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Examiners' Report
June 2023

International Advanced Level Chemistry WCH12 01

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Introduction

This paper provided most candidates with the opportunity to demonstrate their knowledge and understanding of the concepts covered in Unit 2 and the underlying principles of the AS course. All the questions attracted at least some excellent responses but, in general, candidates were more comfortable dealing with calculations, particularly those dealing with standard processes, and questions that permitted the extensive use of prepared material. For many candidates the greatest challenge was dealing with questions that required the application of basic principles in novel contexts, often using learned or standard responses apparently without taking the time to consider whether these were appropriate. Here and elsewhere candidates needed to read the question carefully to ensure that they had answered the question that was set. Some candidates did not take enough care to structure their answers so that the processes could be readily understood; this applied to longer written responses and to calculations.

The multiple choice section was marginally the highest scoring section with a mean mark of 10.14. The most difficult question was Q04, with just 11% of candidates giving the correct response, whilst the easiest was Q13 which 86% of candidates answered correctly.

Question 19 (a)

The type and mechanism of these reactions were correctly identified by most candidates. Some candidates gave correct answers that included superfluous but correct detail while others added incorrect information; the latter resulted in the mark being lost.

(a) Name the type and mechanism of these reactions.

(1)

Heterolytic nucleophilic substitution

ResultsPlus Examiner Comments

The word 'heterolytic' is not needed here but it does not affect the marking of the response.

ResultsPlus Examiner Tip

Do not add extra material to an answer, it takes up time and, in some circumstances, can affect the marking.

(a) Name the type and mechanism of these reactions.

(1)

neuclophilic substitution, elimination

ResultsPlus Examiner Comments

As it is a possible reaction type, the inclusion of 'elimination' negates the mark.

ResultsPlus Examiner Tip

Consider carefully what you include in an answer.

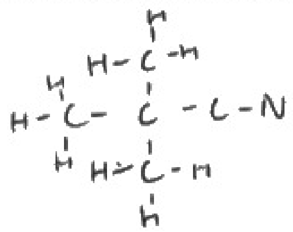
Question 19 (b)

The structure required was usually given correctly although, where the nitrile group was drawn out fully, the C≡N was often drawn with a single or double bond; a few candidates added a potassium atom to the structure.

The IUPAC name was often incorrect. Sometimes this was in details such as '2,2' and 'di' being omitted but the compound was frequently identified as an amine or a cyanide rather than a nitrile. Some candidates were unable to identify the main carbon chain.

(b) Give the IUPAC name and the structure of compound **M**.

(2)



2 - methyl propan- 2-ol

ResultsPlus
Examiner Comments

While the basic framework of the structure is correct, the single bond in the nitrile group means the mark cannot be awarded.

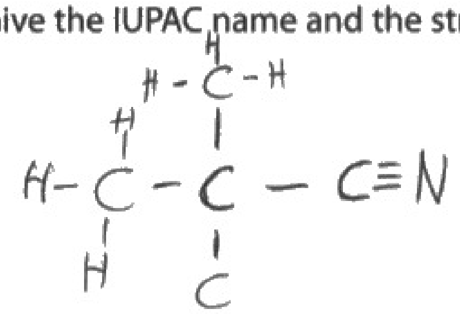
The product of a different reaction has been named.

ResultsPlus
Examiner Tip

Review your answers to make sure that the different parts are consistent.

(b) Give the IUPAC name and the structure of compound **M**.

(2)



2,2-dimethylpropanenitrile

ResultsPlus
Examiner Comments

The omission of the hydrogen atoms from the lower methyl group is a shame because the hard parts of the structure are correct.

A relatively rare example of a fully correct name.

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Examiner Tip

Count up the atoms and bonds of a displayed formula.

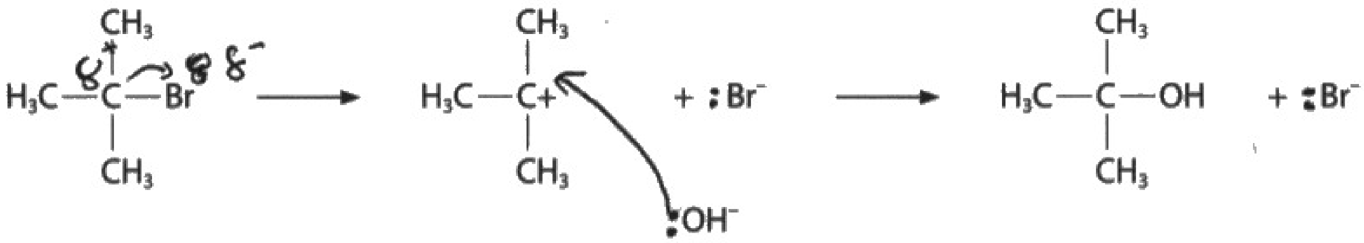
Question 19 (c)

The reagent mark was scored by most candidates but the conditions were less well known, with the frequent inclusion of 'heat under reflux' resulting in the loss of the conditions mark.

Question 19 (d)(i)

Most candidates appreciated what was required for this question but found it difficult to get all four points correct. Many answers indicated a lack of clarity about the significance of the curly arrow which should originate either from a covalent bond or from a lone pair. A number of responses showed a hydroxide ion attacking the carbon atom bonded to the bromine in the starting molecule, even though the hydroxide is clearly involved in the second step of the mechanism.

