Examiners' Report
June 2017

GCE Chemistry 9CH0 02

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Introduction

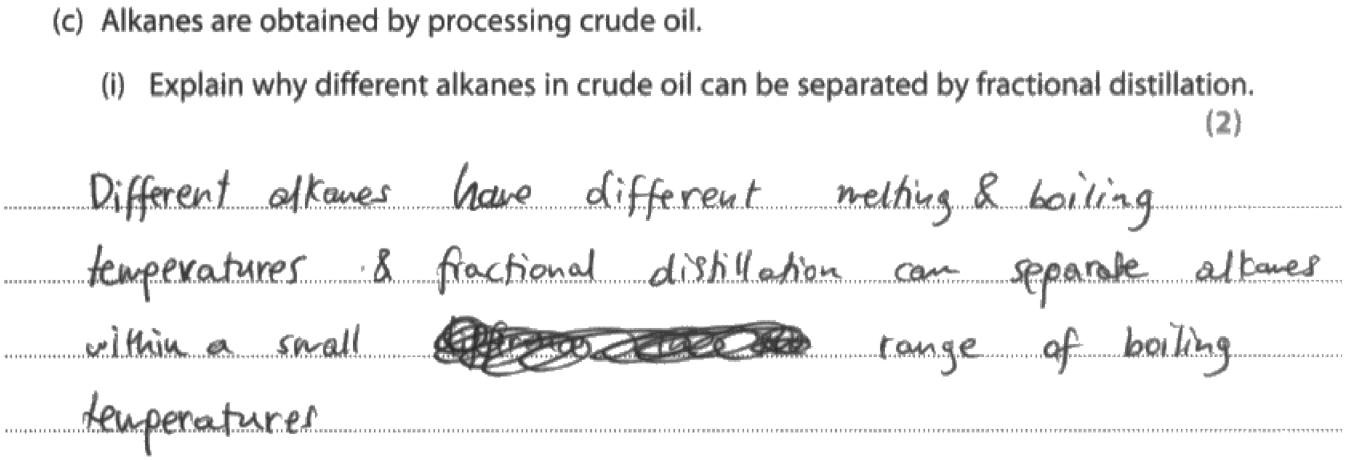
This was the first Paper 2 of the new A Level Chemistry specification and can include questions on topics from all of organic chemistry and some questions from the physical chemistry topic areas such as kinetics. The assessment is for 1 hour and 45 minutes and consists of 90 marks, which can be assessed through a range of question styles from multiple-choice to extended writing. The paper includes at least 20% assessment of level 2 mathematics, spread throughout the paper and on various topic areas. There is a significant difference in the style of questions in comparison to previous specifications, with a particular emphasis being on the removal of supportive scaffolding and instead on the use, where possible, of a single command word from the list of such in appendix 7 of the new specification.

It was evident from the high mean on the paper that it was very accessible to all candidates and also provided the opportunity for candidates of all levels of ability to demonstrate their knowledge and understanding. There was a wide spread of marks obtained by candidates and no evidence that candidates lacked sufficient time to complete the paper. The questions on the paper were set in some novel situations and also in some more familiar situations, all of which enabled candidates to apply their knowledge and understanding of chemistry.

The successful candidates made sure that they read through the questions carefully and made sure that their answers addressed all of the necessary demands. Chemical terminology was used appropriately and great care was taken when drawing diagrams and reaction mechanisms to ensure that no elementary errors were made. The less successful candidates tended to rush through their answers and often only gave cursory responses which did not correspond to the demands of the question set. Careless errors were seen in diagrams and reaction mechanisms which could have easily been remedied if a double-check on the answer had been made. There are valuable lessons to learn from such candidates which can be found in the key points highlighted in the summary.

Question 1 (c) (i)

Reference to the differing boiling temperatures of alkanes without an explanation was often given in weaker responses, while in stronger responses candidates added a justification which drew attention to the carbon chain length and/or the strength of the London forces. On rare occasions there was an incorrect reference to hydrogen bonding as being the intermolecular forces between alkanes. This lost marks and serves to emphasise the need to use the right chemical terms when giving an explanation.



(c) Alkanes are obtained by processing crude oil.

(i) Explain why different alkanes in crude oil can be separated by fractional distillation.

(2)

Different alkanes have different melting & boiling temperatures & fractional distillation can separate alkanes within a small [illegible] range of boiling temperatures

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Examiner Comments

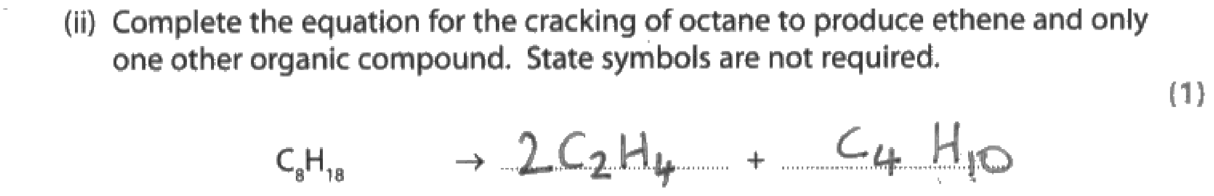
This response refers to melting temperatures which is not appropriate in the context of a fractionating column. Because there is reference to different alkanes having different boiling temperatures, the first marking point was awarded. However, there is no reason given for this difference and so the second marking point was not awarded.

ResultsPlus
Examiner Tip

If the command word is 'Explain', then the answer "must contain some element of reasoning/justification". The command words and what is expected in answers are detailed in the specification.

Question 1 (c) (ii)

A very well-answered question with the vast majority of candidates gaining the mark.



(ii) Complete the equation for the cracking of octane to produce ethene and only one other organic compound. State symbols are not required.

(1)

$C_8H_{18} \rightarrow 2C_2H_4 + C_4H_{10}$

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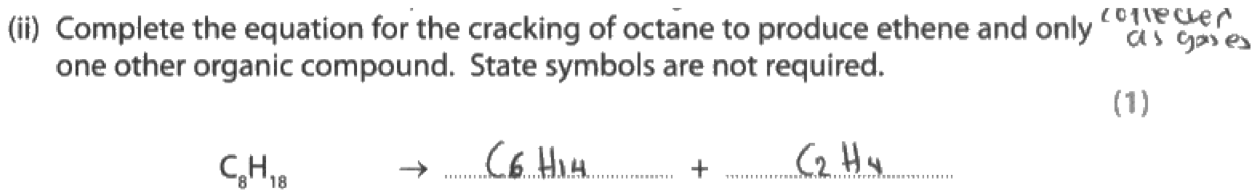
Examiner Comments

This is one of the correct mark scheme alternatives that was not seen very often but was awarded the mark.



(ii) Complete the equation for the cracking of octane to produce ethene and only one other organic compound. State symbols are not required.

collected as gases

(1)

$C_8H_{18} \rightarrow C_6H_{14} + C_2H_4$

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Examiner Comments

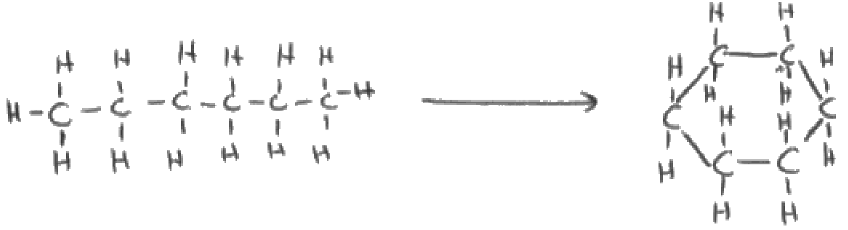
It was much more common for the first product in the equation to be C_2H_4 because the question stated that the products were ethene and one other. However it was of course acceptable for these substances to be given in a different order because the order of substances in a chemical equation does not matter and so this was awarded the mark.

Question 1 (c) (iii)

The most common error made by candidates was the omission of the hydrogen product which is in addition to the cyclohexane. The question instructed candidates to use "displayed formulae" because then the difference of two hydrogens should have been more apparent. However a significant number of candidates gave correct skeletal formulae, which was credited, but this did not help them in answering the question. In addition some responses had 'semi-skeletal' formulae, where the carbon atoms were not shown but the hydrogen atoms were. Centres are advised to get their candidates to practise writing the different types of formulae so that they are comfortable and confident in their use in different settings.

(iii) Write the equation for the reforming of hexane into cyclohexane, using **displayed** formulae for the organic compounds. State symbols are not required.

(1)



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Examiner Comments

This is an example of a response which has not balanced for atoms and thus has omitted the formation of H_2 as the other product. 0 marks.

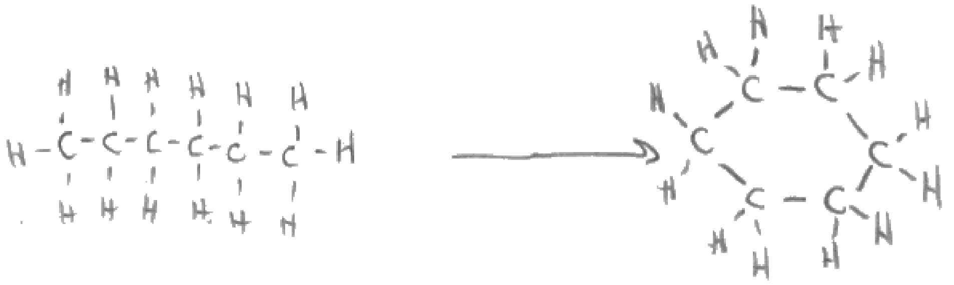
ResultsPlus

Examiner Tip

Always double check that equations are balanced for both charge and for atoms.

(iii) Write the equation for the reforming of hexane into cyclohexane, using **displayed** formulae for the organic compounds. State symbols are not required.

(1)



$+2H^+$

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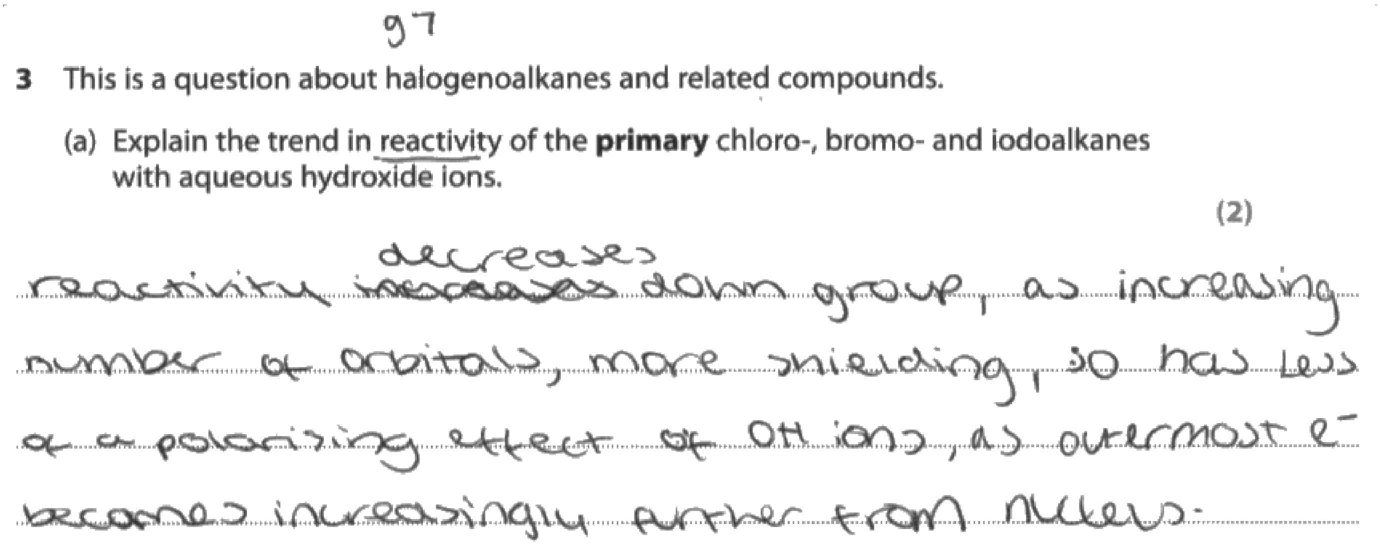
Examiner Comments

This is an example of a response that does balance the equation for atoms but unfortunately does not balance for charge. There are no charged particles on the reactant side and so the overall charge is neutral but the product side has an overall charge of +2 which means that the response is not correct and does not score the mark.

Question 3 (a)

About 60% of the candidates could give an effective reasoned argument concerning the trend in hydrolysis of halogenoalkanes and its relation to the carbon-halogen bond strength rather than the carbon-halogen bond polarity, and thus were able to score both marks. However there were a small number of responses referring to the reactivity trend of the halogens rather than halogenoalkanes. Candidates need to make sure that the correct terms are used so that there is no ambiguity over the substances that they are referring to. In addition, occasionally responses referred to ions or ionic radius as part of an explanation of the trend in hydrolysis of halogenoalkanes but this is an incorrect use of the term 'ion' as halogenoalkanes are covalent. It is likely that candidates did not actually think that the halogenoalkanes are ionic but need to be more careful in the phrasing of their response.



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3 This is a question about halogenoalkanes and related compounds.

(a) Explain the trend in reactivity of the **primary** chloro-, bromo- and iodoalkanes with aqueous hydroxide ions.

(2)

reactivity ~~increases~~ decreases down group, as increasing number of orbitals, more shielding, so has less of a polarising effect of OH ions, as outermost e⁻ becomes increasingly further from nucleus.

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Examiner Comments

This is an example of a response which has an incorrect trend and so was given zero for this item. The reference to the number of orbitals rather than shells of electrons being responsible for shielding is one aspect of the confusion. This is applied to the polarising of the hydroxide ions rather than the strength of the carbon-halogen bond.

Question 3 (b)

The majority of candidates could write the mechanism for this nucleophilic substitution reaction in part (i) in a clear and effective manner. The usual errors/omissions for a mechanism of this kind were seen, such as missing bond dipoles, missing species charges (particularly so for the transition state), missing lone pairs of electrons and missing bromide ion product. The question was very specific in requesting lone pairs and dipole so candidates needed to ensure that these are included in their mechanisms.

In stronger responses to part (ii), candidates demonstrated their understanding but frequently the use of nitric acid was missed by others. It was pleasing, although unnecessary in this instance, for an explanation for the use of nitric acid to be given. Further, these candidates appreciated that the acid could not be hydrochloric acid or sulfuric acid because these produce precipitates themselves with silver nitrate.

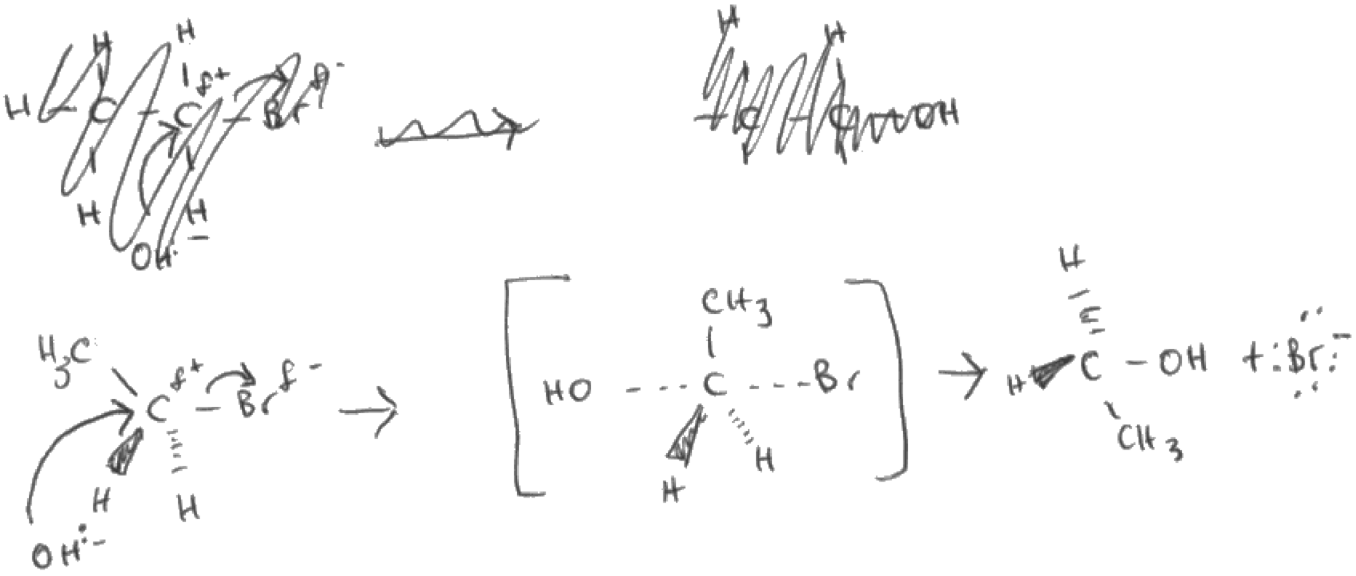
It was not uncommon for candidates to give additional information in part (ii) on the use of ammonia solutions to confirm the precipitate as silver bromide.

