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June 2024

IAL Chemistry WCH12 01R

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Introduction

Many candidates had prepared well for this paper and were able to apply their knowledge of the topics in the specification to familiar and novel situations. However, it appeared that a significant number did not seem to have a good basic understanding of organic test tube reactions, fragmentation of organic molecules in mass spectrometry and the interactions of ions with water molecules. However, calculation questions were once again done with impressive accuracy and there was no evidence of candidates running out of time.

The mean mark for the paper was 43.8 and the multiple choice, Section A had a mean of 12.8.

The most accessible multiple choice questions were Question 5 (gas moles calculation) and Question 14 (oxidation numbers) and the most challenging questions were Question 1(a) (Maxwell – Boltzmann distribution) and 15 (boiling points of organic compounds)

Question 18 (a)

This question proved to be a good discriminator with most candidates able to score at least one mark, with many scoring all three. A common error was using the molar mass of magnesium carbonate for the carbon dioxide calculation.

18 This question is about Group 2 carbonates.

Group 2 carbonates decompose on heating to form the corresponding metal oxide and carbon dioxide. The general equation is shown.

$$MCO_3(s) \rightarrow MO(s) + CO_2(g)$$

(a) A sample of magnesium carbonate was heated for 4 minutes.
The mass of the sample decreased from 4.17 g to 2.35 g.

Calculate the percentage of magnesium carbonate that has decomposed.

[Molar mass of magnesium carbonate = 84.3 g mol^{-1}]

(3)

$m(CO_2) = 4.17 - 2.35 = 1.82g$

$n(CO_2) = \frac{1.82g}{44g \cdot mol^{-1}} = 0.041\,mol$

[redacted]

[redacted]

$n(\text{decomposed } MgCO_3) = 0.041\,mol$

$n(\text{decomposed } MgCO_3) = 0.041\,mol \times 84.3\,g\,mol^{-1} = [redacted]\ 3.487g$

$\text{percentage of } MgCO_3 \text{ decomposed} = \frac{3.487g}{4.17g} = 83.62\%$

ResultsPlus
Examiner Comments

The calculation could be done using either masses or moles with both options equally popular.

Here, the candidate has used masses and scores full marks.

18 This question is about Group 2 carbonates.

Group 2 carbonates decompose on heating to form the corresponding metal oxide and carbon dioxide. The general equation is shown.

$$MCO_3(s) \rightarrow MO(s) + CO_2(g)$$

(a) A sample of magnesium carbonate was heated for 4 minutes.
The mass of the sample decreased from 4.17 g to 2.35 g.

Calculate the percentage of magnesium carbonate that has decomposed.

[Molar mass of magnesium carbonate = 84.3 g mol^{-1}]

(3)

$4.17 - 2.35 = 1.82$ g

$\frac{1.82}{84.3} = 0.0216$ mol

$\frac{4.17}{84.3} = 0.0495$ mol

$\frac{0.0216}{0.0495} \times 100\% = 43.64\%$

ResultsPlus
Examiner Comments

This was a very common incorrect answer.

The candidate has correctly calculated the number of moles of magnesium carbonate and the change in mass due to the loss of the carbon dioxide. However, they then used the wrong molar mass (84.3 instead of 44) to calculate the number of moles of carbon dioxide, so only 1 mark was awarded.

Question 18 (b)