(d) An incomplete mechanism for Reaction **2** is shown.



intermediate **J**

(i) Complete the mechanism by adding curly arrows, and relevant dipoles and lone pairs.

(2)

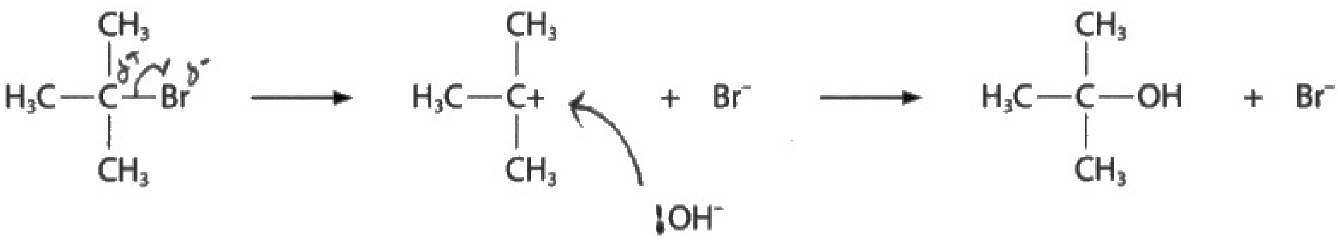
ResultsPlus Examiner Comments

The right-hand curly arrow may just about be acceptable, although the arrow appears to be heading towards the C-C bond rather than the C+ atom, but the left-hand curly arrow clearly originates from the central carbon atom of the reactant molecule.

ResultsPlus Examiner Tip

Curly arrows must originate either from a bond or from a lone pair.

(d) An incomplete mechanism for Reaction **2** is shown.



intermediate **J**

(i) Complete the mechanism by adding curly arrows, and relevant dipoles and lone pairs.

(2)

ResultsPlus
Examiner Comments

The left-hand curly arrow is single-headed and therefore incorrectly shows the movement of a single electron.

The right-hand curly arrow is rather too far from the lone pair.

Question 19 (d)(ii)

The process in the first step was often correctly identified but the descriptions rarely included the essential reference to a bonding **pair** of electrons; sometimes these electrons were referred to as a lone pair, which is, of course, quite a serious error. The most common error was to describe the first step as nucleophilic substitution and describing the role of the hydroxide ion in the process; careful reading of the question might have prevented this.

(ii) Describe how intermediate **J** is formed in the first step, naming the process that occurs.

(2)

• intermediate J is a tertiary carbocation mediate where it is formed Hetrolytic bond fission where the δ- Br takes both electrons to form positive and negative ions.

ResultsPlus
Examiner Comments

Heterolytic bond fission is correctly identified but it is not clear enough that the electrons referred to are coming from the C-Br bond.

ResultsPlus
Examiner Tip

Re-read your answer and try to ensure that you have given all the essential information. Here part of the answer is certainly implied but it needed to be stated.

(ii) Describe how intermediate **J** is formed in the first step, naming the process that occurs.

(2)

- OH ion (nucleophile) attacked the C (slightly + (positive)) & replaced / Substituted Br with OH ~~to form an~~

- Bond Breaking occur → heterolytic fission

ResultsPlus
Examiner Comments

This type of response referring back to nucleophilic substitution was quite common.

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Examiner Tip

It is most unlikely that marks would be awarded for the same answer in different questions.

Question 19 (d)(iii)

The shape of the intermediate was often given correctly but the explanation of the shape often stopped at giving the number of electron pairs involved and failed to mention the minimum repulsion. The most common error was to give the shape as trigonal pyramid based on there being three bond pairs and a lone pair.

(iii) State the shape of intermediate **J**. Justify your answer.

(2)

trigonal planar, carbon has 3 bonding pairs and no lone pairs of electrons.

ResultsPlus Examiner Comments

The shape is correct but the significance of the three bonding pairs and no lone pairs is not explained.

(iii) State the shape of intermediate **J**. Justify your answer.

(2)

the shape will be trigonal planar since there are 3 bonded electrons and 0 lone thus the angle will be 120° in order to maximise separation & minimise repulsion