(b) In aqueous sodium hydroxide, 1-bromoethane reacts to produce ethanol.

(i) Write the mechanism for this reaction, including all relevant curly arrows, lone pairs and dipoles. Include the transition state.

less electron deficient and so nucleophiles are less attracted to it

(4)



(ii) Give the reagents that are used to test that bromide ions are formed in this reaction mixture. Include the result of the test.

(2)

You use nitric acid and silver nitrate and if a cream Preapitate forms then bromide ions are present. To confirm this further you add dilute ammonia, and if the precipitate dissolves, then it confirms the presence of bromide ions

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Examiner Comments

The reaction mechanism in part (i) scores 2 marks for the curly arrow from the C-Br bond and C-Br bond dipole, plus the correct products. Note that the curly arrow from the hydroxide ion does not start from the lone pair of electrons and so does not score. The transition state is lacking an overall negative charge and so does not score. In part (ii) this response does correctly include the use of nitric acid with silver nitrate for the first mark and then gives the correct observation for the second mark. The subsequent addition of ammonia was ignored.

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Examiner Tip

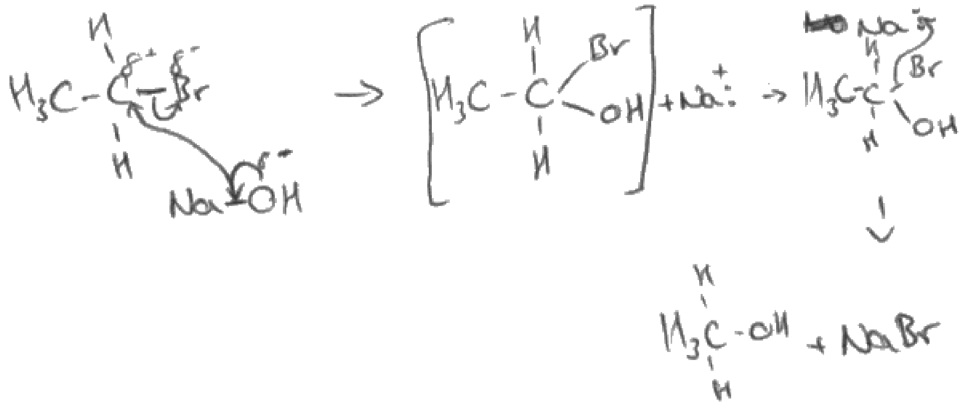
This specification requires the curly arrow to start from the lone pair of electrons and so make sure that care is taken when drawing these arrows from a nucleophile.

(b) In aqueous sodium hydroxide, 1-bromoethane reacts to produce ethanol.

(i) Write the mechanism for this reaction, including all relevant curly arrows, lone pairs and dipoles. Include the transition state.

(4)

$NaOH + C_2H_5Br \rightarrow C_2H_5OH + NaBr$



(ii) Give the reagents that are used to test that bromide ions are formed in this reaction mixture. Include the result of the test.

(2)

Silver nitrate, if it goes a creamy yellow colour then Bromine ions must be present

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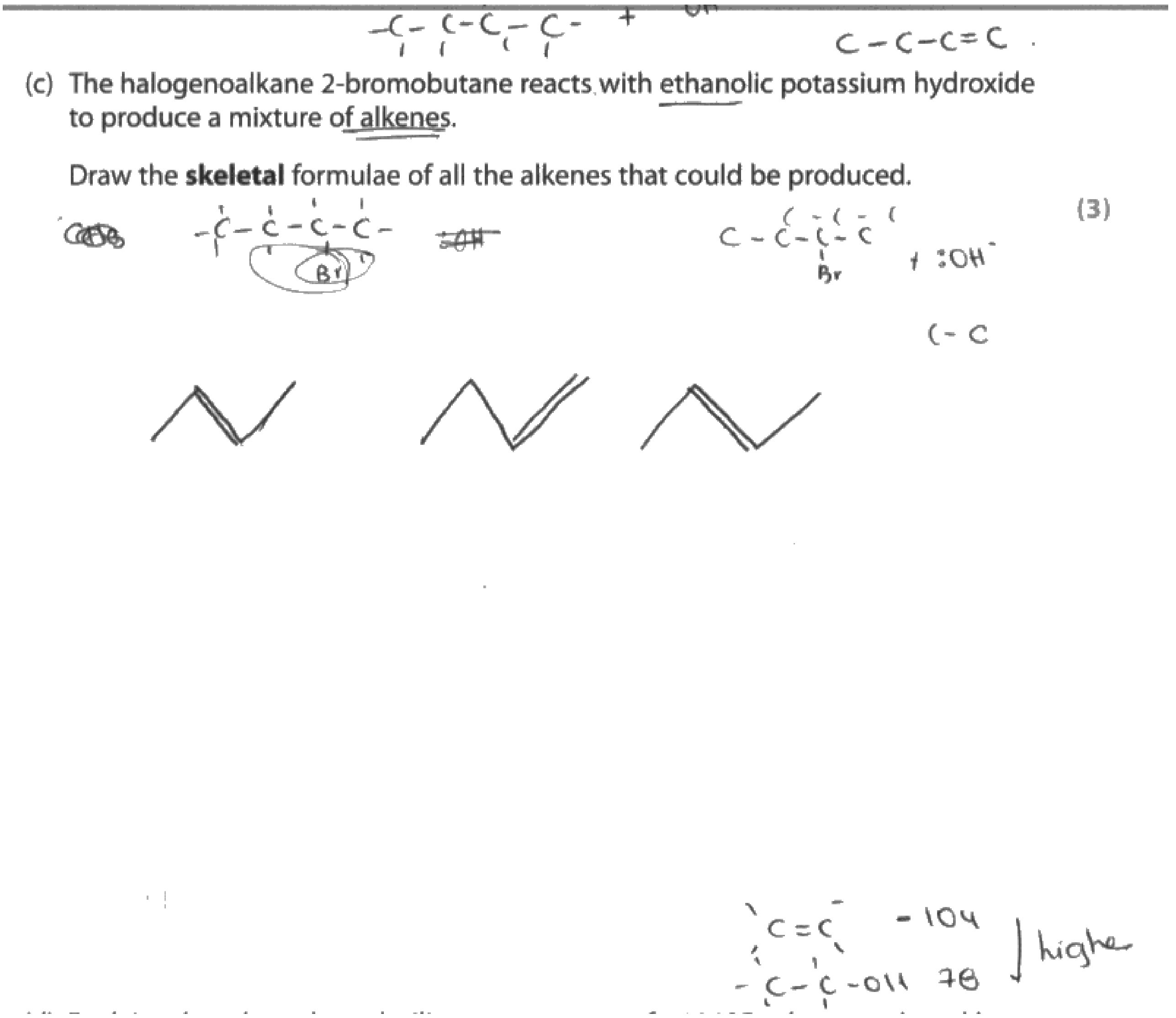
Examiner Comments

There are some serious errors to note here and to ensure that they are avoided by candidates.
Firstly, sodium hydroxide is an ionic compound and there is no covalent bond between the sodium and the OH. In addition the oxygen of the OH group does not have a negative dipole but should have a full negative charge.
Secondly, care is needed when drawing curly arrows as these should be written to show the movement of a pair of electrons. In this response the arrow between the delta positive carbon and the bond between the Na and OH has an arrowhead at both ends. This may be due to the other arrow being drawn from the oxygen, but it serves to emphasise the importance of care when drawing these curly arrows.
Thirdly, the sodium drawn after the transition state is missing the positive charge that it previously had.
Finally, the organic product has been drawn with one carbon that would consequently be hexavalent. It is a simple enough error to make but is of course a serious one.
On a positive note, the curly arrow from the C-Br bond with the necessary bond dipole was correct for one mark in part (i).
In part (ii) the reagent mark was not awarded because of the absence of nitric acid; the observation mark could have been awarded but the colour and the state were required for the product, and the state is missing. Hence zero marks were awarded for this part.

Question 3 (c)

This question produced a wide spread of marks. In the better responses, candidates appreciated that with three marks available it was likely that there would be three formulae required. They were able to draw the *E*/*Z* isomers of but-2-ene. It was most common to see the formulae for but-1-ene and *E*-but-2-ene. Occasionally the formula for the branched 2-methylpropene was drawn but this is not possible to produce from a linear halogenoalkane so did not score.



-C- C-C- C- + OH   C-C-C=C .

(c) The halogenoalkane 2-bromobutane reacts with ethanolic potassium hydroxide to produce a mixture of alkenes.

Draw the **skeletal** formulae of all the alkenes that could be produced.

(3)

-C-C-C-C- Br ~~+OH~~   C-C-C-C Br + :OH⁻

C-C

C=C -104

-C-C-OH 78 higher

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Examiner Comments

There was plenty of space for candidates to do working-out in order to deduce the alkene products and this candidate takes advantage of this to some extent. Working out of this type was ignored and did not detract from any available marks on this question.

Note that the first and third skeletal formulae are the same and so only two marks for this response were awarded.

ResultsPlus

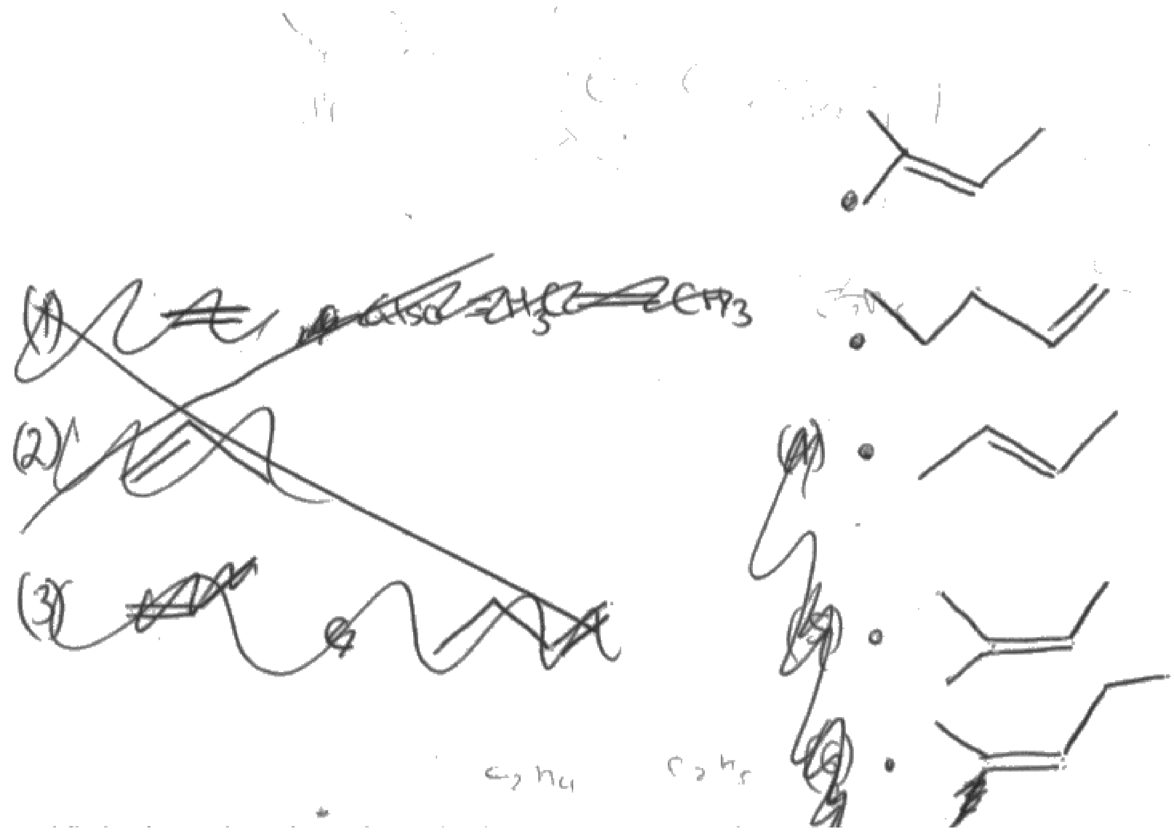
Examiner Tip

Always check and double-check this type of formula because it is easy to write duplicates.

(c) The halogenoalkane 2-bromobutane reacts with ethanolic potassium hydroxide to produce a mixture of alkenes.

Draw the **skeletal** formulae of all the alkenes that could be produced.

(3)



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Examiner Comments

This candidate has demonstrated that they are rather unclear about the number of carbon atoms drawn in skeletal formulae because only the third such formula has the correct four carbon atoms, while the other formulae have five carbon atoms. There are only three correct formulae possible and so any in excess of this number served to negate any correct formulae. Hence this response scored zero.

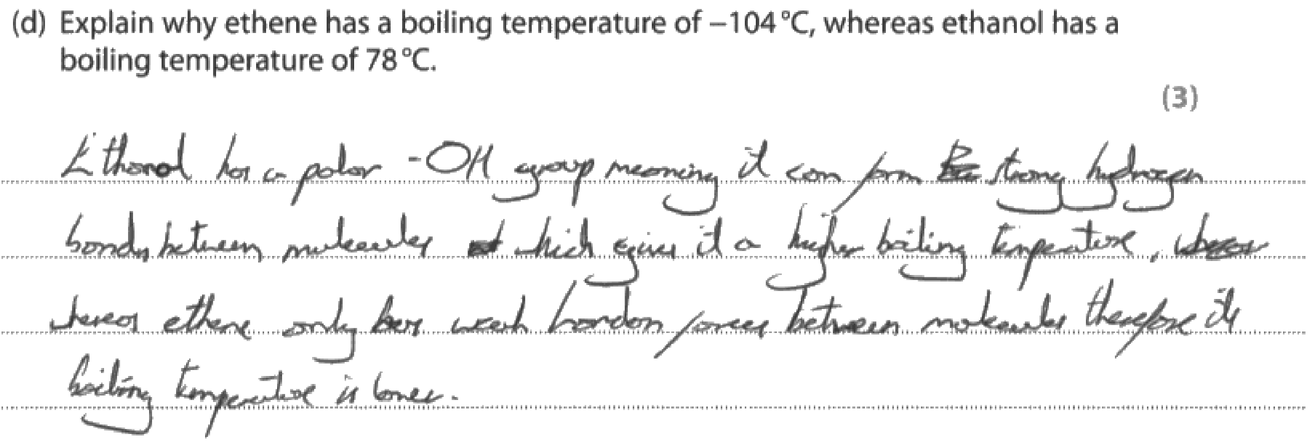
ResultsPlus

Examiner Tip

Practise drawing skeletal formulae.

Question 3 (d)

This was a high-scoring question with over 60% of candidates scoring all three points. The marking point most likely to be missing was the failure to refer to the extra "energy" that would be required to break the hydrogen bonding between ethanol molecules because these are stronger than the London forces between the ethene molecules. On occasion candidates noted that ethanol would also have stronger London forces than ethene because it has more electrons but this would not be responsible for the huge difference in the boiling temperatures between the molecules.



(d) Explain why ethene has a boiling temperature of −104 °C, whereas ethanol has a boiling temperature of 78 °C.

(3)

Ethanol has a polar -OH group meaning it can form ~~the~~ strong hydrogen bonds between molecules ~~at~~ which gives it a higher boiling temperature, ~~whereas~~ whereas ethene only has weak London forces between molecules therefore its boiling temperature is lower.

