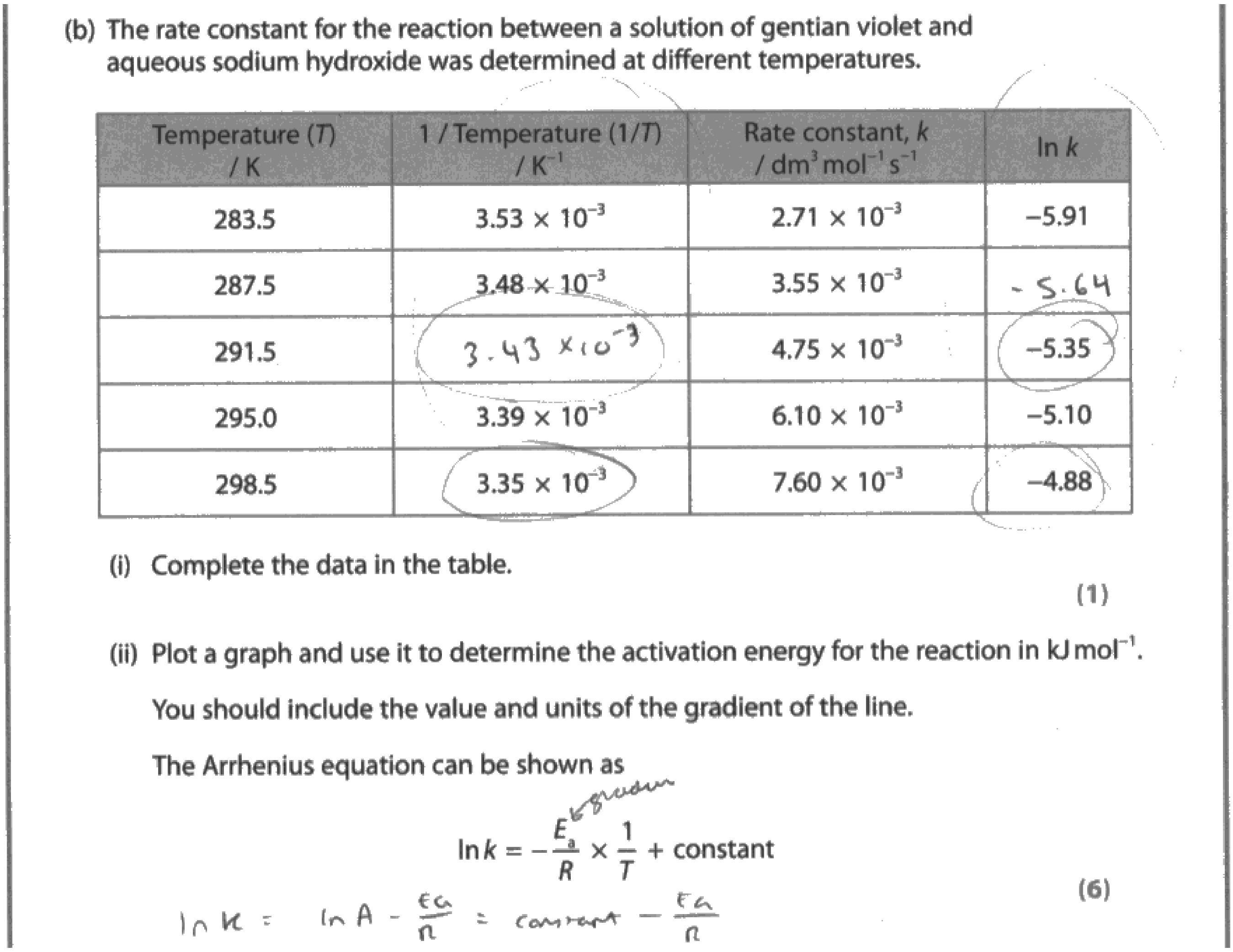
When you carry out a recrystallisation in the core practicals, make up a mnemonic to help you get the stages in the correct order. For instance, if you make up a phrase using the highlighted letters below, in the same order, you will (hopefully) be able to recall the key parts of the process in sequence.

Dissolve in **M**inimum **H**ot **S**olvent, leave to **R**ecrystallise, **V**acuum **F**iltration, **D**ry between **F**ilter **P**aper

Question 8 (b) (i) - (ii)

This question was very similar in structure to examples on previous papers, and some examiners felt there was a resultant improvement in the quality of response seen, in particular with regard to low demand skills such as labelling axes. However, a significant minority did not know what data to plot, so scoring was limited in Q8 (b)(ii). The size of the graph paper given was designed to provide a level of challenge regarding the scale and a number of candidates were not aware of, or ignored the requirement to ensure that **points plotted** cover at least half the available space.

The units for the gradient were often absent, despite being asked for in the 2017 paper. Gradients in the correct range were often seen and nearly always shown with a negative sign. Most candidates who calculated a correct gradient went on to determine the numerical value for the activation but sometimes missed the mark due to confusion between J mol^{-1} and kJ mol^{-1}.



(b) The rate constant for the reaction between a solution of gentian violet and aqueous sodium hydroxide was determined at different temperatures.

Temperature (T) / K	1 / Temperature ($1/T$) / K^{-1}	Rate constant, k / dm^3 mol^{-1} s^{-1}	ln k
283.5	3.53×10^{-3}	2.71×10^{-3}	−5.91
287.5	~~3.48×10^{-3}~~	3.55×10^{-3}	−5.64
291.5	3.43×10^{-3}	4.75×10^{-3}	−5.35
295.0	3.39×10^{-3}	6.10×10^{-3}	−5.10
298.5	3.35×10^{-3}	7.60×10^{-3}	−4.88

(i) Complete the data in the table.