ResultsPlus
Examiner Comments

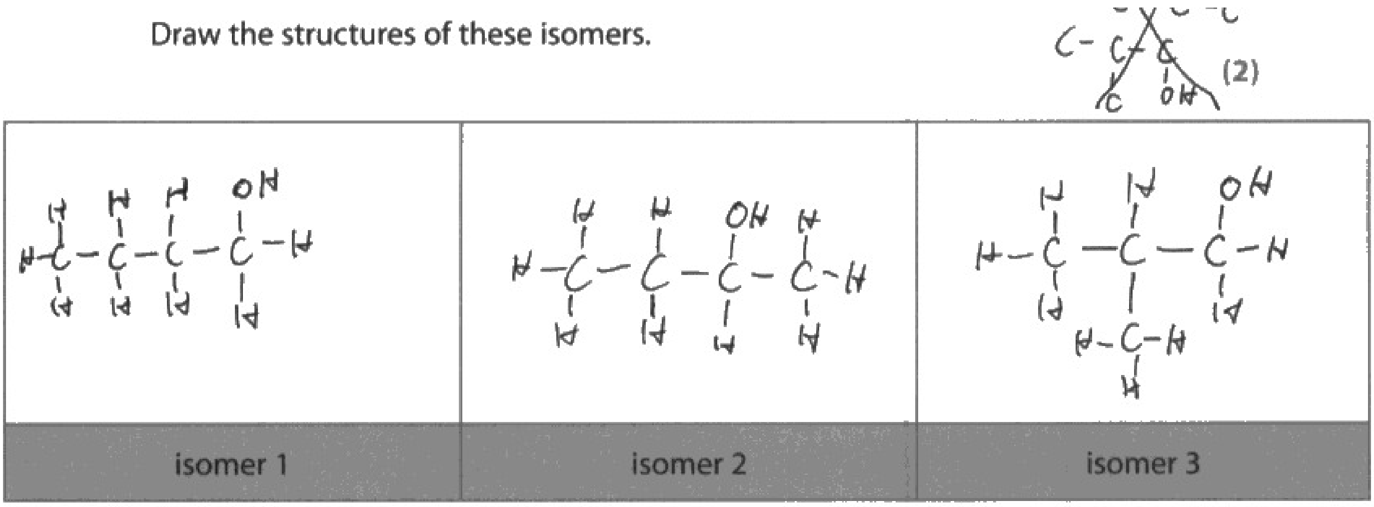
Nearly an excellent answer but the reference to '3 bonded electrons' rather than three electron pairs is critical.

ResultsPlus
Examiner Tip

Once again, the importance of reading an answer to ensure that all the points are clear is shown.

Question 19 (d)(iv)

There were a wide range of responses to this question. Candidates who could work out the three correct structures usually scored full marks although even some of these responses were spoiled by careless minor errors, such as omission of hydrogen atoms from displayed structures or incorrect connections between the carbon chain and the alcohol group. Structures were often duplicated by varying the shape of the carbon chain, particularly that of butan-2-ol, while others took the stem structure (2-methylpropan-2-ol) and rotated it into three different orientations. A small number of candidates included cyclic compounds or structures including a carbon-carbon double bond, failing to consider the effect that these structural changes would have on the formula of the compound.



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Examiner Comments

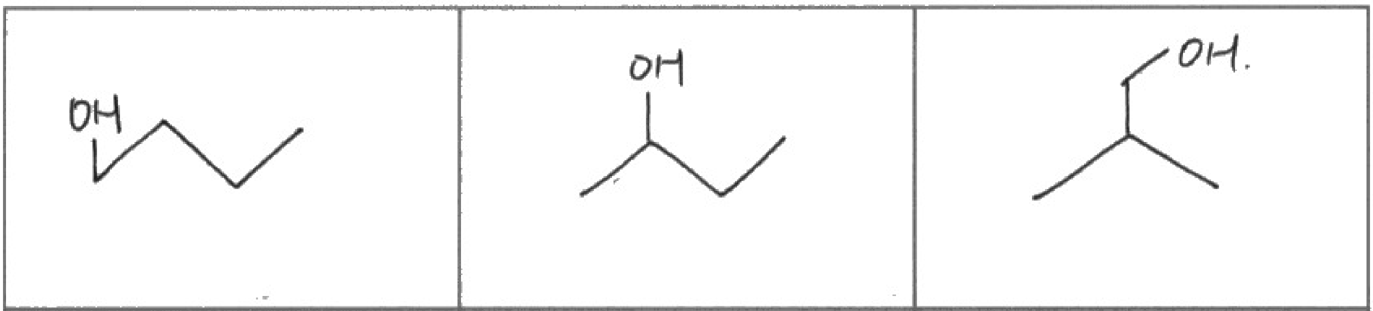
A fully correct answer using displayed structures.

ResultsPlus
Examiner Tip

Note that this candidate has placed all their OH groups so the C-O bond is vertical. This tactic eliminates concerns about the correct connectivity of the OH group to the carbon chain.

Draw the structures of these isomers.

(2)



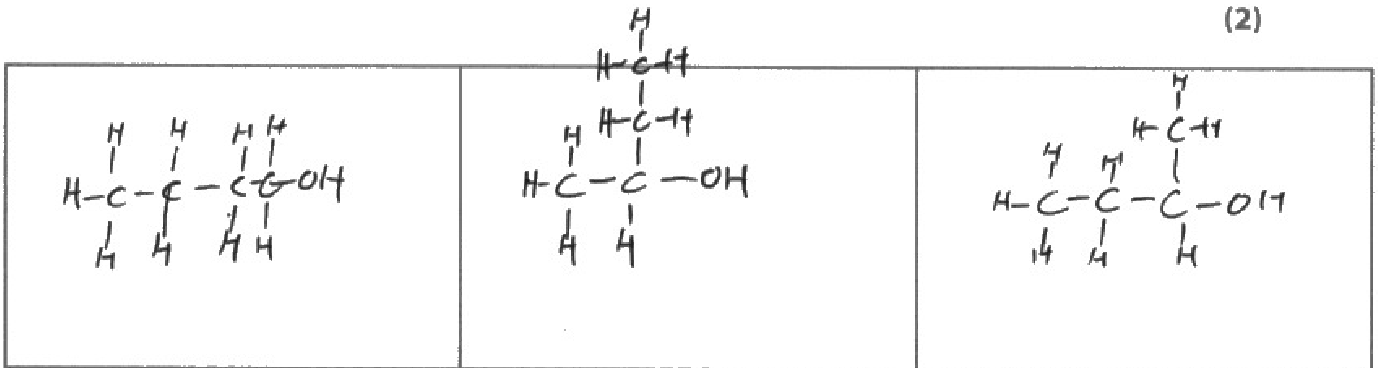
isomer 1	isomer 2	isomer 3

ResultsPlus
Examiner Comments

A relatively rare example of an answer using skeletal formulae.