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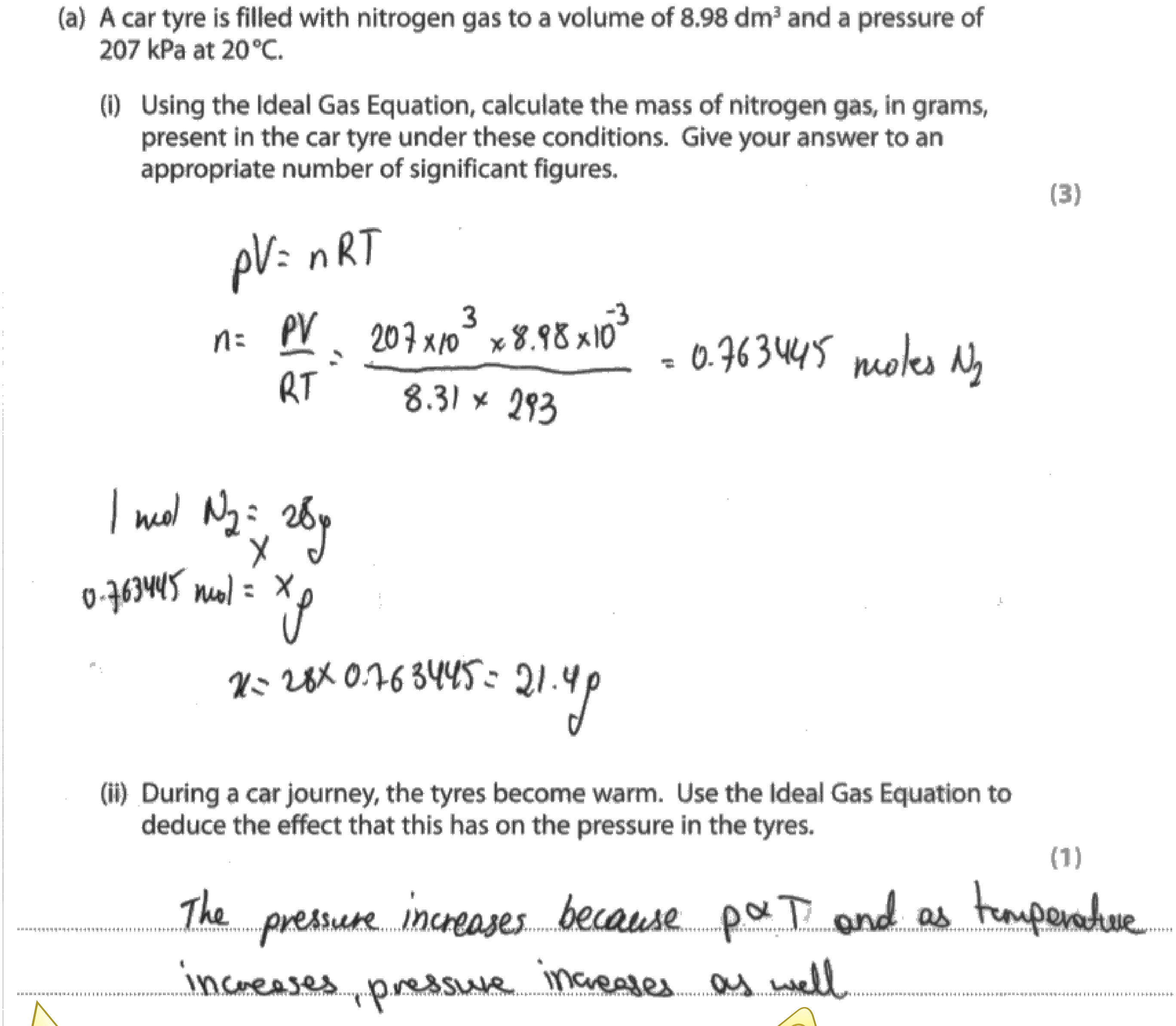
Examiner Comments

An example of a response which correctly identifies the intermolecular forces between the molecules of ethanol and those between the molecules of ethene but does not then explain that more "energy" is thus required to break the stronger hydrogen bonding between ethanol molecules. The reference to 'higher boiling temperature' is simply repeating the information given in the question.

Question 4 (a)

Over half of candidates could make good progress in the calculation in part (i) and achieve either 2 or 3 marks. The most common error was to note that the question asked for the mass of nitrogen gas and not nitrogen atoms. Occasionally the error of excessive significant figures was seen and is a worthwhile reminder that this is an important skill in the new specification where the mathematical requirement is a minimum of 20%.

In part (ii) many candidates simply wrote that 'pressure increases because temperature increases' without reference to the Ideal Gas equation which the question required. Only the best responses made a suitable reference to this equation and gained the mark.



(a) A car tyre is filled with nitrogen gas to a volume of 8.98 dm^3 and a pressure of 207 kPa at 20 °C.

(i) Using the Ideal Gas Equation, calculate the mass of nitrogen gas, in grams, present in the car tyre under these conditions. Give your answer to an appropriate number of significant figures.

(3)

$pV = nRT$

$n = \frac{PV}{RT} = \frac{207 \times 10^{3} \times 8.98 \times 10^{-3}}{8.31 \times 293} = 0.763445$ moles N_2

1 mol N_2 : 28g

0.763445 mol : x g

$x = 28 \times 0.763445 = 21.4g$

(ii) During a car journey, the tyres become warm. Use the Ideal Gas Equation to deduce the effect that this has on the pressure in the tyres.

(1)

The pressure increases because $p \propto T$ and as temperature increases, pressure increases as well

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Examiner Comments

In part (i) this candidate has clearly laid-out their answer and showed how their values have been calculated. Everything is correct and scores full marks.

The response to part (ii) does relate the statement that pressure increases to the proportional relationship between pressure and temperature and thus was awarded the mark.

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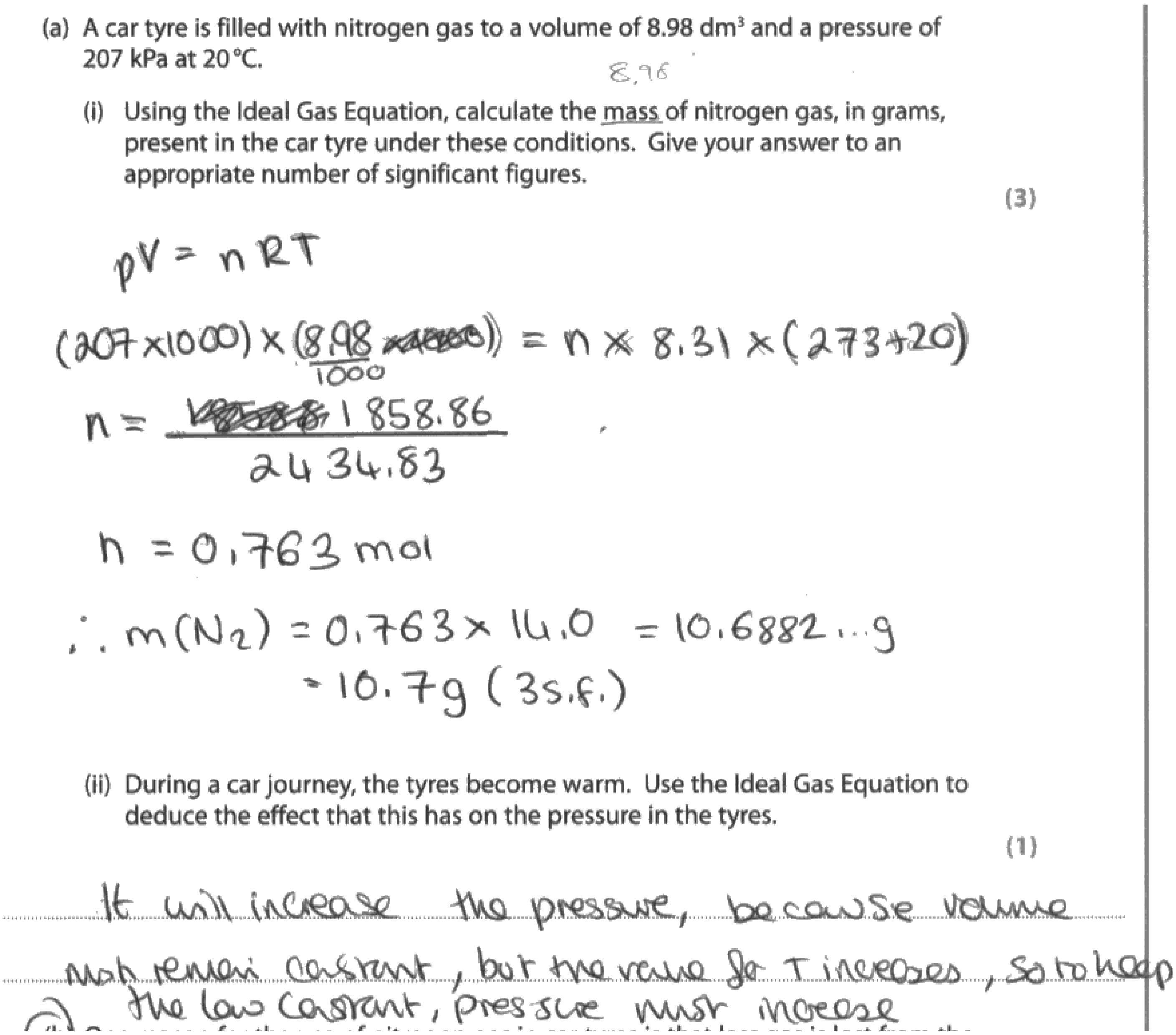
Examiner Tip

Always show your working for a calculation so that if the final value is incorrect, then marks can still be awarded for those parts which are correct.



(a) A car tyre is filled with nitrogen gas to a volume of 8.98 dm^3 and a pressure of 207 kPa at 20 °C.

8.96

(i) Using the Ideal Gas Equation, calculate the mass of nitrogen gas, in grams, present in the car tyre under these conditions. Give your answer to an appropriate number of significant figures.

(3)

$pV = nRT$

$(207 \times 1000) \times \left(\frac{8.98}{1000}\right) = n \times 8.31 \times (273 + 20)$

$n = \frac{1858.86}{2434.83}$

$n = 0.763$ mol

$\therefore m(N_2) = 0.763 \times 14.0 = 10.6882\ldots g$

$= 10.7g$ (3s.f.)

(ii) During a car journey, the tyres become warm. Use the Ideal Gas Equation to deduce the effect that this has on the pressure in the tyres.

(1)

It will increase the pressure, because volume must remain constant, but the value for T increases, so to keep the law constant, pressure must increase

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Examiner Comments

This response is an example of one where the initial calculation is correct for two marks but then the mistake is made to use the value of 14 instead of 28 to convert the number of moles to mass. The question does request the mass of nitrogen gas which is diatomic and so although the final value is appropriately given to three significant figures, it does not score the third mark. In part (ii) the response is insufficient to score. The question requires reference to the Ideal Gas equation and this response does not quite make that connection. The phrase "help the law constant" is unclear.

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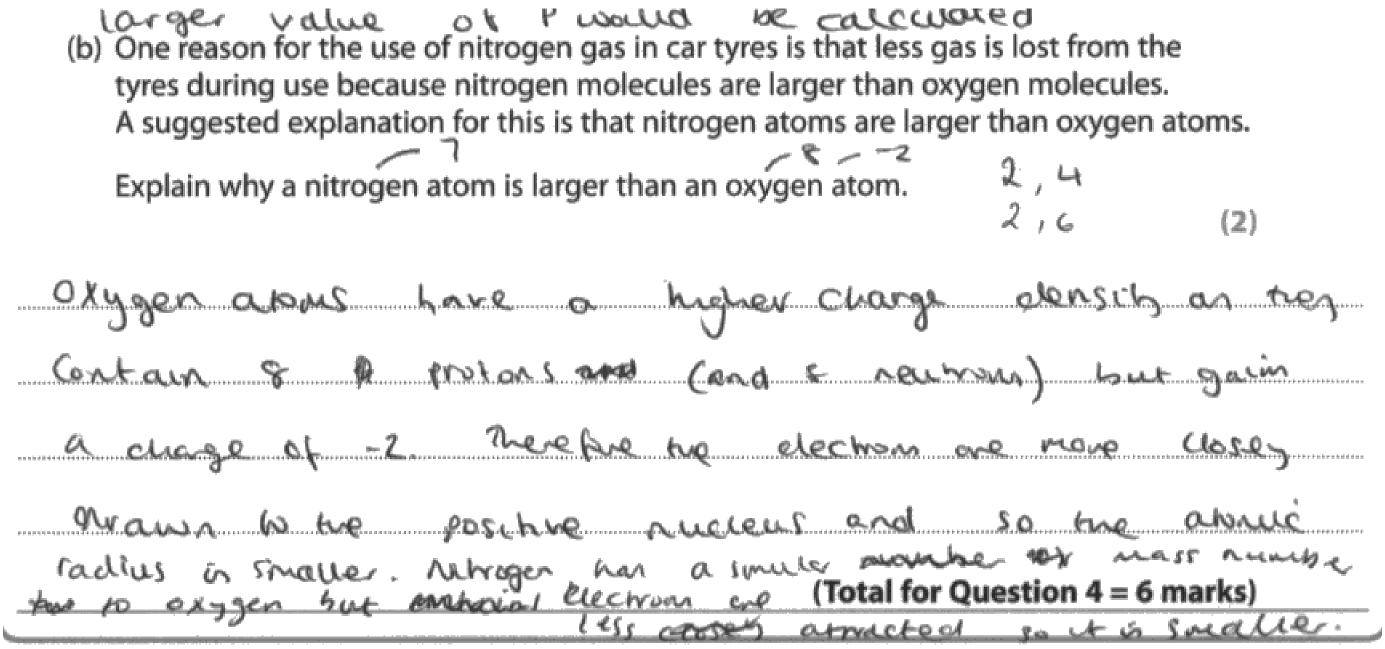
Examiner Tip

Take careful note of the wording in the question so that the answer does match.
If this candidate was asked for the formula of nitrogen gas they likely would have given N_2 but have not used that knowledge in the last step of the calculation.

Question 4 (b)

This question produced a good spread of marks which enabled candidates to demonstrate their understanding. Just under a quarter of candidates scored zero on this question by making a number of errors such as referring to ions, stating the wrong number of protons in the atoms and by just referring to the number of electrons in the outer shells. Just over 40% of candidates were able to correctly reason that the difference in the atomic radius was due to the fact that an oxygen atom has more protons than a nitrogen atom; or vice versa. This leaves just over a third of candidates that were able to reason further that the increased nuclear charge of oxygen had a greater attractive force on the outer electrons because the shielding was the same for both atoms or that the electrons for nitrogen and oxygen are both in the same shell.



larger value of r would be calculated

(b) One reason for the use of nitrogen gas in car tyres is that less gas is lost from the tyres during use because nitrogen molecules are larger than oxygen molecules.
A suggested explanation for this is that nitrogen atoms are larger than oxygen atoms.

-7 -8 - -2

Explain why a nitrogen atom is larger than an oxygen atom. 2, 4 2, 6 **(2)**

Oxygen atoms have a higher charge density as they contain 8 protons ~~and~~ (and 8 neutrons) but gain a charge of -2. Therefore the electrons are more closely drawn to the positive nucleus and so the atomic radius is smaller. Nitrogen has a similar ~~atomic number~~ ~~of~~ mass number ~~two~~ to oxygen but ~~additional~~ electrons are less ~~closely~~ attracted so it is smaller.

(Total for Question 4 = 6 marks)

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Examiner Comments

The term "charge density" is inappropriate here because it applies to ions and this question is about atoms. The mark scheme directs that the use of this term would negate the second marking point. The first marking point was not awarded because this response refers to the difference in the atomic mass number instead of the atomic number or number of protons.

