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Examiners' Report
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GCE Chemistry 9CH0 02

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Introduction

There was evidence that candidates were well-prepared for certain aspects of the chemistry specification which were tested in this paper. No doubt the Advance Notice information contributed to candidates performing especially well on such topics as amino acids, carboxylic acids and kinetics.

Although it is possible that some candidates were 'running out of steam' towards the end of the paper, there was no evidence that the candidates had insufficient time.

There were common errors of exam technique which kept repeating through the paper. For example many responses did not fully answer the question set as evidenced by the omission of equations in the response to Q7(c) by a significant number of candidates, despite the clear instruction for their inclusion. Another example is the apparent failure to double check answers, both numerical and otherwise, which oftentimes would have led to the correction of simple errors. The lack of exam experience by this particular cohort due to the impact of COVID-19 is likely to have contributed to these errors.

However it was clear that a sizeable number of candidates had been well taught and gave excellent answers demonstrating a deep and lucid understanding of chemical concepts. Their performance was evidence that they and their teachers had been able to overcome the challenges of the last few years and their responses were a pleasure to see.

Question 2 (a)

This gentle start to the exam paper was answered well by the majority of candidates. One error seen occasionally was to refer to the hydrocarbon as containing carbon and hydrogen molecules instead of atoms.

2   This is a question about hydrocarbons.

   (a) State what is meant by the term **hydrocarbon**.

(1)

Only contains hydrogen and carbon atoms.

Question 2 (b)

It was pleasing to see only a few answers referred to the breaking of covalent bond instead of intermolecular forces. Many candidates appreciated that branching reduces the strength of the London forces between the molecules because of the decreased surface area contact.

(b) Explain why 2,2-dimethylpropane has a much lower boiling temperature than its isomer pentane.
Detailed descriptions of the <u>forces involved are not required.</u>

$$C-\overset{\overset{C}{|}}{\underset{\underset{C}{|}}{C}}-C \qquad \diagup C-C-C-C-C$$

(2)
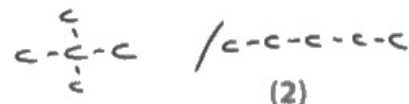
2-2-dimethylpropane is lower as it is branched → causing lower boiling point than a straight chain such as pentane. same number of bonds and atoms.

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Examiner Comments

This candidate has identified that the difference in the boiling temperature is due to the branching present in the isomer of pentane. However there is no explanation as to how this causes the difference and so no mark was awarded.

(b) Explain why 2,2-dimethylpropane has a much lower boiling temperature than its isomer pentane.
Detailed descriptions of the forces involved are not required.

(2)

2,2-dimethylpropane is a branched alkane. The molecules pack less well together compared to pentane. ~~Also~~ Lower molecular surface contact in 2,2-dimethyl propane and less energy is required to break the intermolecular force of attraction.

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Examiner Comments

In this response we can see that the presence of branching is connected to the reduction in surface area contact between the molecules and scores 1 mark. The reference to the general term 'intermolecular force' rather than 'London forces' does not score the second mark.

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Examiner Tip

When referring to intermolecular forces, make sure that the specific type is clearly stated.

Question 3 (a)

(i) Understanding of mechanism is improving with a number of completely correct responses here. Some candidates still do not have a basic understanding of curly arrows as seen by their drawing them originating from atoms or terminating at bonds. Further skeletal formulae proved too challenging for some candidates with a disappearing carbon atom being seen on a number of occasions.

(ii) The most common mistake was to give the name as 2-methyl-1,2-dichlorobutane but this is incorrect. Candidates need to understand that the prefixes are given in alphabetical order.

3 This is a question about dihalogenoalkanes.

(a) Dihalogenoalkanes are formed when alkenes react with halogens.

(i) Complete the mechanism for the production of a dihalogenoalkane from 2-methylbut-1-ene and chlorine.
Include curly arrows and any relevant lone pairs.

(3)

(ii) Give the name of the dihalogenoalkane produced.
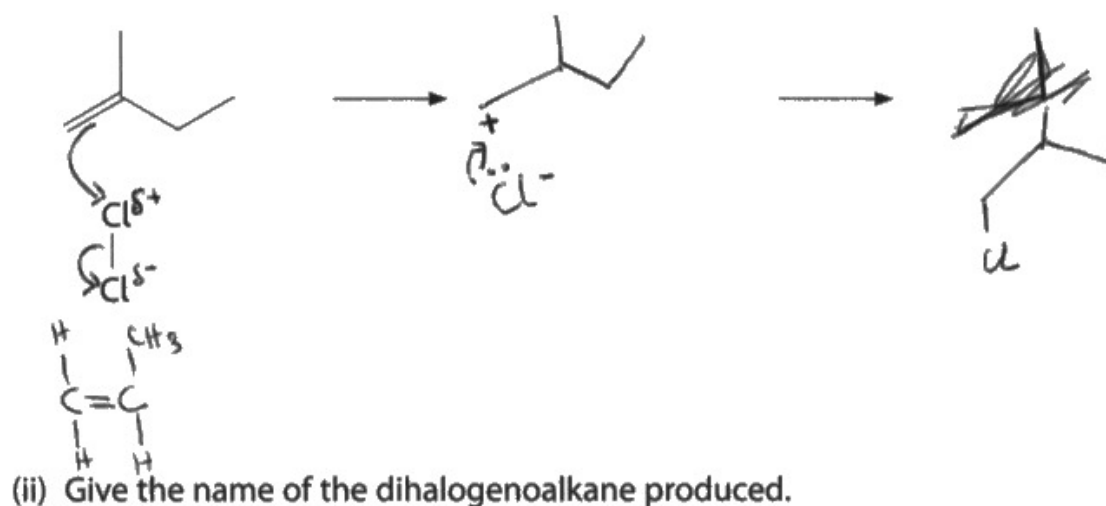
(1)

chloro butane .

In this response the candidate starts well and scores the first mark in part (i). Unfortunately there is nothing else creditworthy. Note that the carbocation structure is incorrect with the positive charge being on the wrong carbon and there is no chlorine atom in the structure. The curly arrow from the chloride ion does not clearly come from the lone pair of electrons. In fact it looks as if there could be three dots or three electrons written.

(ii) There is no transferred error because the name of the structure should be 1-chloro-2-methylbutane.

Curly arrows should always be drawn either from a bond or from a lone pair of electrons.

Use the information in the question to guide you. It states that a dihalogenoalkane is formed so there should be two halogen atoms in the product and not just one.