Draw the structures of these isomers.

(2)



isomer 1	isomer 2	isomer 3

ResultsPlus
Examiner Comments

Here two structures are the same, just the orientation has changed.

ResultsPlus
Examiner Tip

Be careful to check the carbon chain sequence to ensure that the structures are distinct.

Question 19 (e)(i)

Candidates who were able to deduce the formula of silver(I) oxide were well on the way to scoring at least a mark on this item, although this proved surprisingly difficult. Many responses illustrated the difficulties that candidates have in writing ionic equations, particularly the basic requirement that amounts and charges must balance. Answers often included ionised water and hydrogen gas.

Question 19 (e)(ii)

Candidates were most likely to score a mark for the idea of reusing the silver(I) oxide rather than ease of separation. There were many standard suggestions that reflect an unwillingness to consider the information provided and responses such as silver(I) oxide is cheaper or reacts faster gained no credit.

Question 20 (a)(i)

There were many fully correct calculations, often set out with clear explanations of each step. Miscounting the bonds broken was quite common, particularly using eight carbon-carbon bonds but, if the subsequent steps were correct, this error cost candidates only one mark. Most candidates knew that bond breaking is endothermic and bond formation exothermic but some had it the wrong way round. Occasionally the calculation errors were so large that the final answer was endothermic but, instead of reviewing their calculation, candidates frequently compounded their error by simply reversing the sign. A significant minority of responses showed no intermediate calculations and some showed no clear working at all; while correct responses with some working will usually receive full marks, where there is a calculation error marks may only be awarded if the processes are clear.

$16 \times 413 + 7 \times 347 + 12\frac{1}{2} \times 498 + 8 \times 2 \times -805 + 9 \times 2 \times -464 =$

$-5970\ kJ\ mol^{-1}$

$-5970\ kJmol^{-1}$

ResultsPlus
Examiner Comments

There is just enough working shown here to establish the errors in the bond counts and that the data has been used correctly to award M2 and M4.

ResultsPlus
Examiner Tip

If there had also been a calculation error, then a mark of zero would have been awarded as there are no intermediate values given.

$$\Delta H = \Sigma in - \Sigma out$$

$$= \{18(413) + 7(347) + 12.5(498)\}$$

$$- \{16(805) + 18(464)\}$$

$$= -5144 \text{ kJ mol}^{-1}$$

ResultsPlus
Examiner Comments

This response scores full marks but, without intermediate values, the candidate is relying heavily on their accuracy with a calculator.

Question 20 (a)(ii)

The responses were often the standard explanations of experimental error which received no credit. Candidates who understood that the discrepancy was in part due to the use of mean bond energies scored the mark, although not all candidates compared these values to the specific bond energies of the compounds in the reaction. The connection with the specific case of octane combustion was required for the second mark where candidates often just referred to the general point that bond energies relate to gases and failed to mention that in this particular standard enthalpy change of combustion, octane and water are liquids.

(ii) The standard enthalpy change of combustion, $\Delta_c H^{\ominus}$, of octane is $-5470\,\text{kJ mol}^{-1}$.

Give **two** reasons why this value, measured under standard conditions, is different from the value obtained using bond enthalpy data.

(2)

As some of the energy may have been lost to the surrounding.
Some did not undergo complete combustion.
There may have been side reactions.

ResultsPlus Examiner Comments

A stock response to a question about experimental error in thermochemistry practical work that gains no credit.

ResultsPlus Examiner Tip

Read the question and your response carefully and consider whether the two match.

Question 20 (a)(iii)

There were many fully correct responses to this question with candidates using a range of valid approaches. However, the calculation was unfamiliar and it was apparent that some candidates simply could not work out what was required and so resorted to fairly random manipulation of the available data.

isn't taken into account calculating using bond enthalpy data

(iii) When petrol is used to power a car, the energy available is less than the theoretical maximum.

When one kilogram of petrol powers a car, the energy used to move the car is 11 MJ.

Calculate the percentage of the maximum energy that is available to move a car, assuming that this fuel is pure octane.

Use $\Delta_c H^{\ominus} = -5470\,kJ\,mol^{-1}$.

(2)

• 1 Kg = 1000 g

octane mr = 114

$\frac{1000}{114} = 8.77192 \ldots$ mols

−5470 KJ/mol × 8.77192 = −47982.45614 KJ

$\frac{-47982.45614\ KJ}{10000} = 4.798$ MJ

$\frac{4.798}{11} \times 100 = -43.6 = 43.6\ \%$

ResultsPlus
Examiner Comments

In this response the first three steps are completed successfully but then the candidate is unable to calculate the percentage required. The division by 10,000 seems designed to ensure that the number obtained is less than 11 and therefore the percentage below 100%.