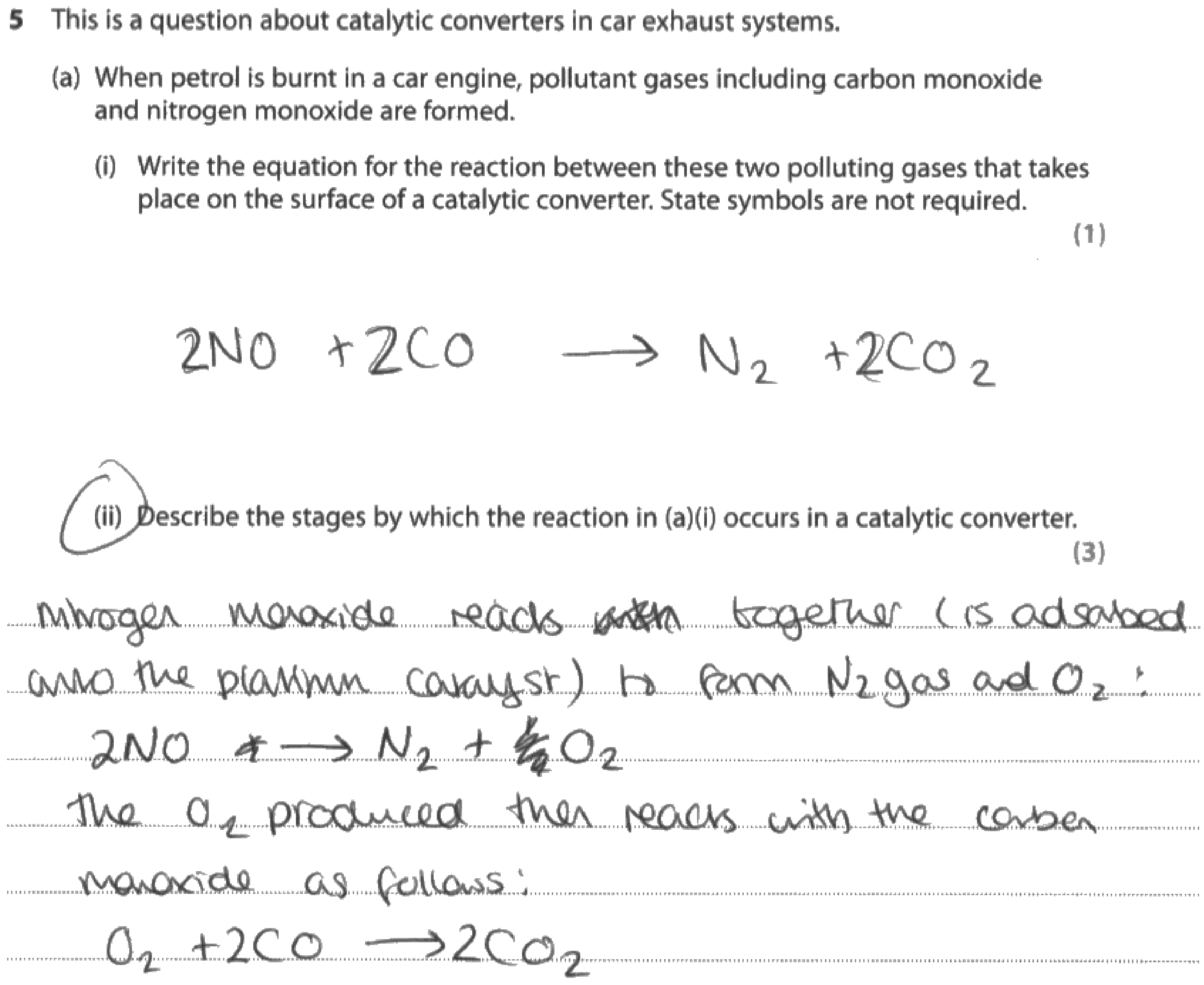
ResultsPlus
Examiner Tip

Specialist chemical terms must be used in the right context otherwise it can lead to the response losing credit if the use is inappropriate.

Question 5 (a)

The equation required for part (i) was often correctly drawn but there was the common error of nitrogen atoms given as a product rather than nitrogen gas. On a limited number of occasions candidates included oxygen in the equation which reflected a failure to read the question carefully.

Full marks were frequently awarded for answers to part (ii) as the mechanism of a heterogenous catalyst was well-understood. On occasion there was a lack of reference to the catalytic surface which lost credit but it was pleasing to see very few spellings of the incorrect "absorption" and the vast majority of candidates correctly used "adsorption".



5 This is a question about catalytic converters in car exhaust systems.

(a) When petrol is burnt in a car engine, pollutant gases including carbon monoxide and nitrogen monoxide are formed.

(i) Write the equation for the reaction between these two polluting gases that takes place on the surface of a catalytic converter. State symbols are not required.

(1)

$2NO + 2CO \longrightarrow N_2 + 2CO_2$

(ii) Describe the stages by which the reaction in (a)(i) occurs in a catalytic converter.

(3)

nitrogen monoxide reacts ~~with~~ together (is adsorbed onto the platinum catalyst) to form N_2 gas and O_2 :

$2NO$ ~~+~~ $\longrightarrow N_2 +$ ~~½~~O_2

The O_2 produced then reacts with the carbon monoxide as follows:

$O_2 + 2CO \longrightarrow 2CO_2$

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Examiner Comments

There is a suitable balanced equation in part (i) which scores the mark.
In part (ii) there is the use of the specialist term 'adsorption' but this needed to be used in context with the surface of the catalyst for any credit to be given. Hence this part did not score.

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Examiner Tip

The use of specialist terms themselves can be insufficient if there is not enough context included in the response.

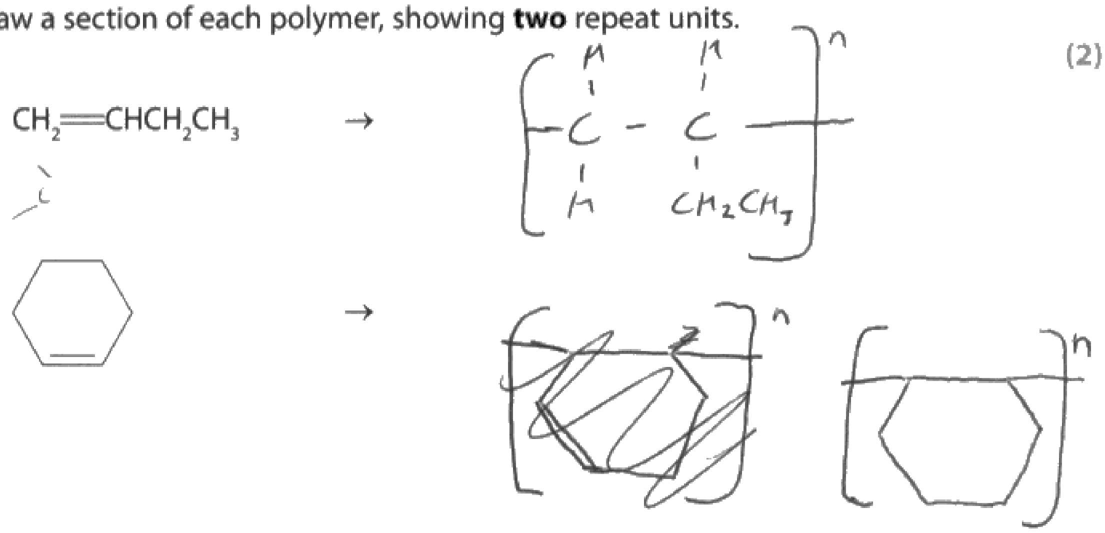
Question 6 (a)

The drawing of polymer repeat units continues to prove problematic for candidates and thus perhaps emphasises the need for more time to be spent on this topic. Only one third of all candidates could successfully complete the drawing of the repeat units for both molecules. A significant number of responses still had the carbon-carbon double bond in the repeat unit.

(a) But-1-ene and cyclohexene both form addition polymers.

Draw a section of each polymer, showing **two** repeat units.

(2)



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Examiner Comments

This candidate clearly knows how to draw repeat units from the monomer molecules; however they have not done what the question requires, which is to draw **two** repeat units. This resulted in the loss of one mark.

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Examiner Tip

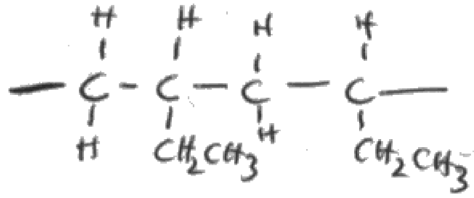
Make sure that the answer given does match the requirements of the question.

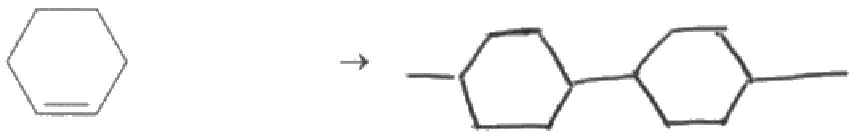
(a) But-1-ene and cyclohexene both form addition polymers.

Draw a section of each polymer, showing **two** repeat units.

(2)

$CH_2{=}CHCH_2CH_3$ →





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Examiner Comments

The repeat unit for poly (but-1-ene) is drawn correctly and is awarded one mark. However the bond between the monomer rings in the attempted drawing of the repeat unit for poly (cyclohexene) is in the wrong place and so does not score.

ResultsPlus

Examiner Tip

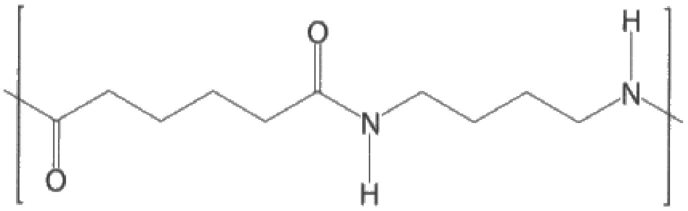
Draw two monomer structures side by side without the carbon-carbon double bond and then simply draw a bond between the structures connecting the carbons which would have had double bonds. Add continuation bonds and "all done".

Question 6 (b)

Skeletal formulae were not compulsory and many correct displayed formulae were seen. This proved to be a much more successful question for candidates with just under 70% gaining full marks. Monomer structures with monofunctionality was the most common error.

(b) Deduce the two monomers needed to produce the polyamide shown.

(2)



$HO-\overset{O}{\overset{\|}{C}}-C-C-C-\overset{O}{\overset{\|}{C}}-OH$

and

$H_2N-C-C-C-C-C-C-NH_2$

ResultsPlus

Examiner Comments

It is not clear why the candidate in this response has not completed the monomer structures. The candidate has correctly deduced the functional groups in each molecule and drawn them at each end of the structure. In this instance one mark would have been lost because the hydrogen atoms have not been drawn on the two structures. However there is a further mistake, namely that the monomer structure drawn on the right has too many carbons atoms; six have been drawn instead of only four. Thus, there are two errors and so neither marking point has been awarded.

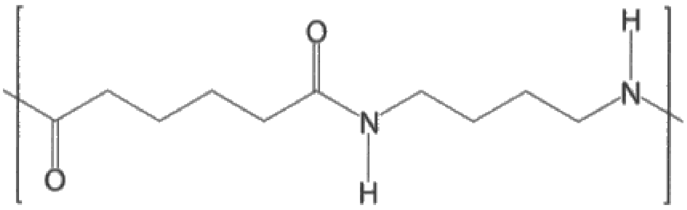
ResultsPlus

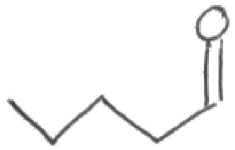
Examiner Tip

Displayed formulae can be very tiresome to draw with all of the hydrogen atoms to include so use skeletal formulae instead. Once this type of formula is understood, it is much quicker and easier.

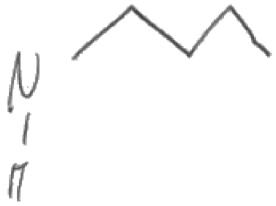
(b) Deduce the two monomers needed to produce the polyamide shown.

(2)





and



ResultsPlus

Examiner Comments

This candidate has wisely stuck with skeletal formulae but has only drawn a functional group on one end of the monomer. If it is a linear polymer then there will have to be a functional group at each end. In addition, the candidate has not appreciated that this is a condensation polymer and so when deducing the monomer structure there needs to be an 'OH' added to each of the functional groups of one monomer and an 'H' added to each of the functional groups of the other monomer. At the moment the monomer on the left is an aldehyde but should be a carboxylic acid. The monomer drawn on the right has an amine group which is missing a hydrogen atom.

ResultsPlus

Examiner Tip

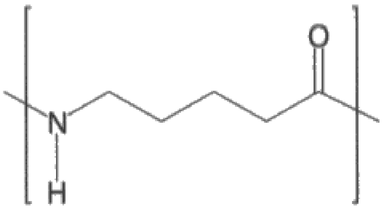
Remember that with condensation polymerisation, HO-H is either removed on formation or 'added' on hydrolysis.

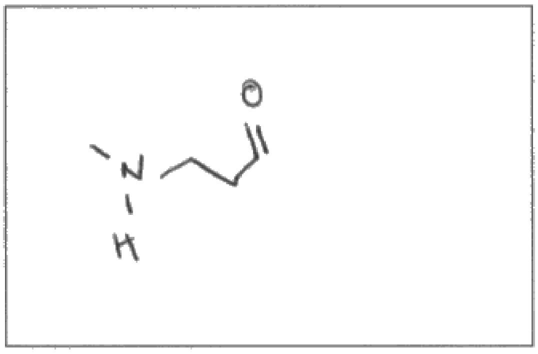
Question 6 (c)

This question tested similar skills to the previous one. It was pleasing to see that the change to a single monomer with two different functional groups presented no major difficulty for most candidates.

(c) Deduce the single monomer that could be used to produce the polyamide shown.

(1)





ResultsPlus
Examiner Comments

An example where a candidate has simply copied the structure from the diagram given and not added the H-OH to the 'ends' of the molecule to reverse the condensation formation process, and scores 0 marks.

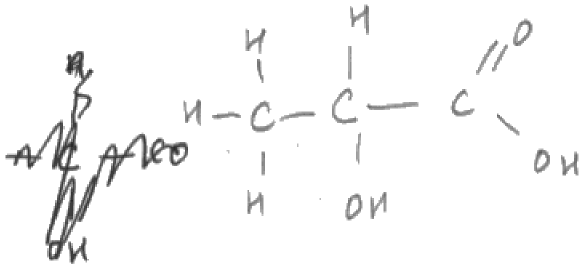
Question 6 (d) (i)

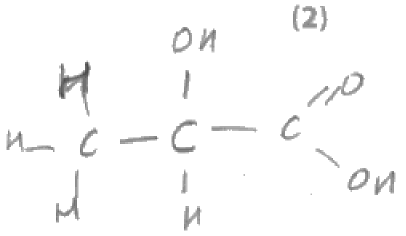
Enantiomers are defined as non-superimposable mirror images and should be drawn with 3D representation. This question thus proved to be an effective test of whether candidates truly understood the meaning of this term. The majority of candidates did well.

(d) PLA is a biodegradable polyester which is made from 2-hydroxypropanoic acid, $CH_3CH(OH)COOH$.

(i) Draw the two enantiomers of 2-hydroxypropanoic acid.

(2)





ResultsPlus
Examiner Comments

This is an example of a response which did not score. There is no attempt to show the mirror images of the two enantiomers and there is no 3D representation.

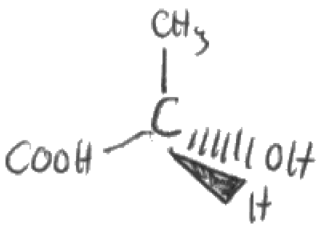
ResultsPlus
Examiner Tip

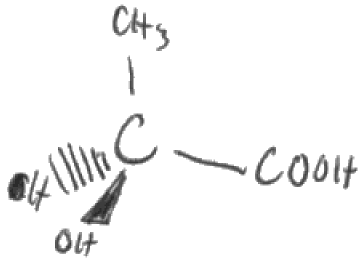
A drawing of enantiomers should have 3D representation.

(d) PLA is a biodegradable polyester which is made from 2-hydroxypropanoic acid, $CH_3CH(OH)COOH$.

(i) Draw the two enantiomers of 2-hydroxypropanoic acid.

(2)





ResultsPlus
Examiner Comments

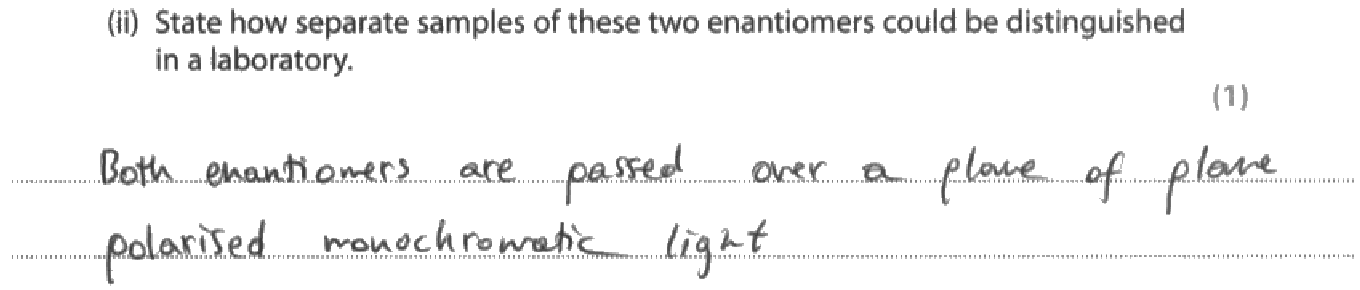
It is good that this candidate has drawn 3D representation of the enantiomers. However because the simple approach with a mirror line between the two structure has not been employed, it is easy to just draw the same enantiomer and this is what has happened here. Hence this response only scored one mark.