Question 4 (a)(i)

Most candidates showed that they knew what to do here since from revision they must have seen this sort of question before on previous versions of paper 2. Just under 50% scored all 4 marks. The most common error was to lose M1 by calculating the moles of nitrogen atoms, instead of molecules.

There were some very questionable conversion of units and it seems that some appear to have the habit of using the pressure in kPa which then gives the volume in dm^3 and so only requires multiplying by a thousand to give cm^3. This is not an approach that is encouraged. There was evidence that some candidates thought that the volume was in m^3 from the use of kPa and still only multiplied by a thousand showing real confusion with the units. It is advised that candidates learn the correct units of the Ideal Gas Equation and stick to those rather than use a supposed 'shortcut'.

4 This question is about nitrogen and some nitrogen compounds.

(a) A study of one brand of crisps found that each packet contained 0.420 g of nitrogen gas at a pressure of 120 kPa and a temperature of 20 °C.

(i) Calculate the volume of nitrogen gas, in **cm³**, in one packet of crisps.

[$R = 8.31\,J\,mol^{-1}\,K^{-1}$]

(4)

$$pV = nRT$$

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

$$V = \frac{0.03(8.31)(293)}{120\,000}$$

$$V = 6.09 \times 10^{-4}\ m^3\ (\times 10^{+6})$$

$P_a = 120\,000$

$m^3 =$

$K = 293$

$$n = \frac{0.420}{14}$$

$$n = 0.03$$

$1m - 100\,cm$

$1m^3 - 10^6\,cm^3$

$$\boxed{V = 609\ cm^3}$$

Question 4 (a)(ii)

Many reasonable suggestions were allowed to gain credit here for a novel application-type question. The most common problem here was vagueness with short statements that the nitrogen wouldn't react but with no explanation as to how or why the air would react.

(ii) Give a possible reason why nitrogen gas and not air is used in packets of crisps.

(1)

air would react with crisps and oxidise them

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Examiner Comments

An example here of a response which was awarded the mark.

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Examiner Tip

Remember that air contains roughly 20% oxygen and so it is not unusual for oxidation to be a result when chemicals are exposed to the air.

Question 4 (b)

It was disappointing that many candidates did not follow the clear instructions in the question for the use of symbols to represent the sodium and the nitrogen electrons. Whilst it is true that electrons from different atoms are indistinguishable, it is a well-established convention that different symbols are used in order to show clearly where such originate.

The nitrogen molecule was more often drawn correctly and the mode was 2 marks so many candidates did well on this question.

(b) Draw dot-and-cross diagrams for a molecule of nitrogen gas and for the nitride ion, N^{3-}, in sodium nitride, Na_3N.
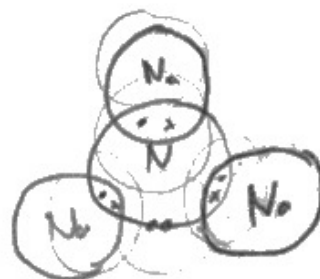
Use dots (•) for nitrogen electrons and crosses (✘) for electrons from sodium.

(2)

Nitrogen molecule   Nitride ion

ResultsPlus
Examiner Comments
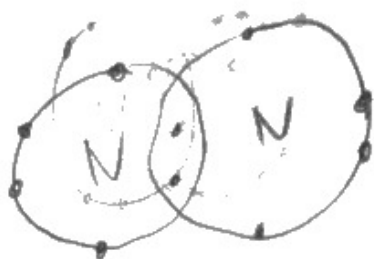
Neither of these diagrams scored a mark.

The diagram of the nitrogen molecule has each nitrogen atom ending up with only 6 electrons.

The diagram of the nitride ion shows the sodium atoms being covalently bonded in the nitride ion, despite the formula of the ion being clearly given above.

Follow the instructions to use whatever labels are given in the questions.

Remember that typically a metal and a non-metal form an ionic bond so electrons are transferred and not shared.

Question 4 (c)

Many answered this well with the mode being 4 and the overall mean being 2.48

The provision of blank space was there for candidates to include diagrams and invariably these helped the candidates who drew them. However diagrams were not essential and all four marks could be obtained through prose. Nonetheless it often proved to be harder for candidates to score all marks since it is seemed easier to annotate both diagrams with shapes and bond angles than to include both in a written answer.

It was surprising that a sizeable number of candidates thought that ammonia is trigonal planar. A further significant number of candidates incorrectly stated ammonia was trigonal bi-pyramidal. In addition some candidates got slightly confused with their bond angles as evidenced by ammonia being given as 107.5° and the ammonium ion as 109° instead of 107° and 109.5°.

(c) Ammonia accepts a proton to form an ammonium ion.

$$NH_3 + H^+ \rightarrow NH_4^+$$

Explain why the ammonia molecule and the ammonium ion have different shapes and different bond angles.
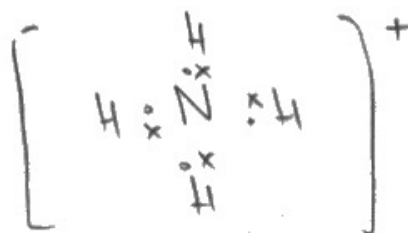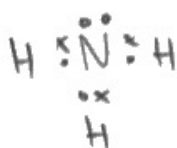
(4)

Ammonia has 3 bonded pairs and 1 lone pair. Electrons repel at maximum separation. Repulsion between bonded lone pair is greater than that between 2 bonded pairs. The bond angle is 107.

This is an example of a response which lacked sufficient comparison. A clear example of this can be seen that only one bond angle is given. In addition the language or expressions used are not clear as can be seen by 'bonded lone pair' which seems a contradiction. However when the remainder of the sentence is read it is evident that the candidate is referring to the repulsion between a bonded (pair) and a lone pair (of electrons). Examiner judgement is required here and the mark was awarded after some consideration. The matter was not helped by the earlier comment that electrons rather than electron pairs repel.

A second mark was awarded for the four bonded pairs of electrons in the ammonium ion, as seen in the diagram, and for the three bonded pairs with one lone pair in ammonia, both seen in the diagram and stated.

Make time to re-read your answer so that you can check that it does make sense and is stating what you want it to say.

Question 4 (d)

This proved to be one of the more challenging questions on the paper. The definition of a Bronsted-Lowry base was frequently the mark gained but a large number of candidates lost this mark by stating the acyl chloride was an acid and donated the proton.

It was also disappointing that so few candidates gave a clear definition of a nucleophile and also thought that it attacked a carbocation. Candidates were expected to know that there is no carbocation in the mechanism but rather that the nucleophile attacks the delta positive carbon of the C=O bond.