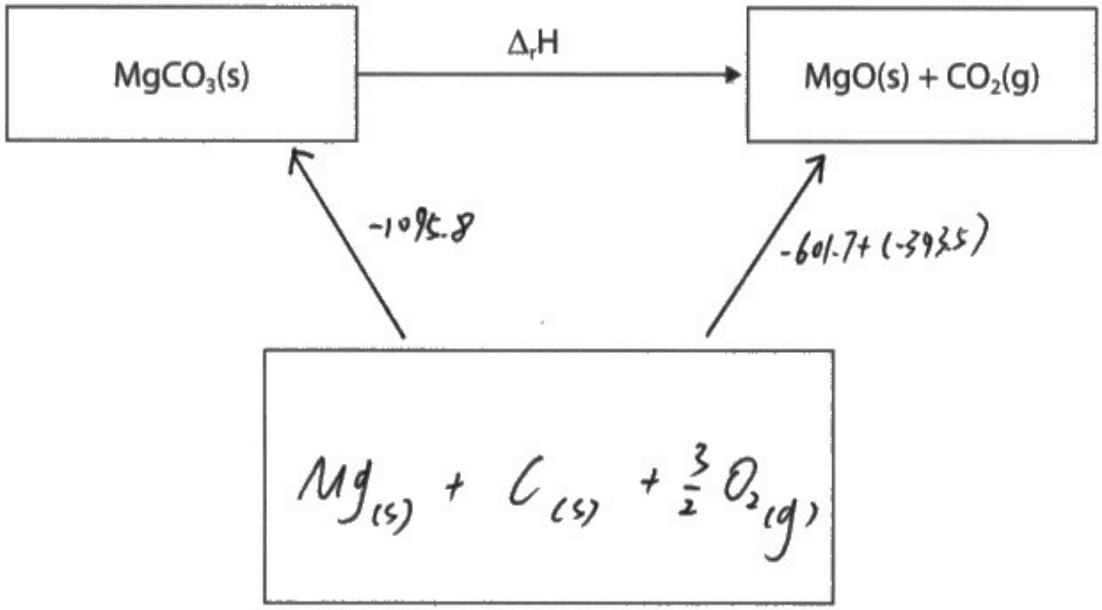
In part (i) most candidates labelled the arrows correctly, but many found identifying the correct species more challenging and elements were sometimes inconsistent with state symbols and balancing was also a problem. In part (ii), although the majority got the correct answer with the correct units, a surprising number omitted them, despite it being asked for in the question.

(b) The enthalpy change, $\Delta_r H$, for the thermal decomposition of magnesium carbonate, $MgCO_3$, can be calculated using the data in the table.

Substance	Enthalpy change of formation / kJ mol^{-1}
$MgCO_3$	−1095.8
MgO	−601.7
CO_2	−393.5

(i) Complete the Hess cycle with two arrows and correct species and state symbols in the box.

(2)



(ii) Calculate the enthalpy change for the thermal decomposition of magnesium carbonate, $\Delta_r H$. Include a sign and units in your answer.

(2)

$-1095.8 + \Delta_r H = -601.7 - 393.5$

$\Delta_r H = 100.6 \text{ kJ mol}^{-1}$

ResultsPlus
Examiner Comments

This is a fully correct answer.

The candidate has shown their working alongside the arrows which is not required and, although they have not included a + sign in their final answer, as no minus is seen it is assumed to be a positive value.

(ii) Calculate the enthalpy change for the thermal decomposition of magnesium carbonate, $\Delta_r H$. Include a sign and units in your answer.

(2)

$\Delta_r H = -1095.8 - (-60.7) - (-393.5)$

$= -100.6$ ~~kg~~ kJ mol^{-1}

ResultsPlus
Examiner Comments

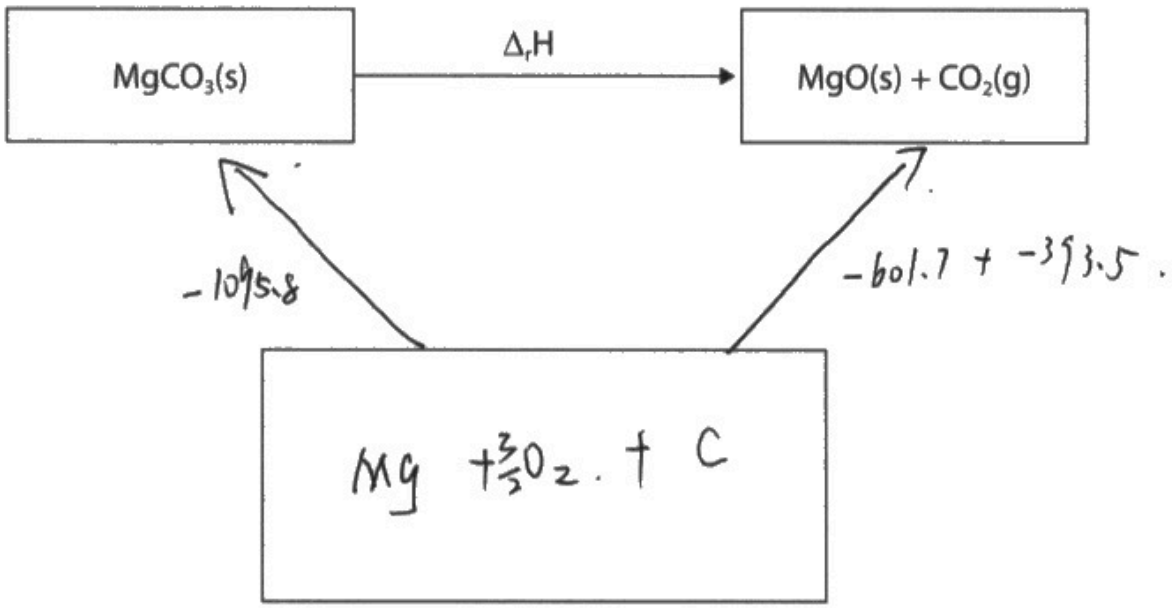
Despite the candidate having the arrows in the correct direction, they have made a mistake with their calculation and the answer has a negative sign. This has to be wrong as the reaction is a thermal decomposition and so must have a positive value.