ResultsPlus
Examiner Tip

When drawing enantiomers, draw a mirror line between the two structures and make sure that they are mirror images of each other.

Question 6 (d) (ii)

The question required a comment on how samples of enantiomers could be distinguished and so the rotation of plane polarised light in "different directions" was essential to score. It was insufficient to simply refer to the 'angle of rotation' being different because the angles could obviously be in the same direction but just to different degrees. Only about 50% of candidates were able to give all of the necessary details to score the mark.


(ii) State how separate samples of these two enantiomers could be distinguished in a laboratory.

(1)

Both enantiomers are passed over a plane of plane polarised monochromatic light

ResultsPlus
Examiner Comments

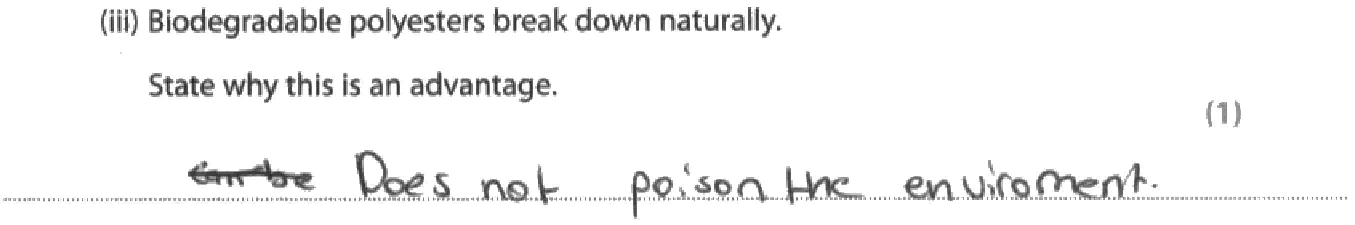
In this response there is the correct reference to the plane of plane polarised light but the effect of the enantiomer on this light is not stated and the question requires how the enantiomers would be distinguished. 0 marks.

ResultsPlus
Examiner Tip

Make sure that the answer given 'follows through' on the demands of the question as a partial answer can score no more than a wrong one.

Question 6 (d) (iii)

The question was rather open-ended and thus provided an opportunity for a wide range of acceptable responses. There did need to be some appropriate justification for the advantage given and it was this that discriminated between candidates. For example, it was insufficient to simply state that there would be less pollution without some rationale being given.


(iii) Biodegradable polyesters break down naturally.

State why this is an advantage.

(1)

~~Can be~~ Does not poison the enviroment.

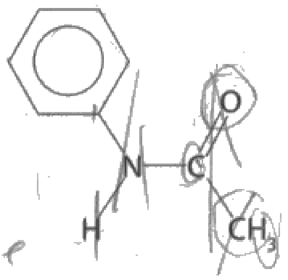
ResultsPlus
Examiner Comments

This is an example of a response which is insufficient. The reference to 'not poisoning the environment' could have been suitable if a reason was given, for example, "incineration, which can produce toxic fumes, would not be necessary".

Question 7 (a)

In this question, all the scores from 0 to 5 inclusive were awarded to at least 10% of candidates, with a score of 4 being the most common at about 27%. There was a lot of good chemistry demonstrated, with the three steps and their reagents largely understood. It was the finer detail such as whether to use dilute or concentrated HCl, or whether heat under reflux was required that proved to be the differentiating factors. In addition, some candidates used additional reagents, including ones that were not in the list provided, which would have prevented the correct product from being formed and so this did not score. Hence this type of question is a very useful means of testing candidates' knowledge and understanding of organic chemistry and is an extremely worthy exercise for centres and their students to practise.

7 Antifebrin was the trade name for N-phenylethanamide which was used as a painkiller until paracetamol was discovered.



Antifebrin

- Alkylation → ethanoyl chloride
- ethanoyl chloride + NH_2

N – C – H
      |
      H

(a) Some of the following reagents can be used to produce Antifebrin from benzene.

- ✓ Aluminium chloride
- Ammonia, concentrated
- ✓ Benzene
- Ethanal
- Ethanoic acid
- Ethanol
- ✓ Ethanoyl chloride
- Hydrochloric acid, concentrated
- Hydrochloric acid, dilute
- Iron
- Nitric acid, concentrated
- Nitric acid, dilute
- Propanone
- Sodium chloride
- Sulfuric acid, concentrated
- Tin

Selecting from only these reagents, devise a **three-step** synthetic pathway to convert benzene into Antifebrin. You should include the structures of the two intermediate compounds and the reaction conditions.

(5)

- nitrobenzene
- reduction
- ethanoly chloride

First ~~react~~ warm benzene with nitric acid, concentrated and sulfuric acid, concentrated at 50-55° so dinitrification does occur. you get

Then reduce the nitrobenze into phenyl amine using Tin as a catalyt and dilute HCl acid. This should be heated in ~~an~~ under reflux. You get

Then react phenyl amine with ethanoyl chloride by warming it together. You get Antifebrin.

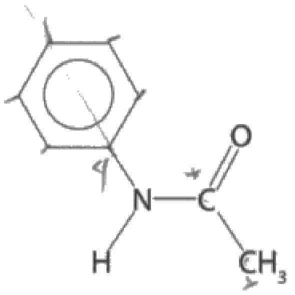
ResultsPlus
Examiner Comments

This response is one of the more 'wordy' descriptions which was perfectly acceptable. The first step in the synthesis is completely correct giving all of the necessary conditions and the formula of the intermediate. The second step states that tin and HCl heated under reflux are required which is correct but the HCl needs to be concentrated and so the mark for the reageants/conditions was not awarded. The structure of the second intermediate is correct and so this did gain the mark. The third step is also correct with the use of ethanoyl chloride.
Hence this response scored 4 marks in total

ResultsPlus
Examiner Tip

Creating your own organic reaction flow chart and learning all of the reagents and conditions can be very beneficial for not just this type of question but for understanding organic chemistry as a whole.

7 Antifebrin was the trade name for N-phenylethanamide which was used as a painkiller until paracetamol was discovered.



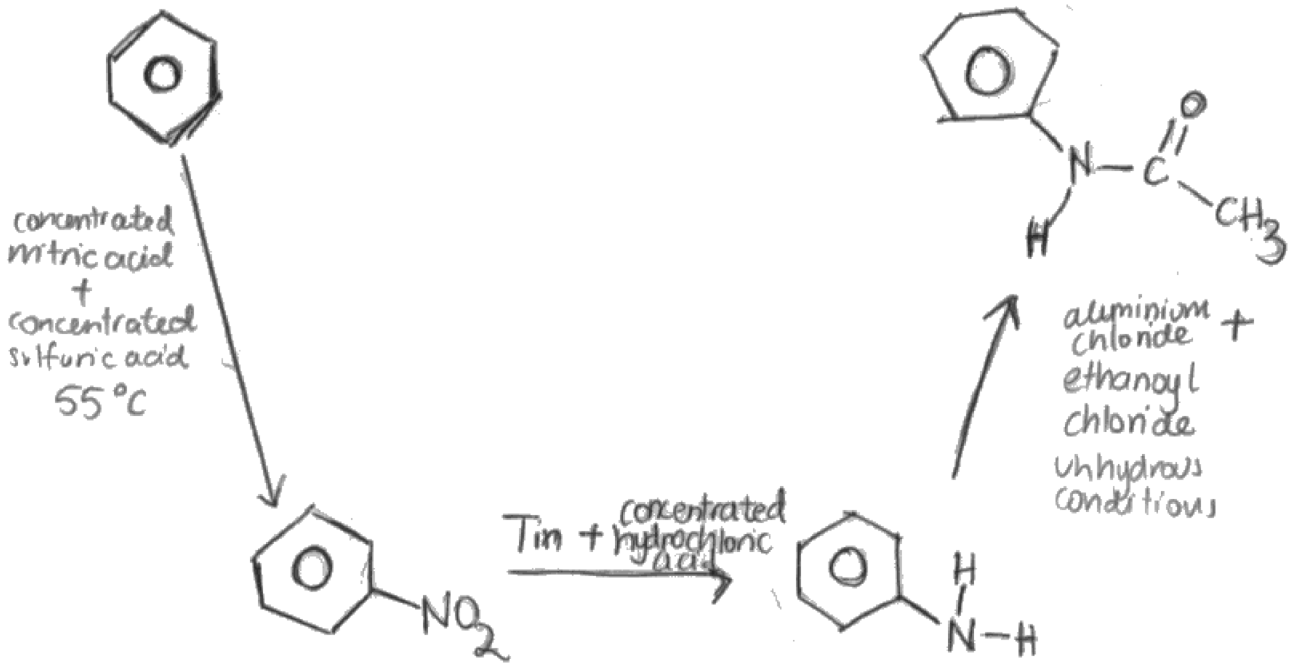
Antifebrin

(a) Some of the following reagents can be used to produce Antifebrin from benzene.

- Aluminium chloride
- Ammonia, concentrated
- Benzene
- Ethanal
- Ethanoic acid
- Ethanol
- Ethanoyl chloride
- Hydrochloric acid, concentrated
- Hydrochloric acid, dilute
- Iron
- [✓ Nitric acid, concentrated]
- Nitric acid, dilute
- Propanone
- Sodium chloride
- [✓ Sulfuric acid, concentrated]
- Tin

Selecting from only these reagents, devise a **three-step** synthetic pathway to convert benzene into Antifebrin. You should include the structures of the two intermediate compounds and the reaction conditions.

(5)



ResultsPlus

Examiner Comments

Step 1 is completely correct for both marks.

In step 2 the necessary conditions of heating/reflux are missing and so only the mark for the intermediate was awarded.

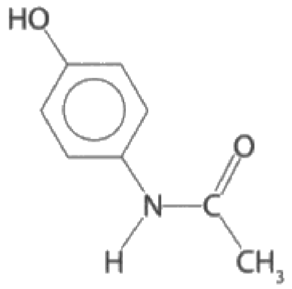
Note that aluminium chloride is used in conjunction with ethanoyl chloride in step 3 and this would result in Friedel-Crafts substitution of the aromatic ring rather than form the amide. Thus the final mark was not awarded.

The total score for this response was 3 marks.

Question 7 (c)

In this question roughly 30% of candidates scored 0 or 1 mark and thus only the more detailed responses scored full marks. It was essential to indicate specifically where the electron density came from to make the aromatic ring in phenol more reactive for the first mark. As an alternative to being 'more susceptible to electrophilic attack' for the second mark it was acceptable to state that the ring was 'more nucleophilic' which is correctly considering the reaction from the opposite direction to the norm, but nonetheless correct chemistry.

(c) Paracetamol is structurally similar to Antifebrin, but has a hydroxy group attached directly to the benzene ring.



The bromination of the benzene ring in paracetamol occurs much more readily compared to the bromination of benzene.

Explain this increased reactivity.

(2)

The OH group close to the benzene ring adds even more delocalised electron activity to the ring, this makes the molecule more reactive and more susceptible to nucleophilic attack.

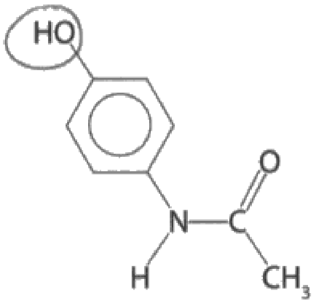
ResultsPlus
Examiner Comments

In this response there are two issues which result in it not gaining any credit. The first and perhaps most obvious is the error towards the end where susceptibility towards "nucleophilic" attack is mentioned but it should be 'electrophilic'. The second problem is that there is no explanation given for how the OH group increases the delocalised electron density of the benzene ring.

ResultsPlus
Examiner Tip

Questions towards the end of the exam paper will increase in demand and an explanation will thus require more detail.

(c) Paracetamol is structurally similar to Antifebrin, but has a hydroxy group attached directly to the benzene ring.



The bromination of the benzene ring in paracetamol occurs much more readily compared to the bromination of benzene.

Explain this increased reactivity.

(2)

The electrons in the OH group in paracetamol ~~[illegible]~~ merge with the electrons in the π orbital of the ring, increasing the electron density above and below the ring, so it's activated, and more prone to electrophilic attack

ResultsPlus

Examiner Comments

This response scores one mark for the reference to increased susceptibility towards electrophilic attack. However, the response does not state specifically where the electrons in the OH group are that contribute to the increased electron density of the aromatic ring in phenol. For example, there is a bonded pair of electrons in the covalent bond between the hydrogen and the oxygen, and it is not these that are involved. The examiners were looking for clear and specific reference to the lone pair of electrons on the oxygen atom of the OH group.

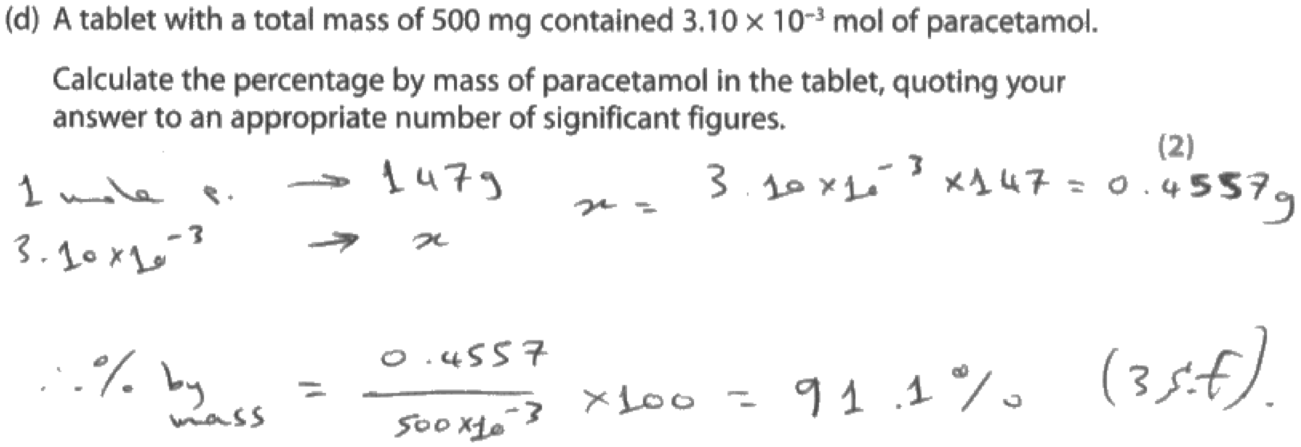
ResultsPlus

Examiner Tip

This question is an example where the mark schemes from the previous A Level Chemistry specification can be of value in highlighting the level of demand of this type of question.

Question 7 (d)

This question is a useful one to highlight and to re-emphasise two key points. Firstly, the understanding of skeletal formulae by candidates continues to be variable and over half of the candidates failed to determine the molar mass of paracetamol correctly from the skeletal formula given, the number of hydrogen atoms around the ring being the main cause of the problem. Secondly, the Ofqual stipulation for all of the A Level Chemistry specifications is that 20% of the questions are to be of level 2 mathematical demand. One relatively straightforward way that this can be assessed in chemistry is through the correct use of significant figures. It is very important that candidates appreciate these two points if they are to do well.



(d) A tablet with a total mass of 500 mg contained 3.10×10^{-3} mol of paracetamol.

Calculate the percentage by mass of paracetamol in the tablet, quoting your answer to an appropriate number of significant figures.

(2)

1 mole e. → 147g

3.10×10^{-3} → x

$x = 3.10 \times 10^{-3} \times 147 = 0.4557\text{g}$

$\therefore \%\text{ by mass} = \frac{0.4557}{500 \times 10^{-3}} \times 100 = 91.1\%$ (3 s.f).