Very few candidates referred to the production of HCl which would immediately react with the excess ethylamine.

(d) Butylamine, $C_4H_9NH_2$, reacts with ethanoyl chloride. *then   bond pair - bond pair   repulsion*

$$2C_4H_9NH_2 + CH_3COCl \rightarrow C_4H_9NHCOCH_3 + C_4H_9NH_3^+Cl^-$$

Explain how this equation illustrates that butylamine acts as a nucleophile and as a base.

(4)

Butylamine accepts a proton from ethanoyl Chloride to form $C_4H_9NH_3^+$. But also acts as a nucleophile as it attacks ethanoyl Chloride's electron deficient Carbon atom to take its Chlorine atom. If Nucleophilic substitution is occurring

ResultsPlus Examiner Comments

This response is an example where the mark was lost by stating that the proton being accepted was from the ethanoyl chloride. This is incorrect and results in the negation of the otherwise correct comment about butylamine being a base as it accepts protons.

Question 5 (a)

It was pleasing that the vast majority of candidates understood this practical demonstration and almost all candidates could give a suitable estimate of the density of the oil, with many explaining their logic lucidly. The less able candidates failed to explain why the density was in between the two given densities.

5   Ice has a density of $0.92\,g\,cm^{-3}$ and water has a density of $1.00\,g\,cm^{-3}$.

(a) About $200\,cm^3$ of water and $200\,cm^3$ of cooking oil were placed in a large beaker and two layers formed. The cooking oil formed the upper layer.

An ice cube made from water with a water-soluble blue food dye was added.

Initially the ice cube floated on top of the cooking oil but on melting the blue-coloured water sank into the bottom layer of water.

Give a possible value for the density of the cooking oil. Justify your answer.

(2)

density of cooking oil ~ $0.95\,g\,cm^{-3}$

the density of cooking oil is between that of ice and water

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Examiner Comments

One mark was awarded here for the suggested density of the cooking oil.

However there is no explanation as to why the density value must be between the other values and so the second mark was not awarded.

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Examiner Tip

Make sure that an explanation includes more than just a restatement of the answer.

Take care to use the information provided when answering questions.

Question 5 (b)

There were a number of different approaches to answering this question and each was given full credit. Generally most candidates could use both the densities and the Avogadro constant correctly.

There remain some important reminders for candidates – namely that rounding of values should only be done for the final answer and it is worthwhile to double-check calculations which helps to eliminate simple errors.

(b) Calculate how many **more** molecules there are in $5.00\,cm^3$ of water compared to $5.00\,cm^3$ of ice.

(3)

$$d = \frac{m}{V}$$

in water

$$5 = \frac{m}{5} \qquad m = 25g$$

in cube

$$n = \frac{m}{m_r} = \frac{25}{18} = 1.38889$$

$$0.92 = \frac{m}{1}$$

$$n \times 6 \times 10^{23}$$
$$= 8.33 \times 10^{23}$$

$$4.6 = \frac{m}{5}$$

$$m = 23g$$

$$n = \frac{m}{m_r} = \frac{23}{18} =$$

$$1.27778 \times 6 \times 10^{23} = 7.67 \times 10^{23}$$

$$8.33 \times 10^{23} - 7.67 \times 10^{23} = 6.63 \times 10^{22} \text{ more}$$

This response shows an incorrect mass for both ice and water. Hence one mark is lost.

The subsequent method is fine and could have got both remaining marks as a transferred error but the result of the final subtraction is not correct. Examiners checked the candidates' values to see if they were correct.

Hence this response only scored one mark.

The use of the simplified value for the Avogadro constant was allowed but is not recommended.

Making time to double check calculations is time well spent.

Do not round intermediate values – keep the rounding until the final step.

Question 6 (c)(i)

The inclusion of the MS allowed reference to the apparatus as "reflux" for M1, resulting in many candidates scoring one mark as indicated by the overall mean of 0.99. However there were a significant number of candidates who negated this mark by referring to the loss of gas through the top of the condenser.

There were also a large number of candidates who understood that the use of reflux apparatus results in the oxidation of the alcohol to the carboxylic acid but this question was focused on the yield of the aldehyde so this comment did not score. There needed to be reference to the propanal or the aldehyde being further oxidised to the carboxylic (which is why the yield is low).

It is worth highlighting to centres and their candidates that use of the term 'complete oxidation' is incorrect in this context and should not be used.

Explain why the use of this apparatus would give a very low yield of propanal.

(2)

The top of the apparatus is of open and the vapours of the reaction mixture (some of them) can escape hence lowers the yeild.

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Examiner Comments

This is an example of a response which shows a misunderstanding of the apparatus used. The reflux apparatus must be kept open at the top to avoid the build-up of pressure but propanal vapour will not escape since it will condense and drop back down into the pear-shaped flask.

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Examiner Tip

Chemistry is a practical subject and so experiments and the apparatus used will always feature in exam questions so make sure that you are familiar with such.

Question 6 (c)(ii)

The majority of candidates scored the mark as evidenced by the mean of 0.81. However there was evidence of some candidates 'doing all the hard work' by calculating that there needed to be +12 for the chromium part of the compound but then missing the fact that there were two chromium atoms present. Hence the need to divide the value by 2 in order to obtain the correct answer of +6.

(ii) The oxidising agent is acidified $Na_2Cr_2O_7$.

State the oxidation number of chromium in $Na_2Cr_2O_7$.

(1)

+12

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Examiner Comments

An example of a response where the individual oxidation number of chromium was not calculated so did not score.
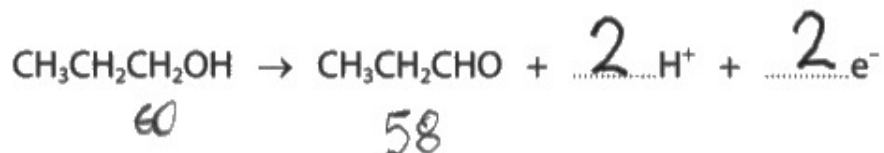
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Examiner Tip

Oxidation numbers should always be quoted for the single atom of the element.

Question 6 (c)(iii)

The majority of candidates were able to work out the required numbers of hydrogen ions and electrons to complete this oxidation half-equation.

(iii) Complete the ionic half-equation for the oxidation of propan-1-ol.

(1)

$$CH_3CH_2CH_2OH \rightarrow CH_3CH_2CHO + \underline{2}\,H^+ + \underline{2}\,e^-$$

60   58

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Examiner Comments

The working can clearly be seen and the correct final values placed in the appropriate places.