Question 20 (a)(iv)

Most of the usual explanations for errors in enthalpy change experiments could be used here to score both marks, although some candidates possibly avoided these having applied them incorrectly in Q20(a)(ii). Some responses specifically referenced combustion in a car engine but others slipped into standard answers, such as evaporation, which were appropriate to laboratory situations.

Question 20 (b)

Candidates who read the question carefully and structured their responses were likely to achieve a good mark in this question. The intermolecular forces present in hydrogen and ammonia were correctly identified in many answers and there were some excellent descriptions of the formation of London forces, with candidates often showing a good understanding of the factors affecting the strength of London forces. The nature of the hydrogen bond in ammonia seemed less well understood, with candidates often failing to make it clear that the hydrogen bonds were between different molecules. The accounts of liquefaction were often incorrect. Some candidates confused liquefaction with dissolving in water or with combustion to form water, while others assumed that liquefaction was an endothermic process which led to great complications when comparing hydrogen and ammonia. Some candidates made excellent use of diagrams to illustrate their answers and these seemed useful in helping the candidates avoid some of the common errors such as confusing hydrogen bonding with the covalent bond in the hydrogen molecule.

*(b) Two alternatives to hydrocarbon fuels are hydrogen and ammonia. Hydrogen burns to form water as the only product but hydrogen is extremely hard to liquefy. Ammonia is easily liquefied but it is toxic.

Compare and contrast the intermolecular forces involved when hydrogen and ammonia liquefy, by describing how these forces are formed.

(6)

London forces is formed ~~when~~ between an instantaneous dipole, caused by a temperary ~~as~~ asymmetric distribution of electron density, and ~~th~~ an induced dipole of an adjacent molecule. Hydrogen bond arises ~~when~~ between hydrogen and lone pair electrons of F, O, or N atom. ~~The~~ ~~Only~~ ~~Only~~ London forces is the only intermolecular force present between hydrogen. However, it's weak as ~~th~~ hydrogen has lower number of electrons. Hence, ~~is~~ only small ~~amount~~ amount of energy is needed to ~~be~~ break ~~their~~ London force between them. As a result, it has a low boiling point, making it difficult to ~~be~~ be liquefied.

For ammonia, both London forces and hydrogen bond present between them. Its ~~Mr~~ ~~mo~~ molecular mass is larger than that of hydrogen, hence its London force is higher. Also, hydrogen bonds form between the lone pair of ~~the~~ electrons of N atom and hydrogen atom from another NH_3. Hydrogen bond is much stronger than London forces. Hence, much more energy is needed to overcome the intermolecular forces between NH_3 ~~molecules~~ molecules, so they have a relatively higher boiling point, making them easier to be liquefied.

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Examiner Comments

This response scored full marks. Note the logical development of the explanation and the concise but accurate statements, which indicate a significant degree of planning of the response

ResultsPlus
Examiner Tip

These questions will have six points called 'indicative points' which form the core of the response. Try to ensure that you cover this many points in your answer.

Ammonia has hydrogen bonding. This is the strongest intermolecular force of attraction. Ammonia also has the ability to bond to one more ammonia. This means that due to the hydrogen bonding, ammonia has a strong force of attraction between molecules so it is harder to break the bonds hence harder to liquefy.

Hydrogen on the other hand has only london forces as its intermolecular force. London forces is the weakest form of intermolecular force. This means that it requires very little energy to liquefy hydrogen. The bonds between the molecules ~~are~~ of hydrogen are broken much more easily compared to ammonia.

Ammonia has an overall larger london force than hydrogen due to more electrons and more ~~pon~~ points of contact

ResultsPlus
Examiner Comments

This response scores IP1, IP3 and IP4. The ideas about liquefaction are very confused as it suggests that the process is endothermic. The absence of any description of London forces or hydrogen bonds are important omissions, given that the question clearly requires their inclusion.

ResultsPlus
Examiner Tip

Careful reading of the question would have alerted the candidate of the need to expand their response.

Question 21 (a)

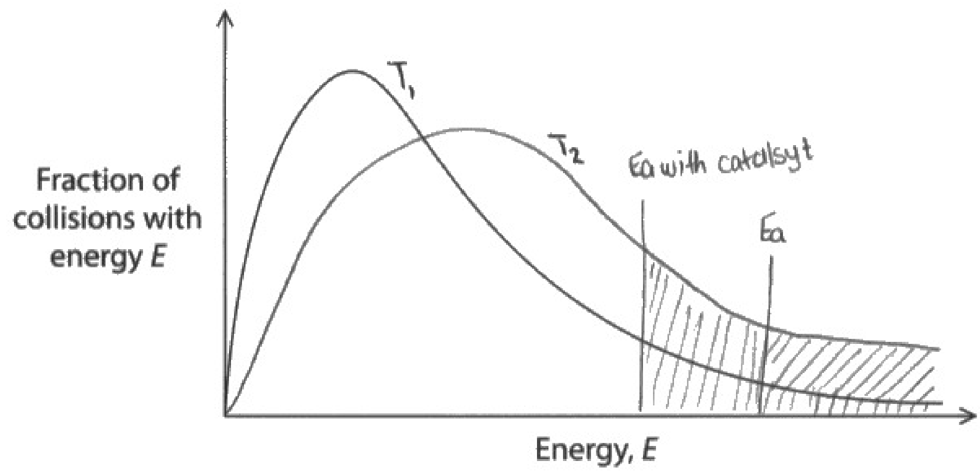
While most candidates appeared to understand how increasing the temperature would affect the general shape of the Maxwell-Boltzmann curve, many responses were insufficiently careful of the details. This particularly affected the asymptote which was often drawn crossing the lower temperature line and sometimes placed far above it. Less common errors included drawing a lower temperature line or, in some cases, a curve that was simply higher than the curve in the question. Candidates should be aware that the total area under a Maxwell-Boltzmann curve does not change with temperature.