ResultsPlus

Examiner Comments

This is an example where the molar mass of paracetamol has been incorrectly determined and so the first mark is lost but the calculation is otherwise correct and the answer to given to an appropriate number of significant figures, so one mark was awarded.

ResultsPlus

Examiner Tip

The practice of determining molar masses from skeletal formulae is an activity that is well worth the time and effort.

(d) A tablet with a total mass of 500 mg contained 3.10×10^{-3} mol of paracetamol.

Calculate the percentage by mass of paracetamol in the tablet, quoting your answer to an appropriate number of significant figures.

(2)

1 mol paracetamol $\longrightarrow$ 151g

$3.1 \times 10^{-3} \longrightarrow x$

$x = 3.1 \times 10^{-3} \times 151 = 0.4681\text{g}$

$= 468.1\text{mg}$

$\therefore \%\text{ mass} = \frac{468.1}{500} \times 100$

$= 93.62\%$

ResultsPlus

Examiner Comments

An example of a response where the molar mass of paracetamol has been correctly determined but then the candidate has quoted their final answer to an excessive number of significant figures and so does not score the second mark.

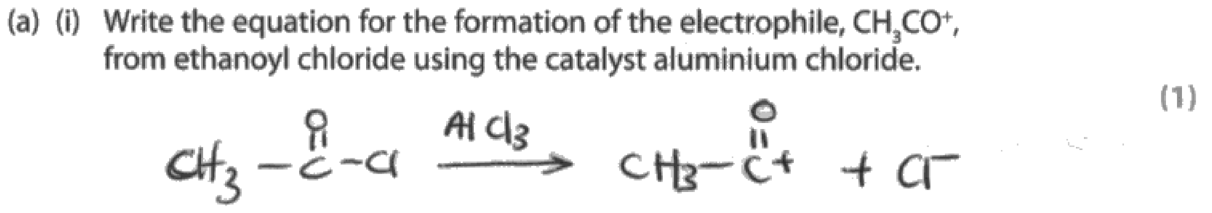
ResultsPlus

Examiner Tip

Take careful note of the number of significant figures quoted for the figures in the question and do not exceed these.

Question 8 (a) (i)

This was a relatively straightforward question and over 80% of candidates could correctly write the equation. It nicely set the scene for the following question on the mechanism of electrophilic substitution. The most common error was the omission of charge on one or both of the product species. Occasionally candidates used A or even Ag as a symbol for aluminium.



(a) (i) Write the equation for the formation of the electrophile, CH_3CO^+, from ethanoyl chloride using the catalyst aluminium chloride.

(1)

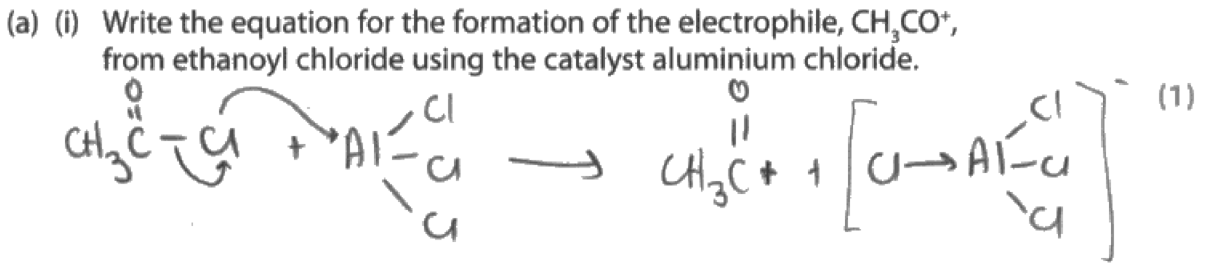
$$CH_3-\overset{O}{\overset{\|}{C}}-Cl \xrightarrow{AlCl_3} CH_3-\overset{O}{\overset{\|}{C}}{}^+ + Cl^-$$

Examiner Comments

This response did not score. The question requires the formation of the electrophile which is given, but it was insufficient to just write the catalyst above the reaction arrow. The aluminium chloride plays an active role in accepting the chloride ion to create the electrophile and so must be shown to be involved in the reaction. This is evident from the subsequent question (a) (ii) where the question asks for details to be given for the reformation of the catalyst.

Examiner Tip

At times the following questions can give a hint or provide additional guidance on what was required for previous questions and so by all means go back and make any necessary changes if required.



(a) (i) Write the equation for the formation of the electrophile, CH_3CO^+, from ethanoyl chloride using the catalyst aluminium chloride.

(1)

$$CH_3\overset{O}{\overset{\|}{C}}-Cl + AlCl_3 \longrightarrow CH_3\overset{O}{\overset{\|}{C}}{}^+ + [Cl\rightarrow AlCl_3]^-$$

Examiner Comments

The question simply requires an equation for the formation of the electrophile. If curly arrows were required then they would be asked for. In this instance the curly arrows were ignored and the mark awarded.

Examiner Tip

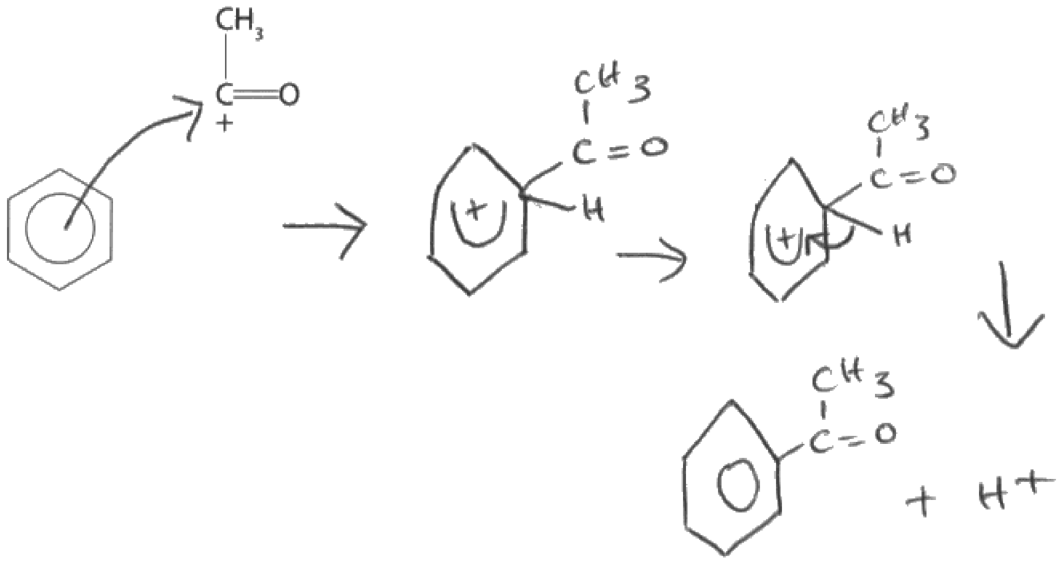
It is advisable to stick to what the question required.

Question 8 (a) (ii)

Just over 50% of candidates were able to draw the electrophilic substitution mechanism correctly and gain all four marks. The errors seen were the usual ones of curly arrows drawn in the wrong direction, curly arrows going from and to the wrong places, the 'horseshoe' facing the wrong carbon atom of the ring, the positive charge drawn outside of the 'horseshoe' and omission of the regeneration of the catalyst. The candidates that had clearly practised drawing this type of mechanism generally avoided these errors and such an activity is well-advised.

(ii) Complete the diagram, including curly arrows, to show the mechanism for the reaction between this electrophile and benzene to produce phenylethanone. Include the regeneration of the catalyst.

(4)



Regeneration =

$AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$

ResultsPlus
Examiner Comments

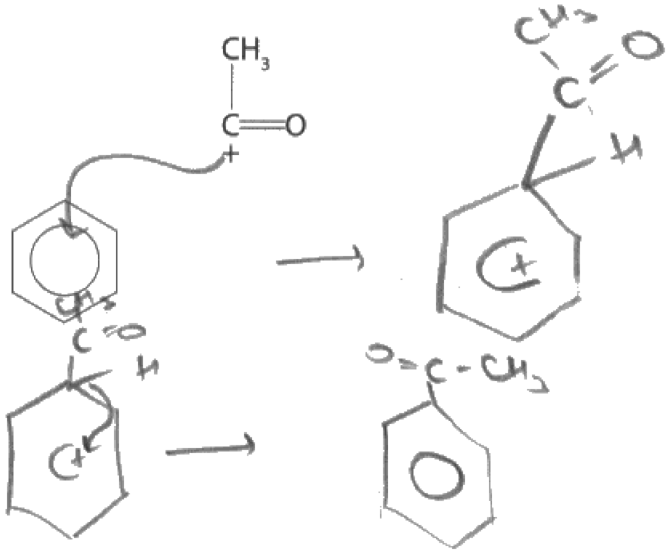
This response has been drawn neatly and clearly which was good to see. However there is one problem with the mechanism, namely that the 'horseshoe' and plus charge are facing the wrong carbon atom of the ring. They should face the tetravalent carbon atom where the substitution is taking place. This resulted in a loss of one mark but otherwise the mechanism is correct and so the response was awarded 3 marks.

ResultsPlus
Examiner Tip

Draw the mechanism for the substitution occurring at different places of the ring in order to be confident in getting the different stages correct.

(ii) Complete the diagram, including curly arrows, to show the mechanism for the reaction between this electrophile and benzene to produce phenylethanone. Include the regeneration of the catalyst.

(4)



ResultsPlus
Examiner Comments

This response illustrates a number of errors to avoid. Remember that the curly arrow shows the movement of a pair of electrons and not necessarily the attacking species. Hence the first curly arrow should go from the aromatic ring to the carbon of the electrophile and not the other way around as seen here. As in the example above, the 'horseshoe' is not facing the correct carbon atom and so does not score. A transferred error can be applied in the second drawn stage because the curly arrow does correctly go from the carbon - hydrogen bond back into the ring to reform the delocalised ring of electrons. The response finishes without attempting to regenerate the catalyst which is asked for in the question.

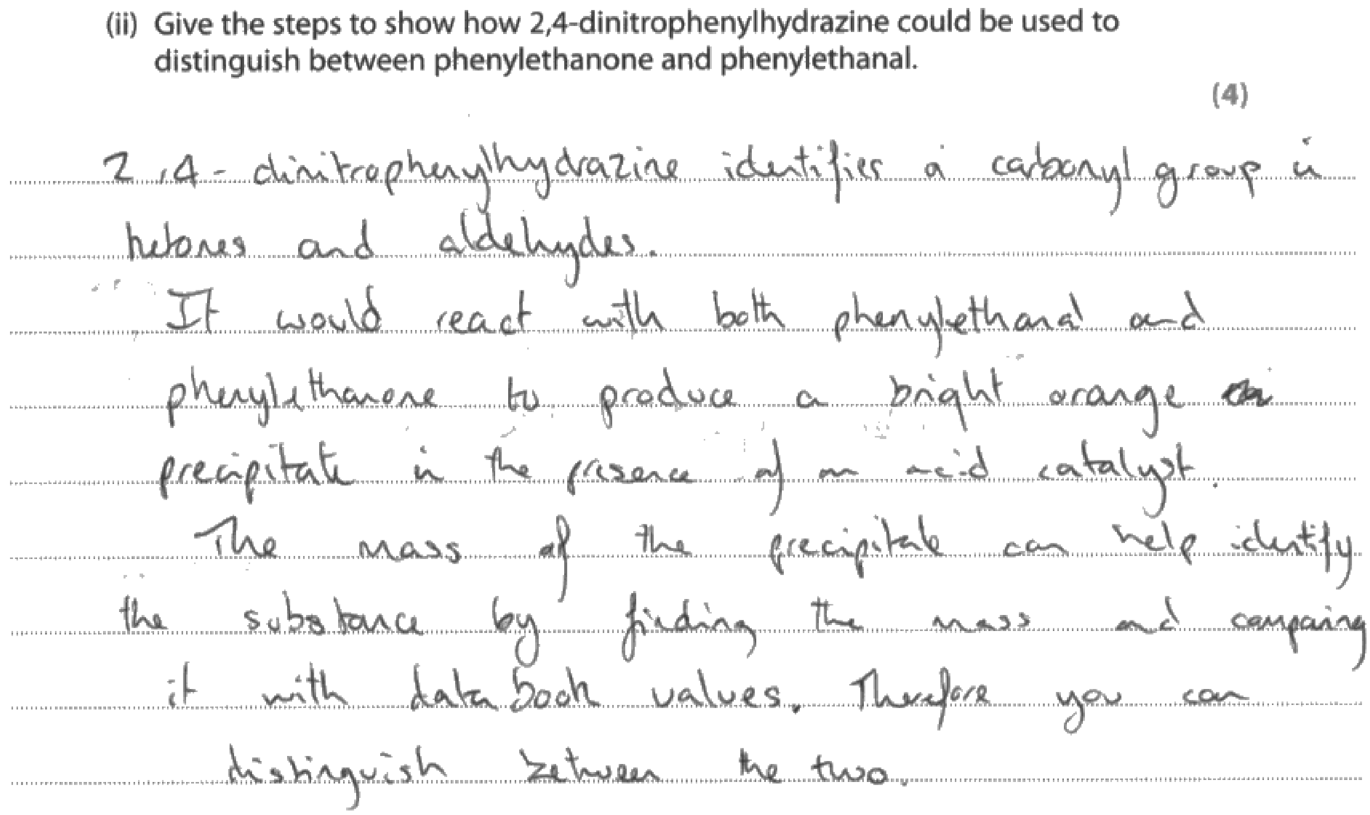
Thus this response scores 1 mark.

ResultsPlus
Examiner Tip

Once the answer has been completed and before moving on, just check to make sure that all aspects of the question have been addressed.

Question 8 (b) (ii)

This question produced a wide range of marks. In the less successful responses, candidates appreciated that both compounds would form a yellow/orange precipitate but were then not able to describe how this could be used to differentiate the compounds. In better responses, the candidates knew that the melting point of the crystals was the property which could be used to identify the unknown sample by referring to a database. Only in the very best of responses did candidates appreciate the need to recrystalise the initial precipitate in order to have a pure sample for the determination of the melting temperature. A small number incorrectly referred to the boiling temperature of the crystals and this resulted in the loss of marking point 3, even if it was seen in conjunction with the melting temperature, because it is not what is done.



(ii) Give the steps to show how 2,4-dinitrophenylhydrazine could be used to distinguish between phenylethanone and phenylethanal.

(4)

2,4-dinitrophenylhydrazine identifies a carbonyl group in ketones and aldehydes.

It would react with both phenylethanal and phenylethanone to produce a bright orange precipitate in the presence of an acid catalyst.

The mass of the precipitate can help identify the substance by finding the mass and comparing it with data book values. Therefore you can distinguish between the two.

ResultsPlus

Examiner Comments

This response scores one mark for the formation of the "orange precipitate" by both compounds, but there is nothing else which was viewed as creditworthy. The reference to a databook was not a 'standalone' mark and in this example would not have been a suitable way of distinguishing between the two.

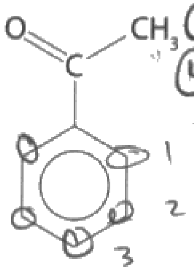
Question 8 (b) (iii)

This question proved to be challenging for candidates, and the vast majority of responses lacked clear structure and reasoning. However, it did produce a spread of marks. There were a few common errors which are worth noting. A significant number did not refer to hydrogens/protons at all and simply referred to peaks or to peaks due to the C=O bond. The number of hydrogen atoms as part of the aromatic ring was frequently incorrect, with numbers ranging from 6 to 11. These lost a structure and reasoning mark, if there was to be any awarded. The chemical shift ranges quoted for the peaks by a large number of candidates were excessive and outside the ranges of the mark scheme. At times this could be by just a difference of 0.1 but the mark schemes gives specific ranges to allow and these are important for candidates to appreciate. The peaks of the aromatic hydrogens are complex in nature and often do not adhere to the simplified splitting rules that A Level candidates are expected to know. It had been anticipated that candidates would just state that the aromatic hydrogens of both compounds would produce similar peak patterns, and some candidates did do this; others spent time predicting splitting patterns and hydrogen equivalency for these hydrogen atoms which does not exist - this was ignored. The splitting patterns of the alkyl hydrogens were least well-known and is the main area of improvement for candidates. The peak area ratios for the hydrogen atom peaks were often rather 'buried' in the response or unclear. Candidates should lay out their response as clearly as possible.