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Examiner Tip

Working is fine and in fact encouraged but in many occasions it is best to strike through so that it does not detract from the final answer.

Question 6 (c)(iv)

The use of anti-bumping granules has been asked many times before and the overall mean of 0.51 is lower than expected. The candidates frequently expressed incorrect ideas such as stating that these granules prevented bumping. It is possible that a lack of practical work/discussion in class due to COVID-19 contributed to this. Nonetheless there were a significant number of candidates who gave the preferred answer of the provision of nucleation sites for smaller bubbles rather than the 'allow' answer of to distribute heat more evenly.

(iv) State how the use of anti-bumping granules gives smoother boiling.

(1)

the anti-bumping granules allow for a greater surface area for the reaction to occcur.

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Examiner Comments

Here is another example of a common incorrect response.

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Examiner Tip

The Core Practicals are an important part of the A Level programme and should be a prominent part of revision.

Question 6 (c)(v)

The majority of candidates (62%) scored all 3 marks by correctly calculating the percentage yield. A minority used both masses to determine a percentage but this did not gain any credit. This type of calculation is well worth considerable practice by all candidates but perhaps especially those at the grade E boundary.

(v) Another student used the correct apparatus for this oxidation. 1.50 g of propan-1-ol produced 0.609 g of propanal.

Calculate the percentage yield of propanal by mass.

(3)

$$\text{Moles of propan-1-ol} = \frac{1.5}{60}$$

$$= 0.025$$

$$\text{Ratio} = 1 : 1$$

$$\text{Mass of propanal} = 0.025 \times 58$$

$$= 0.625 \text{ g}$$

$$\therefore \% \text{ yield} = \frac{0.609}{0.625} \times 100$$

$$= 97.4 \% \quad (3 \text{ sf})$$

This is another example of the benefit to candidates of transferred error and hence the wisdom of at least attempting a question as opposed to leaving it blank.

This candidate has correctly determined the starting moles of propan-1-ol for M1 and understands that the 1:1 molar ration indicates that this is also the number of moles of propanal. The next step to determine the theoretical maximum mass of propanal is laid out correctly but unfortunately the answer is incorrect and so loses M2. This incorrect mass is then used correctly to determine the percentage yield for M3. Hence this response scores 2 marks.

Attempt all questions.

Double-check all calculations.

Question 6 (d)(i)

A disappointing performance by candidates of lower ability on this intermolecular forces question. One mark for hydrogen bonding by ethanoic acid should have been achievable for the grade E boundary but occasionally was negated by comments that propanone can also form hydrogen bonding as well, although weaker ones.

A sizeable number of candidates identified the small difference in molar masses between propanone and ethanoic acid but then still went on to infer that this was part of the reason for the large difference in boiling temperatures. Only the more able candidates were able to appreciate that the similarity of London forces given the equal number of electrons in propanone and ethanoic acid would mean that these could be discounted from the reason for the difference in boiling temperatures.

Similarly the reference to propanone having permanent dipole – dipole forces was indicative of candidates at the higher grade A boundary.

There was some evidence of candidates not reading the question properly as seen by comments on miscibility in water which should have been made in part (ii).

(d) The table contains data on propanone and ethanoic acid.

Substance	Molar mass / g mol^{-1}	Boiling temperature / °C	Solubility in water
Propanone	58	56	completely miscible
Ethanoic acid	60	118	completely miscible

(i) Explain, by reference to the data and any intermolecular forces involved, the difference in the boiling temperatures.

(4)

Ethanoic acid has a higher boiling point while having a similar Molar mass to propanone as it is able to form hydrogen bonds between its molecules. Propanone is only able to form Vander walls forces. Thus more energy is required to break the bonds in Ethanoic acid. Propanone is able to form hydrogen bonds with water, making it soluble, however, its molecule does not have the δ+ H to which the lone pair on the oxygen can form the H bond to. Thus its molecules do not form hydrogen bonds. Hydrogen bonds are much stronger than vanderwalls forces.

This response scores the mark for referring to only ethanoic acid being able to form hydrogen bonds to other ethanoic acid molecules. The further mark for a comparison of intermolecular forces strength was not awarded because this candidate has not stated that more **energy** is required to break them.

The misspelling of van der Waals' would not have been penalised given that it cannot be confused with anything else in this context.

Question 6 (d)(ii)

It was disappointing that some candidates drew the hydrogen bond between the oxygen atom of the water molecule and a hydrogen atom of the methyl group of propanone. Incorrect structures of propanone and of water (HO_2) were also seen.

The mark awarded for the diagram of the hydrogen bond was generously given since the angle and the inclusion of the oxygen lone pair of electrons was judged on paper 1. Hence this was not penalised on two occasions.

(ii) Explain, with the aid of a diagram, why propanone is completely miscible with water.

(2)

[Handwritten diagram showing propanone and water structures with hydrogen bond labelled "hydrogen bond"]
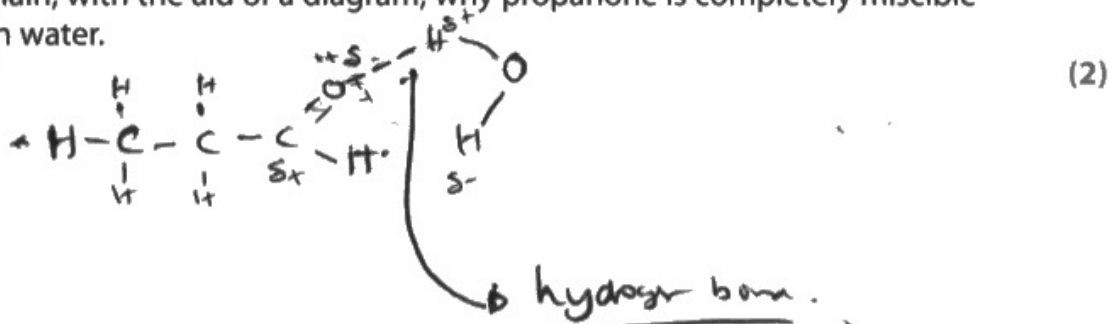
- The lone pair of electrons on propanone attract hydrogen molecule on water on propcane forms hydrogen bonds with the H's on water molecule. Due to forming hydrogen bonds with water It's soluble miscible in water. i.e soluble.

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This is an example of an incorrect structure being drawn for propanone which loses one mark. Note that the hydrogen bonding between the propanone and the water could have scored one mark but this is lost by the reference to the 'hydrogen molecule' being involved.