Despite the wording in the question, few candidates made direct use of the Maxwell-Boltzmann curves. Candidates often failed to refer to activation energy in their explanations of the effect of temperature on the rate of reaction and just described the increase in kinetic energy and collision frequency. The effect of a catalyst on the activation energy was better understood, although some candidates suggested that the catalyst increased the energy of the reactants.

21 Methanal is used in the production of many materials and chemical compounds. It is manufactured from methanol by reaction with oxygen at 300–400 °C using an iron-molybdenum oxide catalyst.

$$CH_3OH(g) + ½O_2(g) \rightarrow HCHO(g) + H_2O(g)$$

(a) The Maxwell–Boltzmann distribution for the reaction mixture at 300 °C is shown.



(i) On the diagram, sketch the Maxwell–Boltzmann distribution for this reaction mixture at a **higher** temperature.

(1)

(ii) Using the Maxwell–Boltzmann distributions, explain why increasing the temperature and adding a catalyst both increase the rate of reaction.

(2)

Increasing the temperature, more molecules have greater kinetic energy so more ~~molecules~~ successful collisions occur per unit time. ~~as more molecules have energy~~ Adding a catalyst lowers the activation energy of the reaction so more molecules have energy greater than the activation energy. As a result more successful collisions occur per unit time

ResultsPlus
Examiner Comments

The higher temperature curve is the correct shape and in the right place; the asymptote is just low enough to be acceptable. Although the areas under the curves are shaded there is no explanation of their significance. The explanation of the effect of increasing the temperature only refers to the increase in kinetic energy and there is no mention of the role of the activation energy. The explanation of the effect of the catalyst is complete and gains the mark.

ResultsPlus
Examiner Tip

Check that the answer that you have written covers all the relevant points. Any use of a diagram must be supported by appropriate labelling and explanation.

Question 21 (b)

Candidates were much more likely to score the mark for a disadvantage of the system using a silver catalyst, realising that the higher temperature would involve significant energy costs. Few responses mentioned that the production of hydrogen as a useful by-product is an advantage, with improved atom economy most likely to score this mark. Candidates often relied on generalised answers such as increased rate as an advantage and, notwithstanding its exclusion in the question, the cost of the silver catalyst as a disadvantage.

(b) An alternative method for producing methanal uses a silver catalyst at a temperature of 650 °C. The reaction is shown.

$$CH_3OH(g) \rightarrow HCHO(g) + H_2(g)$$

Suggest **one** advantage and **one** disadvantage of this method, other than the cost of the silver catalyst.

(2)

Advantage

Higher atom economy.

Disadvantage

Higher energy costs as higher temperature used.

ResultsPlus
Examiner Comments

Where two marks were awarded, it was usually for this combination of responses.

Question 21 (c)

There were many fully correct responses to this question, predominantly using the wavenumbers for the O—H and O—H bonds; fewer candidates used the aldehyde C—H wavenumbers and some included all the possible correct wavenumbers. Candidates were most likely to lose a mark by failing to link the bonds and the relevant wavenumbers and there were some candidates who used the ketone C=O wavenumber.

(c) Explain how the infrared spectra of methanol and methanal can be used to distinguish between the two compounds, stating the relevant bond stretching vibrations and their wavenumber ranges.

(2)

methanol have structure (~~CH_3OH~~) of OH group, So it have a range of 3750 - 3200.

methanal have structure of CHO, which have a range of 2900 - 2820 and 2775 - 2700

ResultsPlus
Examiner Comments

This response scores the mark for two correct sets of wavenumber ranges. Identifying the functional groups is insufficient for the second mark.

ResultsPlus
Examiner Tip

The question specifically requires 'bond stretching' so it was essential to state these. Careful reading of this question gives a clear indication of how it should be answered.

Question 22 (a)

Most candidates scored this mark with the overwhelming majority choosing gloves rather than some form of eye protection. Despite the wording of the question some responses suggested more than one precaution, which is fine if all the suggestions are correct. The context of the question precluded the use of purely laboratory precautions such as using a fume cupboard.

(a) State **one** safety precaution that you should take when using a toilet cleaner containing hydrochloric acid.

(1)

wear goggles / lab coat / gloves.

ResultsPlus
Examiner Comments

Despite the question stating that just one precaution is required, this candidate gave three. Fortunately two were correct and the laboratory coat was ignored by examiners.

ResultsPlus
Examiner Tip

Read the questions carefully and avoid extra responses.

(a) State **one** safety precaution that you should take when using a toilet cleaner containing hydrochloric acid.

(1)

wear a mask, gloves, in the fume cupboard.