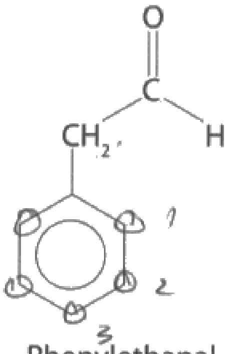
*(iii) Compare and contrast the high resolution proton NMR spectra of phenylethanone and phenylethanal.

You should use the Data Booklet.

① No. of peaks
② Area
③ Splitting
④ δ shift.



Phenylethanone



Phenylethanal

(6)

Phenylethanone will 4 peaks, while phenylethanal will have 5 peaks. The relative area under the peaks of phenylethanone will be 3, at the peak with δ ≈ 2 from the $H_3-C-C=O$, and 2 at 2 of the peaks at δ ≈ 2·25, and 1 at a peak at δ ≈ 2·25. The relative areas under the peaks of phenylethanal will be 1 at the peak at δ ≈ 9·5 from the aldehyde, and 2 at the peak at δ ≈ 2 from the $H_2-C-C=O$, and 2 at 2 peaks at δ ≈ 2·25, and 1 at a peak at δ = 2·25. ~~for phenylethanone~~,
⇒ they therefore both have
~~the peak δ = 2, will be~~ 2 peaks at δ = 2·25, which are from

the benzene ring, and these peaks have the same areas under them. For phenylethanal, the peak at $\delta = 9.5$ will be split to a triplet, and the peak at $\delta = 2$ will be split into a doublet. For phenylethanone, the peak at $\delta = 2$ will be a singlet. For both the compounds, the 3 peaks at $\delta \approx 2\text{-}2.5$, from the benzene ring, will all be complex multiplet splits.

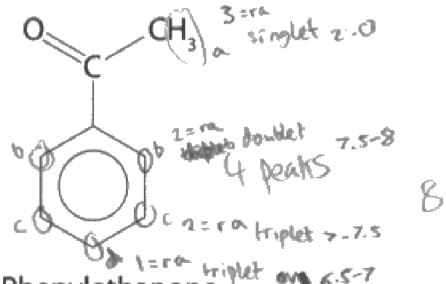
ResultsPlus

Examiner Comments

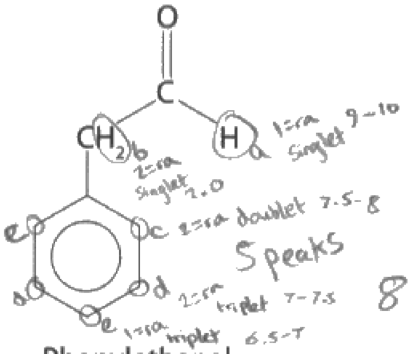
This response was awarded all IPs except for IP1 because the chemical shift range quoted for the aromatic hydrogens is incorrect. There is reference to the hydrogens of the CH_3 and CH_2 groups being the cause of their respective peaks and so both structure and reasoning marks were awarded. Thus this response was given 5 marks.

*(iii) Compare and contrast the high resolution proton NMR spectra of phenylethanone and phenylethanal.

You should use the Data Booklet.



Phenylethanone



Phenylethanal

(6)

The spectrum for phenylethanone would show 4 peaks with a splitting pattern of 1:3:3:2 whereas the spectrum for phenylethanal would have 5 peaks with a splitting pattern of 1:3:3:2:1. The furthest right peak on the spectrum of phenylethanone would be a singlet with a chemical shift of around 2.0ppm. This refers to the H-C-C=O in the methyl group where there are no hydrogens on the neighbouring carbon. The relative area under the peak is 3. The furthest right peak on the phenylethanal is also at a chemical shift of around 2.0ppm as it refers to the H-C-C=O in the CH_2. It has a relative area of 2 under the peak. The other three peaks on the spectrum of phenylethanone are also at similar chemical shift values to three of those on the phenylethanal spectrum (6.5-7, 7-7.5, 7.5-8ppm) as these are the hydrogens bonded to the arene ring. Their chemical shift values vary due to proximity to the oxygen. They also have the same relative areas under each peak (1, 2, 2 respectively). The 5th peak on phenylethanal is at a chemical shift of around 9.5ppm and refers to the H-C=O in the aldehyde group. It has a relative area under the peak of 1. The total area under all of the peaks is 8 for both spectrums.

ResultsPlus

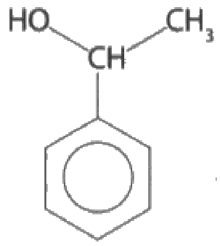
Examiner Comments

This response is an example of one where the structures at the top of the page were annotated and this is often helpful in understanding the candidate's responses. In this response all IPs were awarded except for IP 4 which is because the splitting patterns of the peaks due to the hydrogens in phenylethanal are not singlets. Both structure and reasoning marks were awarded for a suitable response which refers to the hydrogens of the substances and does not make any chemical errors. Hence a total of 5 marks was awarded.

Question 8 (c)

High-performing candidates found this a straightforward question and confidently gave the reagent and conditions required. However candidates do need to take care when expressing their answer because occasionally some candidates gave additional information which could negate their correct answer. The reagent required was lithium tetrahydridoaluminate (III) and the conditions for its use are 'dry ether'. This was all that was required. If this reagent is actually used in an experiment then, after the reaction has been carried out, either water or acid is added to hydrolyse any unreacted reducing reagent. If a candidate referred to this then it had to be made clear that the addition of water/acid was after or following the use of $LiAlH_4$ in dry ether. On occasion responses were seen where the water/acid were additional reagents, and if used at the same time as $LiAlH_4$ then this would mean that the procedure would not work, which lost credit.

(c) The compound 1-phenylethanol can be formed from phenylethanone.



Give the reagent and conditions that would be used to form 1-phenylethanol.

(2)

$K_2Cr_2O_7 + H_2SO_4$ and heat under distillation

ResultsPlus
Examiner Comments

An example of a response which illustrates a likely misunderstanding of the question since the reagents quoted are the oxidising agents which could be used to convert phenylethanol to phenylethanal. However, the question is about the opposite reaction and so reducing reagents are required. 0 marks.

ResultsPlus
Examiner Tip

The maxim "RTQ^2" is a good one, namely 'Read The Question Twice" so that the answer given does correspond to the question asked.

Question 9 (a)

This was a somewhat novel question but successfully answered by the vast majority of candidates. However it did confuse some: perhaps it appeared too easy and too little thought was given to it. If this was the case then it serves as a useful reminder to take care with even the most straightforward of tasks set.

(a) Compound **A** decomposes in a first order reaction.

Calculate the time it takes for the mass of **A** to decrease from 600 g to 37.5 g if the decomposition has a constant half-life of 14 minutes.

(1)

From 600 to 300 17 min
300 to 150 17 min
150 to 75 17 min
75 to 37.5 17 min

17 x 4 = 68 minutes

ResultsPlus
Examiner Comments

The correct method or working out is shown here and indeed four half-lives of 17 minutes would give an answer of 68 minutes. Unfortunately the half-life in the question is 14 minutes and so this response did not score.

ResultsPlus
Examiner Tip

Double-checking answers does take up valuable exam time but often errors such as seen here would be quickly spotted and corrected.

(a) Compound **A** decomposes in a first order reaction.

Calculate the time it takes for the mass of **A** to decrease from 600 g to 37.5 g if the decomposition has a constant half-life of 14 minutes.

(1)

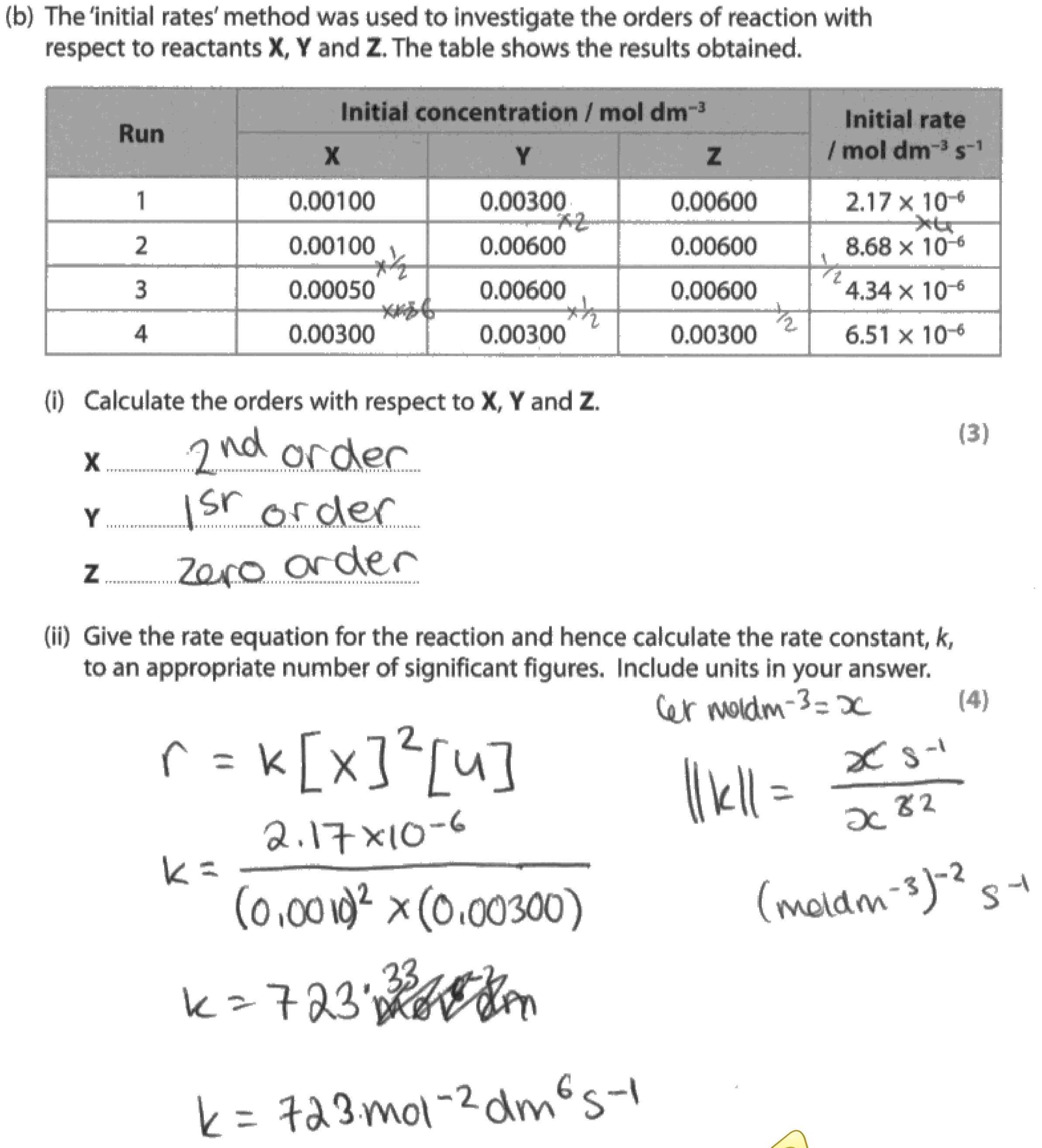
56 minutes

ResultsPlus
Examiner Comments

No working was required for this response and with only one mark available, there was no credit given for such. Hence this response scores the mark. However there is no means of double-checking the working which as illustrated by the previous response is an advantage.

Question 9 (b)

This was a high-scoring question with just under 75% of candidates scoring six or seven marks. The application of transferred error was especially beneficial to many candidates. It was clear that candidates were well prepared for this type of question and it was pleasing to see the understanding and knowledge shown. Only a very small minority of candidates omitted the rate constant from the rate equation.



(b) The 'initial rates' method was used to investigate the orders of reaction with respect to reactants **X**, **Y** and **Z**. The table shows the results obtained.

Run	Initial concentration / mol dm^{-3}			Initial rate / mol dm^{-3} s^{-1}
	X	**Y**	**Z**	
1	0.00100	0.00300	0.00600	2.17×10^{-6}
2	0.00100	×2 0.00600	0.00600	×4 8.68×10^{-6}
3	×½ 0.00050	0.00600	0.00600	½ 4.34×10^{-6}
4	×6 0.00300	×½ 0.00300	½ 0.00300	6.51×10^{-6}

(i) Calculate the orders with respect to **X**, **Y** and **Z**.

(3)

X 2nd order

Y 1sr order

Z zero order

(ii) Give the rate equation for the reaction and hence calculate the rate constant, *k*, to an appropriate number of significant figures. Include units in your answer.

(4)

$$r = k[X]^2[Y]$$

$$k = \frac{2.17 \times 10^{-6}}{(0.0010)^2 \times (0.00300)}$$

$k = 723.33$ ~~$\text{mol}^{-2}\,\text{dm}$~~

$k = 723\,\text{mol}^{-2}\,\text{dm}^{6}\,\text{s}^{-1}$

Ler $\text{moldm}^{-3} = x$

$$\|k\| = \frac{x\,s^{-1}}{x^{\cancel{3}2}}$$

$(\text{moldm}^{-3})^{-2}\,s^{-1}$

ResultsPlus

Examiner Comments

This is an example of a response which benefits hugely from the application of transferred error (TE). In part (i) only the order with respect to Z is correct and so one mark is awarded for this part. However in part (ii) the rate equation, the subsequent calculation of the rate constant from the candidate's rate equation, with its associated units, are all correct for maximum marks. Hence four marks were awarded for part (ii)

ResultsPlus

Examiner Tip

Even if an error is made in a calculation, it is always best to carry on as best as possible because there may be some credit that can be awarded for correct steps/procedures that are carried out.

Question 9 (c) (ii)

It was pleasing that the vast majority of candidates scored full marks on this question. The ability to rearrange formulae and to use powers in calculations is clearly very strong in most candidates.

(ii) Calculate the concentration of bromide ions required to produce a reaction rate of 4.08 × 10^{-3} mol dm^{-3} s^{-1} at 298 K given that

$k = 8.00\ dm^9\ mol^{-3}\ s^{-1}$

$[BrO_3^-] = 0.200\ mol\ dm^{-3}$

$[H^+] = 0.100\ mol\ dm^{-3}$

(2)

$$4.08 \times 10^{-3} = (8.00)(0.200)[Br^-](0.100)^2$$

$$[Br^-] = \frac{4.08 \times 10^{-3}}{0.200 \times 0.100^2 \times 8}$$

$$= 0.255\ mol\ dm^{-3}$$

$$= 0.260\ mol\ dm^{-3}\ (3s.f)$$

ResultsPlus
Examiner Comments

It would have been perfectly acceptable to round up the final answer to two significant figures, which in this instance would have been 0.26 mol dm^{-3}. If the answer had been 0.2555 then this would have been rounded to 0.260 but the calculator value was 0.255 and so does not round up to 0.260. Hence this response was awarded 1 mark.

ResultsPlus
Examiner Tip

Rounding up/down and the difference between decimal places and significant figures is something that candidates are well advised to practise, and even if confident then to review just before the exam to reinforce correct practice.