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Examiner Tip

Be careful in your choice of words as an incorrect use of a term can result in the loss of a mark that otherwise would have been gained.

Question 7 (a)

In part (i) candidates needed to realise that they had to start from propanenitrile, with some starting from butanenitrile. The reagent was usually known – and the solvent – but the equation was often not balanced correctly with [H] rather than 4[H] or H_2 rather than $2H_2$.

In part (ii) the equation was often correct as was the reagent, but reference to the 'ethanolic' solvent was often omitted, as was the need for an elevated pressure. The stock answer 'heat under reflux' was also seen but this will not work because the ammonia gas would not condense and escape out of the top of the condenser.

7 Organic compounds containing nitrogen include amides, amines, amino acids and nitriles.

 (a) Propylamine, $CH_3CH_2CH_2NH_2$, may be formed from either a nitrile or a halogenoalkane.

   (i) Give the reagent and essential condition for the formation of propylamine from a nitrile.
   Include an equation for the reaction.
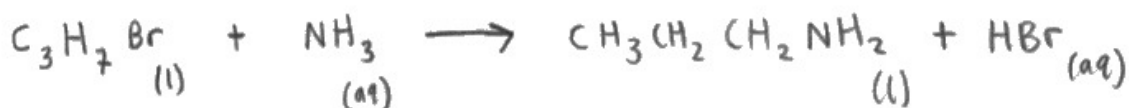
   (2)

   hydrogen gas

   ~~150°C~~ 150°C high temperature

   nickel catalyst

   $C_2H_5C\equiv N_{(l)} + 2H_2 (g)$

   nickel $\downarrow$ 150°C

   $C_2H_5CH_2NH_2 (l)$
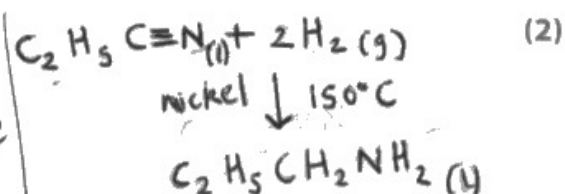
   .... $H_{2(g)}$, 150°C, nickel ....

   (ii) Give the reagent and essential conditions for the formation of propylamine from a halogenoalkane.
   Include an equation for the reaction.

   (3)

   $C_3H_7Br_{(l)} + NH_{3(aq)} \longrightarrow CH_3CH_2CH_2NH_{2(l)} + HBr_{(aq)}$

   .... ethanolic aqueous ammonia , dilute acid ....

In part (i) both marks were awarded. This candidate has used up crucial time and effort in writing the same reagent and catalyst three times. This is obviously unnecessary and raises the danger of losing a mark by introducing a mistake such an incorrect formula; fortunately this is not the case here.

In part (ii) this candidate has scored one mark for a suitable equation but then gives a contradictory chemical, dilute acid that would react with the ammonia, which negates the use of 'ethanolic' ammonia. Hence only one mark awarded.

Avoid repeating yourself. Save the time for other questions.

Make sure that 'opposing' chemicals such as an acid and a base are not added at the same time since they will negate each other.

Question 7 (c)

On the whole this 6-mark question was answered rather well which may be a reflection of the fact that amino acids are included in the first topic on the Advance Notice.

It was disappointing that IP3 and 4 often couldn't be given because of the absence of any equations despite the clear instruction in the question that these were required. In addition, it was not uncommon to see one or more of the equations being balanced incorrectly, often with H_2O missing as a product. However, the MS had a rescue mark for a suitable description of amino acid behaviour with an acid and a base which helped many score a mark here.

Chirality and the ability to rotate the plane of plane polarised light were often given, but many failed to show mirror images of alanine's enantiomers.

It would seem that many had obviously noted on the Advance Notice information that amino acids were the first topic listed and so had revised their chemistry of amino acids. There were a sizeable number of excellent responses achieving full credit.

*(c) Alanine and glycine are amino acids.

Amino acid	Structure
alanine	
glycine	

Compare and contrast the structures, optical activity and reactions with acids and bases of alanine and glycine.
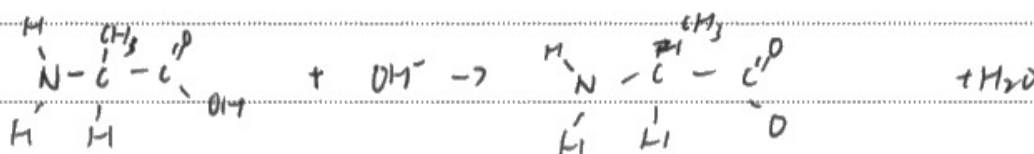
Include diagrams, structures and equations to illustrate your answer.

(6)
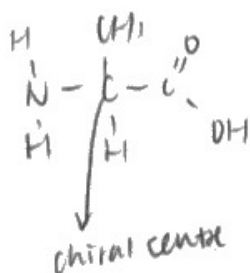
chiral centre

Alanine ~~z~~ has a chiral centre since it bonds to 4 different groups. Glycine does not have a chiral centre. Both of them can form optical isomers and it will polarise light. The reactions of them with acid and base are similar.

This response only scored one IP and consequently only one mark.

The mark scored is for the comment that alanine, and not glycine, has a chiral carbon/centre. This response incorrect states that the effect of this is to 'polarise light' instead of rotating the plane of polarised light.

There is almost another mark awarded for the equation between alanine and an alkali but close inspection reveals that there is a missing negative charge on the deprotonated caboxyl group.
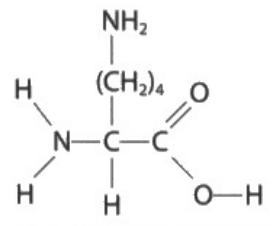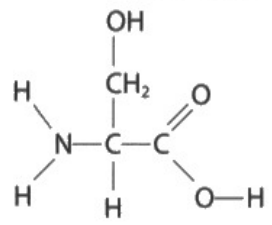
Check that your equations are balanced both for atoms and for charge.

Question 7 (d)

Despite the presence of several numbers in the question candidates often only answered qualitatively regarding the volumes of acid required and the number of amino groups present. Some candidates incorrectly thought the alcohol group was acidic.

(d) Lysine and serine are two more amino acids.

Amino acid	Structure of amino acid
lysine	
serine	

Explain the difference in the volumes of $0.010\,mol\,dm^{-3}$ hydrochloric acid required to completely react with separate $10.0\,cm^3$ samples of aqueous lysine and of aqueous serine, both of concentration $0.010\,mol\,dm^{-3}$.