ResultsPlus
Examiner Comments

Suggesting the use of the fume cupboard negates the mark which would have been awarded for 'gloves'.

Question 22 (b)(i)

The conversion of the full equation into an ionic equation caused difficulties for many candidates even though this should be a well-known reaction. Responses in which the principles of writing an ionic equation were understood could still be marred by incorrect charges on the ions or unbalanced equations. Many candidates seemed unfamiliar with the principles of writing ionic equations.

(i) Write the **ionic** equation for this reaction.
State symbols are not required.

(1)

$$CaCO_{3(s)} + 2H^+ + 2Cl^- \rightarrow Ca^{2+} + 2Cl^- + H_2O_{(l)} + CO_{2(g)}$$

$$CaCO_{3(s)} + 2H^+ \rightarrow Ca^+ + H_2O_{(l)} + CO_{2(g)}$$

ResultsPlus
Examiner Comments

The approach work is impeccable: the candidate writes out the full equation showing all the ions that exist separately and then eliminates the spectator ions. Unfortunately in the final version of the ionic equation the charge on the calcium ion is incorrect.

ResultsPlus
Examiner Tip

In all equations the masses must balance; in an ionic equation the charges must also balance. A quick glance at the charge balance of the final equation should have shown the error.

(i) Write the **ionic** equation for this reaction.
State symbols are not required.

(1)

$Ca^{2+} CO_3^{2-} + 2 H^+ Cl^- \rightarrow Ca^{2+} Cl_2^- + H^+ OH^- + CO_2$

$$CO_3^{2-} + H^+ \rightarrow CO_2 + H_2O$$

ResultsPlus
Examiner Comments

This approach was considered sufficient for the mark even though it is less accurate because the calcium ions change state.

The final equation does not balance in mass or charge.

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Examiner Tip

Ensuring that equations balance in mass and charge should be a routine check.

Question 22 (b)(ii)

There were many excellent answers to this question with the steps clearly set out and the working shown. The scaling mark was sometimes omitted, particularly where the candidates calculated the amount of HCl in 750 cm^3. Another common error was to omit the reacting ratio step or use it the wrong way round. A significant minority of candidates made little attempt to show or explain their working; when the final answer is incorrect, this approach makes it difficult to award marks.

(ii) A 750 cm³ bottle of a toilet cleaner contains 85.0 g of hydrochloric acid.

Calculate the maximum mass of calcium carbonate limescale that could be removed by 50.0 cm³ of this toilet cleaner.

(4)

~~n HCl = 85 / (1+35.5)~~

~~= 2.328~~

~~1 : 2~~

~~1.164 : 2.32~~

~~n CaCO₃ = 1.164~~

85 : 750

x : 50

x = (85×50) / 750

x = 5.66 g

n HCl = 5.66 / (1+35.5)

= 0.1552

2 : 1

0.155 : 0.077

n CaCO₃ = 0.077

m CaCO₃ = 0.077 × (40.1+12+16×3)

= 7.77 g

≃ 7.80 g

ResultsPlus
Examiner Comments

There is enough explanation for the working of this response to be followed and it is easier because it is fully correct. The final answer is technically incorrect as rounding 7.77 to two significant figures gives 7.8 (7.80 is three significant figures) but this has not been penalised.

ResultsPlus
Examiner Tip

Make sure that you understand the rules for rounding numbers and the difference between significant figures and decimal places.

Question 22 (c)(i)

Most candidates realised that this was a disproportionation reaction and many appreciated the detail that was required for full marks. Some candidates gained full marks by virtue of oxidation numbers added to the formulae in the equation rather than in the text, while others omitted reference to the oxidation numbers or failed to specify which species were oxidised or reduced. A number of candidates referred to gain or loss of electrons, which gained no credit.

(c) Chlorine gas reacts with water.

$$Cl_2(g) + H_2O(l) \rightleftharpoons HClO(aq) + HCl(aq)$$

0   +1   −1

(i) State the classification of this reaction. Justify your answer in terms of the relevant oxidation numbers.

(3)

Disproportionation reaction.

cl goes from 0 to +1 in Hclo and −1 in Hcl

ResultsPlus
Examiner Comments

This answer does not state which oxidation number change is oxidation and which is reduction so scores two marks out of three.

ResultsPlus
Examiner Tip

This is a very standard question so the three points required for full marks should be well known.

(c) Chlorine gas reacts with water.

$$\overset{0}{Cl_2}(g) + \overset{+1\ \ -2}{H_2O}(l) \rightleftharpoons \overset{+1\ +1\ -2}{HClO}(aq) + \overset{+1\ -1}{HCl}(aq)$$

(i) State the classification of this reaction. Justify your answer in terms of the relevant oxidation numbers.

(3)

disproportionation reaction. The Cl is from 0 oxidation number to +1 and −1 oxidation number. One element is increased and decreased in one reaction.

ResultsPlus
Examiner Comments

Again, the candidate has omitted the identification of the oxidation and reduction processes. The oxidation numbers shown in the equation are sufficient to gain the mark for linking these with the chlorine species but it is best to give these in the written answer.

Question 22 (c)(ii)

Most candidates understood the steps required for this calculation but it was not always completed with the necessary precision. Some candidates omitted the conversion of moles into mass or used NaCl for NaOCl in doing so. The requirement to give the final answer to two significant figures was sometimes omitted or the answer was given to two decimal places. Once again, some responses were set out in a way that made it difficult to understand their logic.