ResultsPlus
Examiner Tip

When you have done a calculation, check the sign and magnitude carefully. Use all the information in the question and decide if the answer is sensible.

(i) Complete the Hess cycle with two arrows and correct species and state symbols in the box.

(2)



ResultsPlus
Examiner Comments

Here the candidate has got the arrows in the correct direction, but the state symbols are missing in the box despite them being asked for in the question.

Question 18 (c)

This standard question about thermal stability was quite well done by the majority of candidates. Most were able to state that the enthalpy change of calcium carbonate was larger than magnesium carbonate. However, when explaining the reason for this difference, a number did not refer to the size of the cation and simply said the Ca was larger so did not score the mark. Despite this, many candidates were able to correctly identify the calcium ion as being less polarising and many good responses were seen commenting on the anion being less distorted. Occasionally, candidates did get muddled and wrote about increased polarising power instead of less.

(c) Explain how the enthalpy change for the thermal decomposition of calcium carbonate, $CaCO_3$, compares to that for magnesium carbonate in (b)(ii).

(3)

the enthalpy change of $CaCO_3$ is higher
Mg have smaller radius than Ca
so it have higher polarising power to C-O bond
therefore $MgCO_3$ is easy to break

ResultsPlus
Examiner Comments

The candidate has correctly noted that the enthalpy change for calcium carbonate is larger than that of magnesium carbonate. They are also correct about the smaller size and greater polarising power of Mg. However, there is no mention of ions so a mark is lost.

ResultsPlus
Examiner Tip

When answering questions about thermal stability, you must mention ions.

Question 19 (a)

This straightforward equilibrium question scored quite well. In (a)(i) the majority of candidates were able to get the correct colour change, but quite a number failed to state the correct reason why, with some responses simply referring to the increased rate of reaction and its endothermic nature. Marks were dropped in some cases, where candidates included both correct and incorrect observations. A response such as 'the colour would go darker blue and there would be bubbles' negated the scoring point.

In (a)(ii) most candidates scored both marks as they were able to link an increase in pressure with a shift to the side where there are fewer gaseous molecules.

19 This question is about ozone, O_3.

Ozone is formed by the action of ultraviolet radiation on oxygen molecules.

$$3O_2(g) \rightleftharpoons 2O_3(g) \qquad \Delta_r H = +143\,kJ\,mol^{-1}$$

Ozone is a pale blue gas and oxygen gas is colourless.

A mixture of oxygen and ozone was placed in a sealed container and left to reach equilibrium.

(a) (i) Explain what you would **see** on heating the mixture.

(2)

The container becomes more blue because forward reaction is an endothermic reaction, as heating the mixture equilibrium shifts to right, so percentage of O_3 will increase, lead to mixture more blue.

(ii) Explain what you would **see** on increasing the pressure.

(2)

As pressure increases, LHS with 3 volume gas and RHS with 2 volume gas, the equilibrium ~~wil~~ will shift to right. And as pressure increase, density of gases increase. So container suddenly more blue then slowly becomes more blue.

ResultsPlus
Examiner Comments

This is a fully correct answer where the candidate correctly states what they would see and explains why the equilibrium moves in this direction.

19 This question is about ozone, O_3.

Ozone is formed by the action of ultraviolet radiation on oxygen molecules.

$$3O_2(g) \rightleftharpoons 2O_3(g) \qquad \Delta_r H = +143\,kJ\,mol^{-1}$$

Ozone is a pale blue gas and oxygen gas is colourless.