(2)

More HCl would be required to react with lysine as it has 2 NH_2 groups, so 2 protons (H^+) must be donated to the NH_2 group per molecule of lysine, compared to just one H^+ for serine.

ResultsPlus
Examiner Comments

One mark was awarded for the awareness that there are two amine groups in lysine compared to only one in serine. However it was insufficient to simply state that 'more' HCl was required and given that the concentrations with volumes were given, a specific quantity was needed.

Question 8 (b)

Translation of skeletal formulae into molecular formulae continues to prove challenging to many candidates, although about two-thirds did score the mark here. This may be a reflection of the inclusion of this topic area on the Advance Notice.

(b) State the molecular formula of amyl acetate.

(1)

$\cancel{CH_3CH_2}$ $CH_3COOCH_2CH_2CH_2CH_2CH_3$

> **ResultsPlus**
> **Examiner Comments**
>
> Here is an example of a candidate not understanding the meaning of the term 'molecular formula' and giving the structural formula instead which did not score.

> **ResultsPlus**
> **Examiner Tip**
>
> Learn your chemistry definitions.

Question 8 (c)

The vast majority of candidates could deduce the structural formula of the carboxylic acid that would be used to form the two esters stated in the question.

(c) Deduce the structural formula of the carboxylic acid that could be used to form both isoamyl acetate and amyl acetate.

(1)

H COOH

Question 8 (d)

It would seem that more practice is required for naming organic molecules since only about 50% of candidates could name the alcohol correctly as 3-methylbutan-1-ol.

Common wrong answers were:

2-methylbutan-1-ol where the carbon chain was numbered in one direction for the alcohol group and then in a different direction for the position of the methyl group.

3-methylbutanol where the position of the alcohol group is missing.

(d) Deduce the **name** of the alcohol that forms isoamyl acetate.

(1)

3- methylpropan-1-ol

ResultsPlus
Examiner Comments

Unfortunately this candidate is very close to the name required but has stated 'prop' rather than 'but'.

ResultsPlus
Examiner Tip

Mnemonics are very useful ways to help remember the naming stems of organic molecules – for example Monkeys Eat Peanut Butter or Most Elephants Prefer Bananas for the sequence Methane – Ethane – Propane – Butane.

Alternatively make up your own which you can easily remember.

Question 8 (e)

Candidates did better with the systematic name for amyl acetate that had been anticipated as nearly 50% scored the mark.

(e) Give the systematic name for amyl acetate.

(1)

propyl ethanoate

ResultsPlus
Examiner Comments

Another example where the prefix used is incorrect for the number of carbons present.

ResultsPlus
Examiner Tip

If the number of carbon atoms in a consecutive sequence is above 4 then remember the names of the shapes to help you – for example, pent as in pentagon for 5, hex as in hexagon for 6

Question 8 (f)(i)

It was pleasing to see that candidates drew skeletal formulae and were not tempted to give displayed formulae.

Many excellent answers were seen. The two common errors were (i) drawing two of the same isomer and (ii) adding an extra carbon atom to the chain.

(f) The carboxylic acid used to make isoamyl acetate and amyl acetate can also be used to make five further ester isomers. The structures of two of these esters, **A** and **B**, are shown.

(i) Complete the **skeletal** formulae of the three remaining esters. Names are **not** required.

(3)

isoamyl acetate	amyl acetate	
ester A		
ester B		
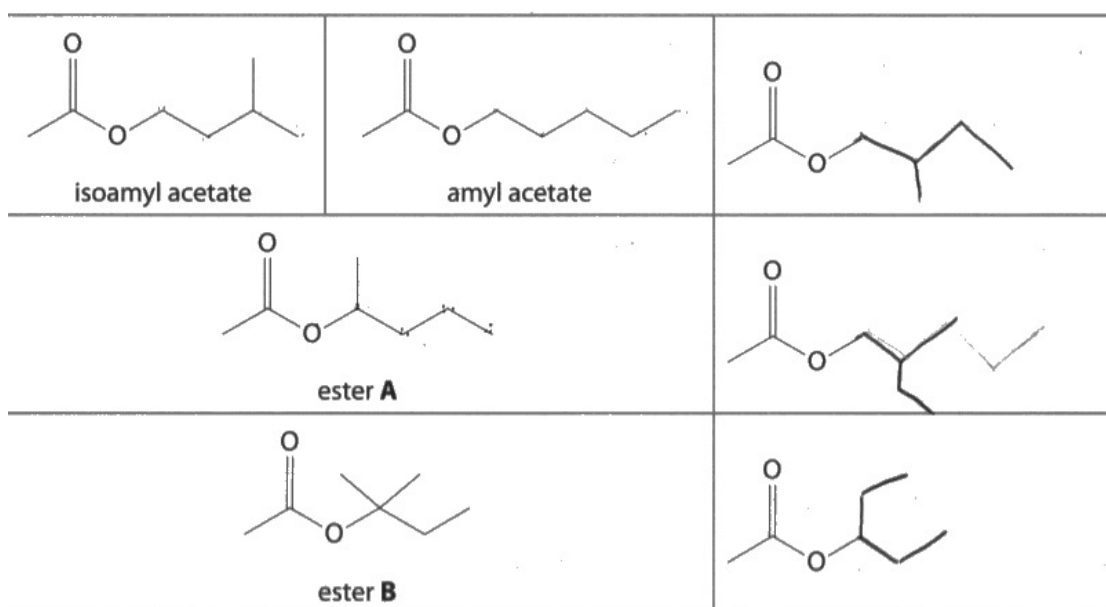
ResultsPlus
Examiner Comments

In this example the first and second skeletal formulae are identical. The third formula is correct so two marks were awarded.
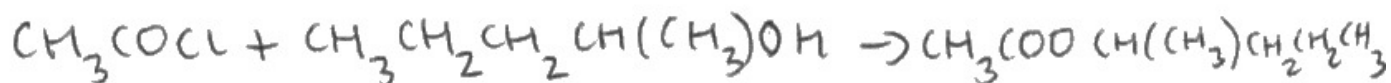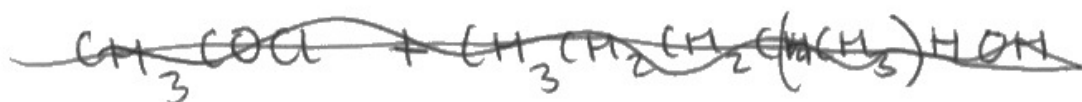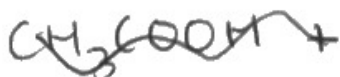
ResultsPlus
Examiner Tip

Practise, practise and practise again drawing isomers with the carbon chain drawn at all manner of different angles.