(ii) Calculate the concentration of bromide ions required to produce a reaction rate of 4.08×10^{-3} mol dm^{-3} s^{-1} at 298 K given that

$$k = 8.00 \text{ dm}^9 \text{ mol}^{-3} \text{ s}^{-1}$$

$$[BrO_3^-] = 0.200 \text{ mol dm}^{-3}$$

$$[H^+] = 0.100 \text{ mol dm}^{-3}$$

(2)

$$\text{Rate} = k[BrO_3^-][Br^-][H^+]^2$$

$$4.08 \times 10^{-3} = 8\,(0.2)(0.1)^2\,[Br^-]$$

$$[Br^-] = \frac{4.08 \times 10^{-3}}{8(0.2)(0.1)^2}$$

$$= 0.0255 \text{ mol dm}^{-3}$$

ResultsPlus

Examiner Comments

Unfortunately this candidate has omitted to square the 0.1 value in the denominator and so got the wrong final answer. One mark was lost. The layout of the answer suggests that the candidate is confident with this question and knows what they are doing. If they had double-checked their answer they could have discovered a simple error. They scored 1 mark out of 2

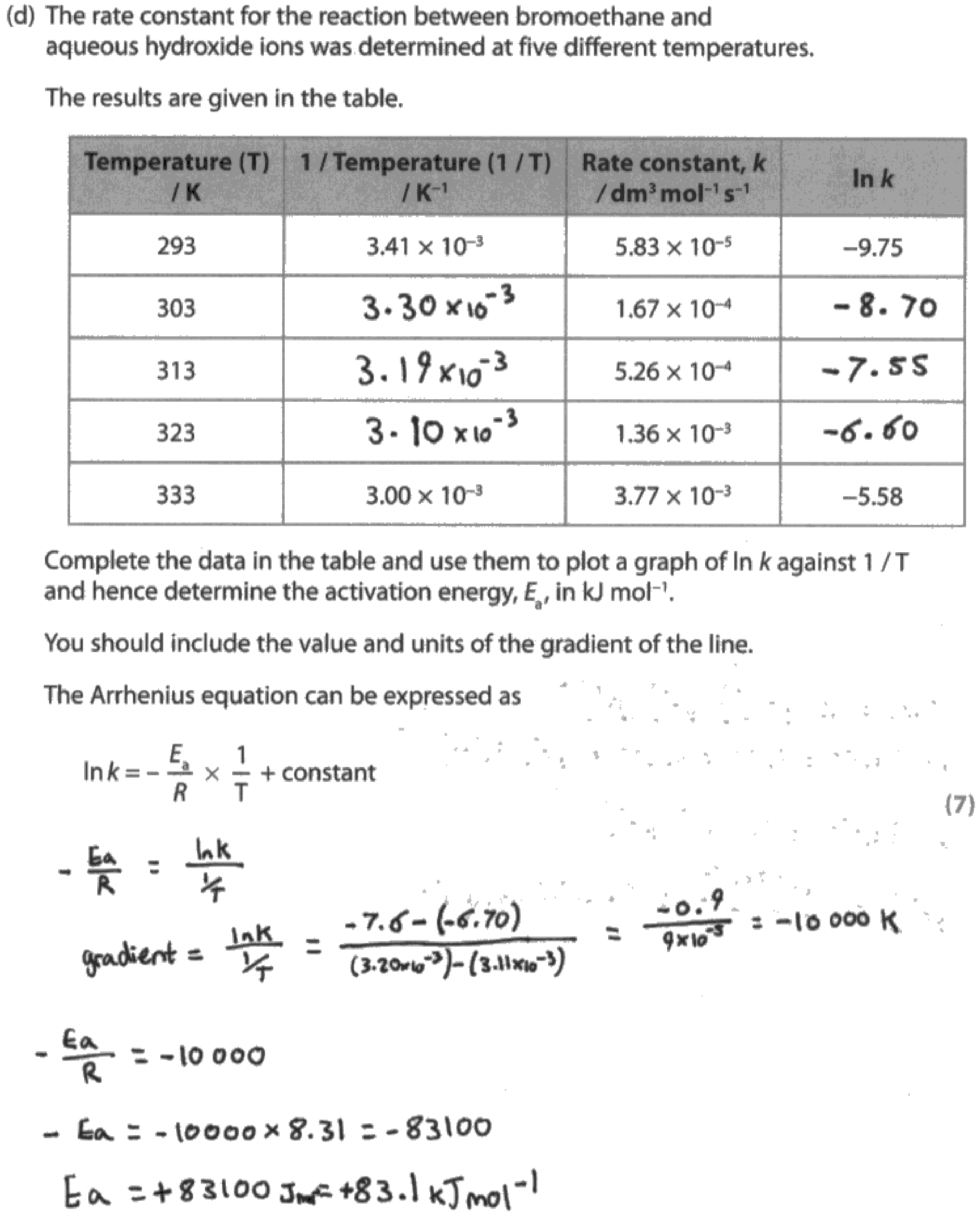
ResultsPlus

Examiner Tip

Double-checking calculations is of great benefit, even if only to provide reassurance that the correct answer has been obtained.

Question 9 (d)

It was good to see such a strong performance by candidates on the last question of the paper. This showed that candidates were managing their time effectively and/or they had sufficient time to complete the exam paper. The full spectrum of marks was seen showing that all candidates could demonstrate their knowledge and ability. The common errors were: incorrect number of significant figures and incorrect calculated figures in the table, the y axis plotted upside down and to a scale such that less than half of the graph paper was covered, omission of units on the x axis, incorrectly plotted points, the gradient value not clearly identified and its units omitted, and finally a negative activation energy. It is worth noting that significant figures were not addressed on this question.



(d) The rate constant for the reaction between bromoethane and aqueous hydroxide ions was determined at five different temperatures.

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
293	3.41×10^{-3}	5.83×10^{-5}	−9.75
303	3.30×10^{-3}	1.67×10^{-4}	−8.70
313	3.19×10^{-3}	5.26×10^{-4}	−7.55
323	3.10×10^{-3}	1.36×10^{-3}	−6.60
333	3.00×10^{-3}	3.77×10^{-3}	−5.58

Complete the data in the table and use them to plot a graph of ln k against 1 / T and hence determine the activation energy, E_a, in kJ mol^{-1}.

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

The Arrhenius equation can be expressed as

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

(7)

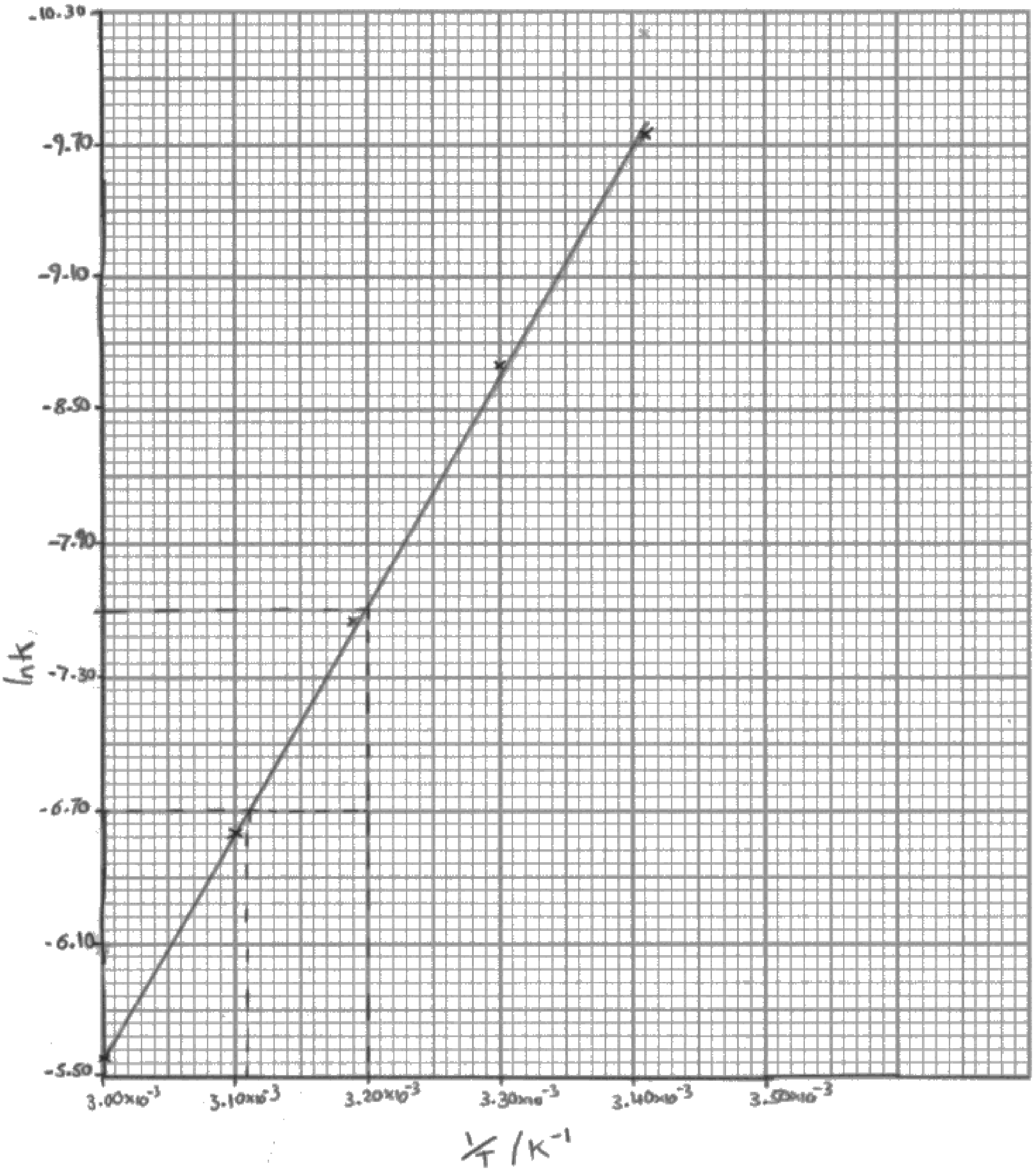
$$-\frac{Ea}{R} = \frac{\ln k}{1/T}$$

$$\text{gradient} = \frac{\ln k}{1/T} = \frac{-7.6-(-6.70)}{(3.20\times10^{-3})-(3.11\times10^{-3})} = \frac{-0.9}{9\times10^{-5}} = -10\,000\ \text{K}$$

$$-\frac{Ea}{R} = -10\,000$$

$$-Ea = -10000 \times 8.31 = -83100$$

$$Ea = +83100\ \text{J} = +83.1\ \text{kJ mol}^{-1}$$



ResultsPlus

Examiner Comments

In this response, the candidate correctly completes the table for the first two marks but one mark is lost from the graph because the y axis should go down with increasing magnitude of negative values. The calculation is clearly laid out, gives a gradient value within the acceptable range including units and has appropriate value for the activation energy. Hence this response scores 6 out of the 7 marks.

(d) The rate constant for the reaction between bromoethane and aqueous hydroxide ions was determined at five different temperatures.

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*
293	3.41×10^{-3}	5.83×10^{-5}	−9.75
303	$3{,}30 \times 10^{-3}$	1.67×10^{-4}	−8,72 ✓
313	$3{,}19 \times 10^{-3}$	5.26×10^{-4}	−7,55 ✓
323	3.10×10^{-3}	1.36×10^{-3}	−6.60 ~~[illegible]~~ ✓
333	3.00×10^{-3}	3.77×10^{-3}	−5.58 ✓

Complete the data in the table and use them to plot a graph of ln *k* against 1 / T and hence determine the activation energy, E_a, in kJ mol^{-1}.

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

The Arrhenius equation can be expressed as

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

(7)

gradient $= -\dfrac{Ea}{R} = $ ~~[illegible]~~

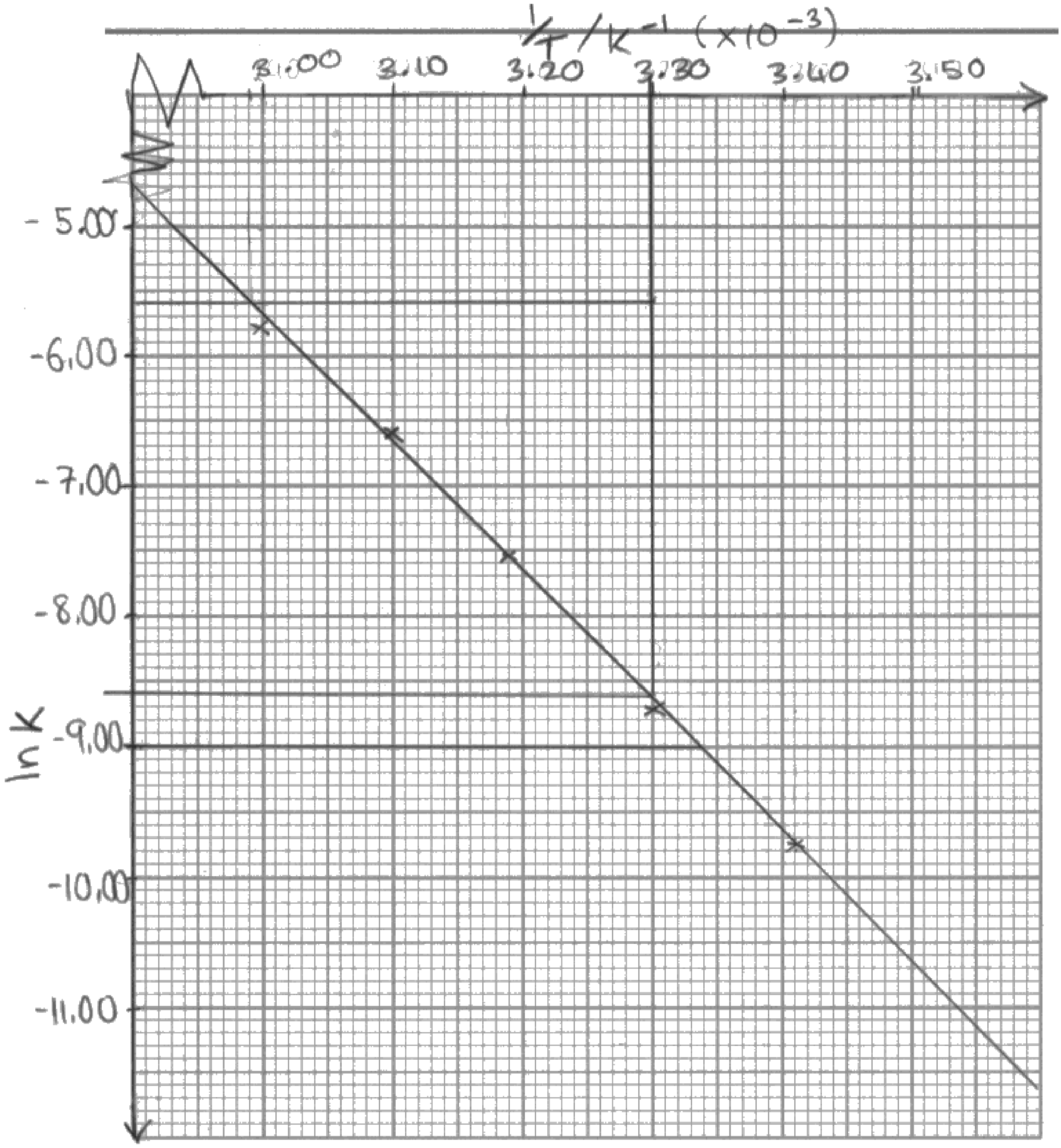
$= \dfrac{8{,}6 - 5{,}6}{(3{,}3 \times 10^{-3} - 2{,}99 \times 10^{-3})}$

$= 9677.4$ ~~K~~ ln[illegible]

$Ea = 9677{,}4 \times 8{,}31$

$= 80419{,}4\ J$

$= +80.4\ kJ$



ResultsPlus
Examiner Comments

This response scores 3 marks.
The value of ln *k* for the temperature of 303 K is incorrect as it should be -8.70. Hence one mark out of two was awarded for the table. The graph has appropriate labelled axes, is to a suitable scale and the points are plotted correctly for two further marks.
The calculation has a number of errors. The gradient value should be negative and the units are Kelvin not 'ln'. The gradient should be multiplied by -8.31 to give rise to a positive activation energy and so the multiplication by 8.31 to ensure a positive value was not accepted. In addition the units are not just kJ but kJ mol^{-1}.

ResultsPlus
Examiner Tip

Repeating calculator functions to ensure correct answers is a worthwhile habit to get into and can avoid elementary errors and the consequential loss of marks.

Paper Summary

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

- RTQ^2. In other words, read the question twice before answering to make sure that the answer will address all that is required, and then read again after it has been answered to make sure that all of the points required have been made. This includes the information in the stem of the question which may be on a previous page, because it may include relevant details that are required to answer the question effectively;
- Use the correct chemical terminology in the appropriate places;
- Avoid giving more than one answer to a question as an incorrect response can negate a correct one;
- Always check calculations several times because it is easy to make an error when either inputting a value into a calculator or when copying down a value from a calculator;
- The appropriate number of significant figures is an important way in chemistry of testing the 20% of level 2 mathematics required and so understanding exactly what is meant is vital;
- Double-check the chemical formulae written so that errors such as pentavalent carbon atoms are avoided and that skeletal formulae have the correct number of carbon atoms;
- Non-standard abbreviations such as IMF should not be used without giving an explanation of their meaning;
- Chemistry is a practical subject and carrying out experiments will undoubtedly help you in your understanding and grasp of this subject.

Grade Boundaries

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

http://www.edexcel.com/iwantto/Pages/grade-boundaries.aspx

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