(1)

(ii) Plot a graph and use it to determine the activation energy for the reaction in kJ mol^{-1}.

You should include the value and units of the gradient of the line.

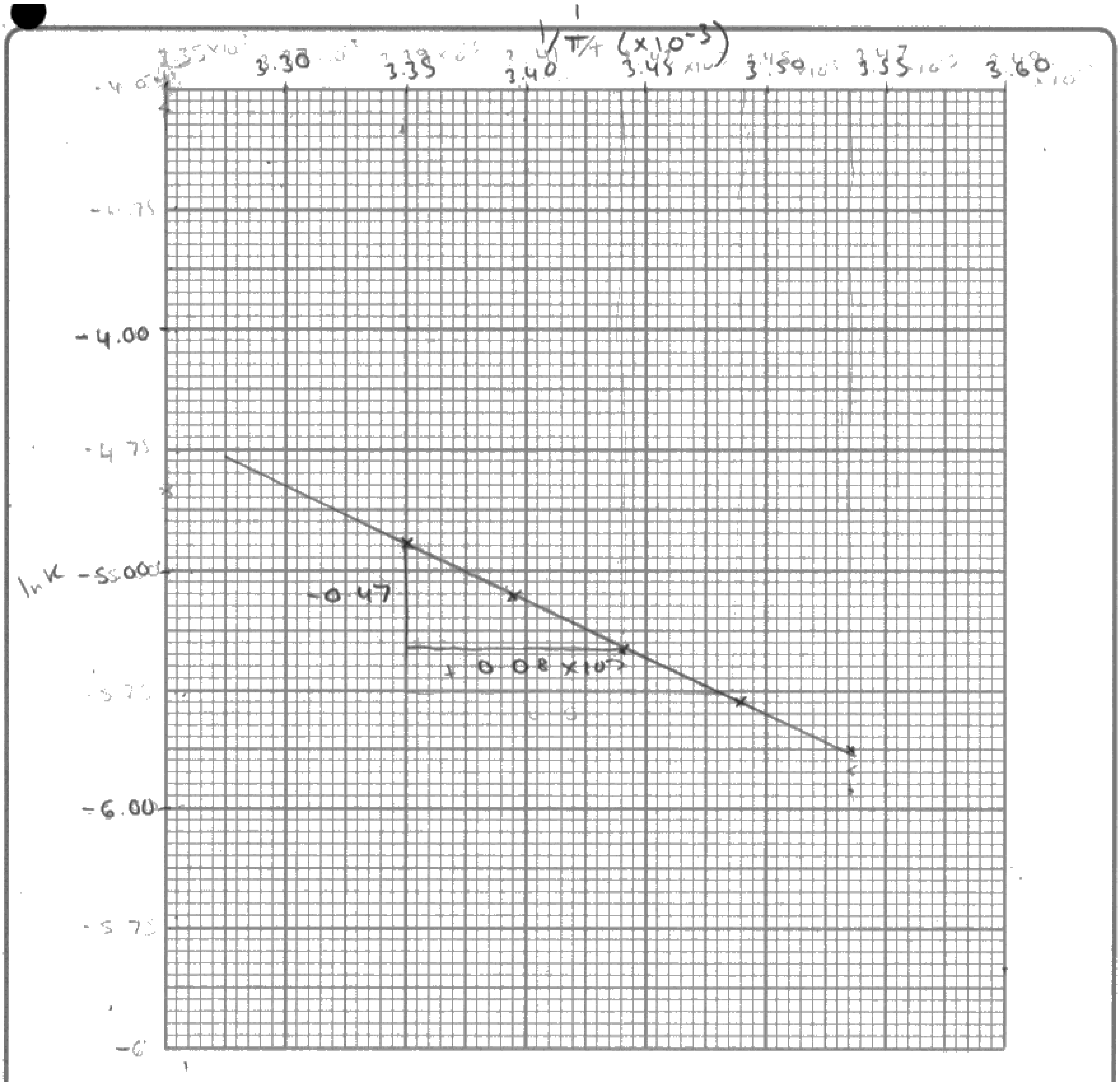
The Arrhenius equation can be shown as

gradient

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

(6)

$\ln k = \ln A - \frac{Ea}{R} = \text{constant} - \frac{Ea}{R}$



Gradient

gradient = − 5875

Activation energy

~~706~~ 707.0 J

ResultsPlus
Examiner Comments

This candidate scored 2 marks for Q8 (b)(ii) and illustrates the four most common errors seen.

Firstly, they do not score M1 on the mark scheme, as the units are missing on the x axes. M2 is not given as the points plotted only cover about 2 of the large square vertically. M3 is given for the plotting of the points and the line of best fit. The gradient is in range so M4 is given but has no units so does not score M5. The activation energy is inconsistent with the gradient and has incorrect units, so missed M6.

ResultsPlus
Examiner Tip

Make sure your scale is such that the points plotted covered at least half the available space in both directions.

Paper Summary

Based on their performance on this paper, candidates are offered the following advice:

- Read the stem of each question carefully to ensure you focus your response more precisely on what the question is asking.

- Make sure you try to give answers that are specific to the compounds in the question asked, rather than discussing ideas in general terms.

- Take care to revise all the required mechanisms from the specification and practice applying them to a variety of compounds.

- When revising mechanisms try to explain what is happening as well as recalling each step as a diagram.

- When carrying out practical work in Organic Chemistry, make sure you can describe key tasks, such as recrystallisation in a logical order.

- Practice drawing shapes of molecules to clearly show there 3-dimensional nature.

- When plotting a graph, design your scale so the plotted points take up at least half the available space.

Grade Boundaries

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

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