Question 8 (f)(ii)

The majority of candidates scored on this question but only about a third scored both marks. The most common error was the failure to include the HCl product but also errors in the structure of the alcohol to make the branched chained ester were often seen.

(ii) Write an equation to show the formation of ester **A** from an acyl chloride and an alcohol.

(2)

$CH_3COOH +$

$CH_3COCl + CH_3CH_2CH_2CH(CH_3)HOH$ (crossed out)

$CH_3COCl + CH_3CH_2CH_2CH(CH_3)OH \rightarrow CH_3COO CH(CH_3)CH_2CH_2CH_3$

Question 8 (g)

There were some good answers seen to this answer on ester hydrolysis. The main criticism is that many candidates failed to give a proper comparison.

For example if there are only two options such as one reaction is an equilibrium whilst the other is irreversible, then it is fine to state that 'one is and the other is not'. However this was only the case with one of the three differences. To illustrate, a comment which states the acid hydrolysis produces the carboxylic acid is a good start but there are large numbers of other organic molecules and so to simply state that alkaline hydrolysis doesn't produce the carboxylic acid is insufficient. It fails to state what is made instead.

Similarly it was not enough to state the the acid is a catalyst whereas the alkali is not. There needed to be a positive statement that the alkali is a reactant. This was the marking point that was often missing.

(g) Esters can be hydrolysed by heating under reflux with aqueous acid or alkali.

Compare and contrast these two methods of hydrolysis for amyl acetate.

(4)

In aqueous acid, ~~heating an~~ hydrolising amyl acetate would split the ester into a carboxylic acid and alcohol. Specifically under acidic conditions ethanoic acid and ethyl pentanoate. However, under alkaline conditions, the ~~by-hydrolisible~~ hydrolisis still splits the ester into a ~~carbon~~ carboxylic acid ~~and add~~ alcohol but instead a carboxylate molecule would be produced where the metal ion in alkali bonds to the carboxylic acid (if NaOH was used for example, the carboxylate produced would be $CH_3COOH\ Na^+$). As such both the hydrolysis reactions cause the ester linkage to break but the ~~conditions depends~~ products formed depends on the conditions.

ResultsPlus
Examiner Comments

This is an example of a response which almost scores several marks but ends up scoring none.

M1 was for reference to both methods of hydrolysis producing the alcohol but if the alcohol was named then it had to be correct. As you can see here the alcohol is incorrectly named as ethyl pentanoate and so this mark is not awarded.

M3 was given if it was made clear that the carboxylic acid was formed from acid hydrolysis while the carboxylate salt was the product of alkaline hydrolysis. Again the mark was lost if an incorrect name or formula was given. In this response the formula of the carboxylate salt is incorrect and so loses the mark.

Nothing else creditworthy is here.

ResultsPlus
Examiner Tip

If a name and formula are given then both must be correct.

More leeway is allowed with a name, for example phonetic spellings, but chemical formulae must be correct.

Question 9 (a)(b)

This introduction of kinetics was well-answered which was expected given the familiar task and the inclusion of this topic on the Advance Notice.

9 At high temperatures, ethanal decomposes to form methane and carbon monoxide. The reaction is second order with respect to ethanal and second order overall.

$$CH_3CHO \rightarrow CH_4 + CO$$

(a) Write the rate equation for this reaction.

(1)

$$k = (CH_3CHO)^2 \quad (CO)^0 (CH_4)^0$$

(b) Deduce the units of the rate constant given that the units of rate are $mol\,dm^{-3}\,s^{-1}$.

(1)

$$mol\,dm^{-6}\,s^{-1}$$

Question 9 (c)(d)

In part (c) many candidates could correctly calculate the reaction rates given the data but then gave their final answers to an unjustifiable number of significant figures.

In part (d) many answers concentrated on explaining why this reaction is second order rather than answering the question and explaining why it isn't zero or first order. There were some excellent answers however.

(c) The table shows the concentration of ethanal in a sample at different times.

Time / s	Concentration of ethanal / mol dm^{-3}
0	0.72
420	0.36
1260	0.18

Calculate average values for the rate of reaction between 0 and 420 seconds and between 420 and 1260 seconds.
Give your answers to an appropriate number of significant figures.

(2)

$$0.72 - 0.36 = 0.36$$

0 s – 420 s ~~8.57×10^{-4}~~ 8.57×10^{-4}

~~840×0.18~~

420 s – 1260 s 2.14×10^{-4}

$\dfrac{840}{0.18}$ $\dfrac{0.18}{840}$

(d) Explain why the data given and your answers in (c) show that the reaction is **neither** zero order **nor** first order.

(2)

$$\frac{8.57 \times 10^{-4}}{4} = 2.14 \times 10^{-4}.$$ The data given and my answer shows that it is second order because. the concentration decreased from 0.72 to 0.18 by $\frac{0.72}{0.18} = 4.$ Supporting $K = [CH_3CHO]^2$

ResultsPlus Examiner Comments

In (c) we see that example of an answer to three SF which scored 1 mark out of two.

In (d) the response is an example of one which doesn't answer the question directly by explaining why it isn't first or zero order, but does gain one mark for explaining why it is second order.

ResultsPlus Examiner Tip

Remember RTQ^2 – Read The Question Twice

(c) The table shows the concentration of ethanal in a sample at different times.

Time / s	Concentration of ethanal / $mol\,dm^{-3}$
0	0.72
420	0.36
1260	0.18

Calculate average values for the rate of reaction between 0 and 420 seconds and between 420 and 1260 seconds.
Give your answers to an appropriate number of significant figures.

(2)

0 s – 420 s   ~~0.3~~ $8.57 \times 10^{-4}\, mol\,dm^{-3}\,s^{-1}$ $\dfrac{0.36}{420} =$

420 s – 1260 s $2.14 \times 10^{-4}\, mol\,dm^{-3}\,s^{-1}$ $\dfrac{0.18}{1260-420}$

(d) Explain why the data given and your answers in (c) show that the reaction is **neither** zero order **nor** first order.

(2)

If the reaction was first order, the half life would be constant so the time taken for 0.36 - 0.18 mol dm⁻³ should have taken 420 s. If the reaction was zero order, the rate of reaction would not change with [CH_3CHO].