(ii) When 5.00 cm^3 of a disinfectant reacts with excess hydrogen peroxide, 113 cm^3 of oxygen is produced, measured at room temperature and pressure.

$$H_2O_2(aq) + NaClO(aq) \rightarrow H_2O(l) + NaCl(aq) + O_2(g)$$

Calculate the concentration, in g dm^{-3}, of sodium chlorate(I) in the disinfectant. Give your answer to **two** significant figures.

(4)

[Molar volume of gas at r.t.p. = 24 000 cm^3 mol^{-1}]

O_2 : $n = \frac{V}{24000} = \frac{113}{24\,000} = 4.7 \times 10^{-3}$ mol

NaClO : $n = 4.7 \times 10^{-3}$ mol

$m = n \times Mr$

$= 4.7 \times 10^{-3} \times (23 + 35.5 + 16)$

$= 4.7 \times 10^{-3} \times 74.5$

$= 0.35$ g

$c = \frac{m}{V} = \frac{0.35}{5 \times 10^{-3}} = 70$ g dm^{-3}

ResultsPlus
Examiner Comments

A very neatly set out answer which is easy to follow and fully correct.

ResultsPlus
Examiner Tip

Setting out calculations in a logical way is an important skill. It reduces the likelihood of errors and makes reviewing your work much easier.

Question 22 (c)(iii)

Few candidates were able to link the increased number of alcohol groups and the consequent increase in the number of hydrogen bonds per molecule with the greater intermolecular forces and the increase in viscosity. Responses often relied on generalisations such as 'hydrogen bonding is the strongest intermolecular force' and re-stating the increased viscosity given in the question. Some candidates suggested that propane-1,2,3-triol was a tertiary alcohol and then attempted an explanation based on the surface area of the molecule.

(iii) Commercial disinfectants are often made more viscous by adding propane-1,2,3-triol to the aqueous solution.

Suggest how propane-1,2,3-triol makes disinfectants more viscous.

(2)

~~Propane~~ propane-1,2,3-triol has 3 OH groups and therefore more hydrogen bonding and therefore will have stronger intermolecular forces and be more viscous

ResultsPlus
Examiner Comments

This response covered the major points required and scored full marks.

ResultsPlus
Examiner Tip

Questions that require the application of basic principles in novel contexts will appear in examination papers at this level. It is important to recognise this type of question and to appreciate that the answer needs to move beyond simply re-stating standard ideas.

Question 22 (d)

Candidates were most likely to give the first marking point but this was rarely supported by a valid equation, with use of an explanation in terms of the position of equilibrium very rare indeed. A number of responses suggested that a toxic gas would be formed either without specifying the gas or suggesting unlikely possibilities such as carbon monoxide. Many answers confused the reaction with the chemical cleaners and the reaction of hydrochloric acid with calcium carbonate, suggesting that neutralisation would render the cleaners ineffective.

Question 22 (e)

Almost all candidates were able to convert the percentage masses into moles, although some candidates that knew how to do this omitted one of the elements. In the next step of the calculation the numbers were often severely rounded to give a whole number ratio (with 8.48 converted to 8 or 9) rather than scaled to the correct values. Many candidates were then unable to deduce the borax formula showing the water of crystallisation from their empirical formula.

(e) Borax is another cleaning agent used to remove limescale.

Borax is a compound of sodium, boron and oxygen.
Borax crystals contain water of crystallisation.

The percentage composition by mass of some borax crystals is
H = 5.2%   B = 11.3%   O = 71.4%   Na = 12.1%

Determine the empirical formula of the borax crystals and hence their formula.

(4)

	H	B	O	Na
%age : atomic mass :	$\frac{5.2}{1}$	$\frac{11.3}{10.8}$	$\frac{71.4}{16}$	$\frac{12.1}{23}$
=	$\frac{5.2}{0.524}$	$\frac{1.04}{0.526}$	$\frac{4.46}{0.526}$	$\frac{0.526}{0.526}$
=	9.92	1.97	8.47	1

~~×2~~ .

H B O_8 Na

$H_{10}B_2O_8Na$ Empirical formula.

ResultsPlus
Examiner Comments

This was quite a common response in which the amount of each element was correctly calculated but the values obtained were rounded rather than scaled to give the required ratio. The last two marks were still available but the candidate stopped without attempting to work out the formula.

ResultsPlus
Examiner Tip

The question makes it clear that there is work to do after the empirical formula has been calculated; it is well worth having a go at this.

Paper Summary

Based on their performance on this paper, candidates should:

- Read all of the question carefully and use the information provided to help you frame your answer.
- Ensure that you understand the terminology relevant to the specification and how to use terms such as atom, ion and molecule appropriately.
- State the purpose of each step in calculations, showing your working.
- Not round intermediate values of calculations.
- Give the final answer of a calculation to an appropriate number of significant figures or decimal places, with units if needed.
- Make sure that the organic displayed structures that you draw show all the required atoms and each carbon atom with four bonds.
- Make sure that you understand the significance of curly arrows in organic mechanisms.
- Ensure that if your answer extends beyond the allotted space, you indicate clearly where you have continued your answer.

Grade boundaries

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

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