An example of a response which scores 1 mark for (c) but gives two suitable explanations in (d) for both marks.

Question 9 (e)

This type of calculation based on graph plotting has been seen before in previous papers, so many candidates knew exactly what to do. In addition the inclusion of this topic area on the Advance Notice may have helped some candidates with their exam preparation for this type of task.

It was disappointing to see a number of students who were unable to make the best use of the grid supplied, which lost M3. Also there were still further candidates who plotted negative values becoming decreasingly negative down the page and those who plotted 1n k on the x-axis and 1/T on the y-axis.

Gradients were often determined but, despite clear instructions given in the question, often the units were lacking which lost one mark.

It was pleasing that no negative activation energies were seen.

(e) The rate constant for the reaction was determined at five temperatures.
The results are given in the table.

Temperature (T) / K	1/Temperature ($1/T$) / K^{-1}	Rate constant (k) / units in (b)	$\ln k$
700	1.43×10^{-3}	0.011	−4.51
730	1.37×10^{-3}	0.035	−3.35
760	1.32×10^{-3}	0.105	−2.25
790	1.27×10^{-3}	0.343	−1.07
810	1.23×10^{-3}	0.787	−0.24

Determine the activation energy, E_a, in kJ mol^{-1}, by completing the data in the table and plotting a graph of $\ln k$ against $1/T$.

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

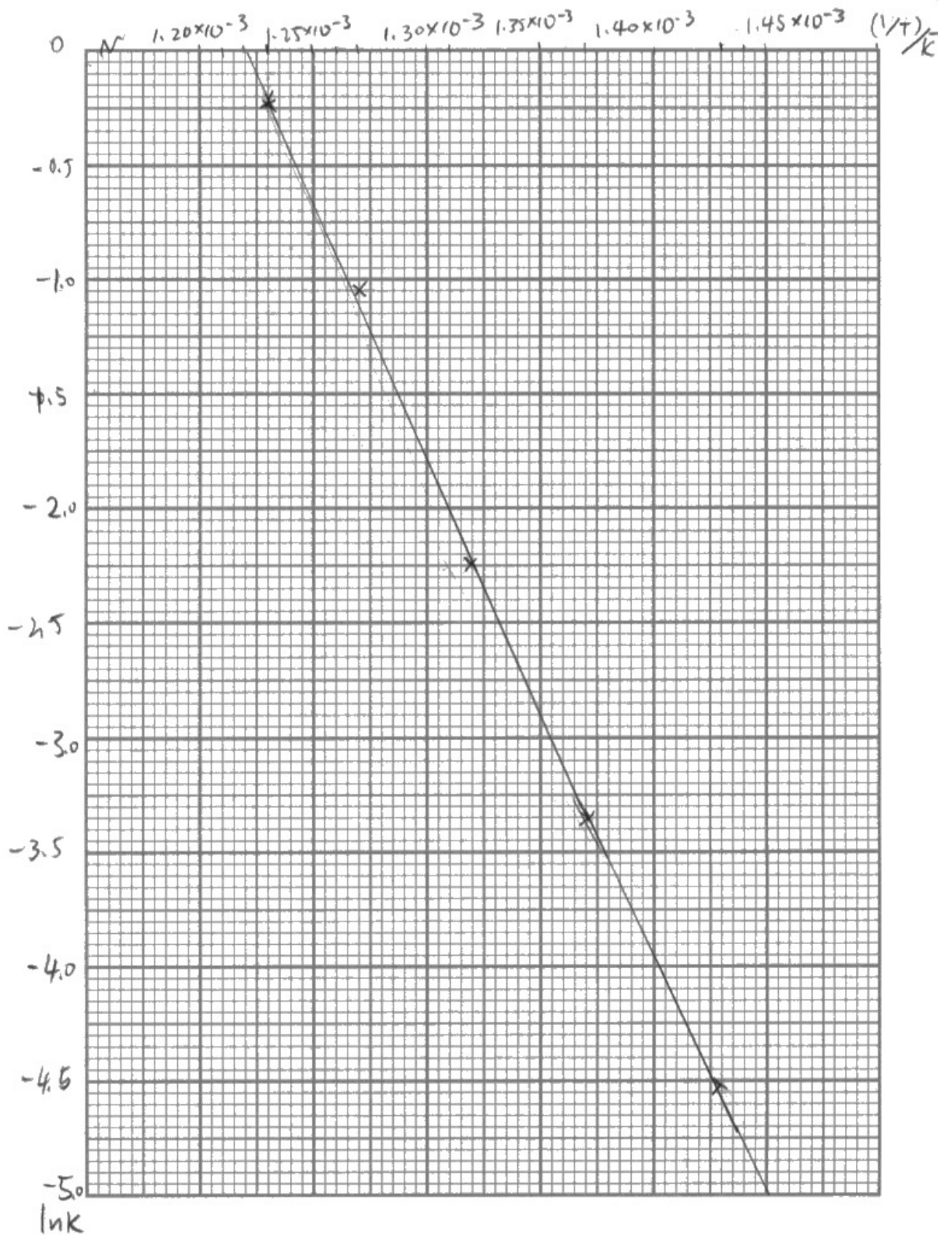The Arrhenius equation can be expressed as $\ln k = -\dfrac{E_a}{R} \times \dfrac{1}{T} + \text{constant}$

(7)

$$\text{gradient} = -\frac{E_a}{R}$$

$$\frac{1}{1.45 \cdot 1.24 = \frac{-5}{0.21 \times 10^{-3}}} = -23809.5$$

$$\cancel{288} -238\,09.5 \times -8.31 \quad \cancel{23809.5}$$

$$E_a = 197,857 \text{ J mol}^{-1}$$
$$= 198\,000 \text{ kJ mol}^{-1}$$

Paper Summary

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

- Double or even triple-check your calculations to make sure that all the values are correct.
- Do not round up intermediate values in a calculation as this should only be done at the end.
- Give the final value to an appropriate number of significant figures which is indicated by the data since 3SF is not always suitable.
- Also check your equations to make sure that they are balanced for atoms and for charge.
- Practise over and over drawing skeletal isomers since 'repetition is the mother of retention'. This maxim applies to many other such chemical skills.
- Make sure that practical work is part of your revision. Consider the reasons why various techniques are employed.
- When drawing a graph make sure that the scale will ensure that the plotted points will cover at least half of the graph paper and that both axes are suitably labelled with appropriate units.
- Always remember RTQ^2 – Read The Question Twice – before starting to answer and when you have finished to make sure that you have addressed what is required in the question.

Grade boundaries

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

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