A mixture of oxygen and ozone was placed in a sealed container and left to reach equilibrium.

(a) (i) Explain what you would **see** on heating the mixture.

(2)

For the forward reaction $3O_2(g) \rightarrow 2O_3(g)$ is endotermic, heating the mixture could speed up the forward reaction. The equilibrium shift to product side.

(ii) Explain what you would **see** on increasing the pressure.

(2)

For $3O_2(g) \rightarrow 2O_3(g)$, the number of moles is smaller at the product side, as the pressure increase, the equilibrium shift to the product side.

ResultsPlus
Examiner Comments

Here the candidate has correctly explained how the equilibrium will shift, so scores a mark for each part.

However, the question asks for an observation of what they would see, which has not been done, so no more marks are scored.

ResultsPlus
Examiner Tip

Read the question carefully and pay particular attention to words in bold as they give a good clue as to the type of response that will score.

Question 19 (b)

Although most candidates had a good understanding of redox reactions and were able to identify ozone as an oxidising agent, many responses lacked sufficient detail to score full marks. In some cases, the correct oxidation numbers were stated, but the candidates failed to relate the change in oxidation number to oxidation or reduction. Other common errors included missing out the oxidation numbers of the sulfur and wrong oxidation numbers such as – 8 for oxygen in H_2SO_4 .

(b) Ozone can be used in the treatment of drinking water. As well as killing bacteria and viruses, ozone also removes other dissolved impurities such as hydrogen sulfide, H_2S. Hydrogen sulfide reacts with ozone to produce sulfuric acid.

$$\overset{0}{4O_3(g)} + H_2S(aq) \rightarrow \overset{-2}{H_2SO_4(aq)} + 4O_2(g)$$

State the role of the ozone in this redox reaction.
Justify your answer using oxidation numbers.

(3)

The oxidation number of ozone decreases from 0 to -2, the number decreases, so reduction occurs. The role of the ozone is oxidising agent.

ResultsPlus
Examiner Comments

The candidate correctly notes the role of the ozone and the change in oxidation number and reduction of the oxygen. However, they do not refer to the oxidation of the sulfur so only 2 marks are scored.

ResultsPlus
Examiner Tip

When answering redox questions, make sure the relevant oxidation numbers of all the species are given.

(b) Ozone can be used in the treatment of drinking water. As well as killing bacteria and viruses, ozone also removes other dissolved impurities such as hydrogen sulfide, H_2S. Hydrogen sulfide reacts with ozone to produce sulfuric acid.

$$\overset{0}{4O_3}(g) + \overset{-2}{H_2S}(aq) \rightarrow \overset{+6}{H_2SO_4}(aq) + 4O_2(g)$$

State the role of the ozone in this redox reaction.
Justify your answer using oxidation numbers.

(3)

The role of ozone is to remove impurities like ~~ozone~~ H_2S. Refer to oxidation number, ozone change from 0 to -8 which is reduction and S change from -2 to +6 which is oxidation.

ResultsPlus
Examiner Comments

The candidate scores a mark for the reduction of the sulfur and the correct oxidation numbers. However, they have given the wrong oxidation number of oxygen in sulfuric acid, which was quite a common incorrect answer.

(b) Ozone can be used in the treatment of drinking water. As well as killing bacteria and viruses, ozone also removes other dissolved impurities such as hydrogen sulfide, H_2S. Hydrogen sulfide reacts with ozone to produce sulfuric acid.

$$\overset{0}{4O_3(g)} + \overset{-2}{H_2S(aq)} \rightarrow \overset{+2}{H_2SO_4(aq)} + \overset{0}{4O_2(g)}$$

O 0 → ~~-2~~ -2

S -2 → +6

State the role of the ozone in this redox reaction.
Justify your answer using oxidation numbers.

(3)

ozone acts as an oxidising agent.
O in O_3 ~~is~~ is reduced, oxidation number changed from 0 to -2.
S in H_2S is oxidised, oxidation ~~num~~ number changed from -2 to +6

ResultsPlus
Examiner Comments

A concise but excellent answer that scores full marks.

Question 19 (c)

This calculation was well understood with large numbers of totally correct, well-presented answers seen. However, a number of candidates did not appear to understand the concept of ppm by mass and instead converted grams into moles and so struggled to score any marks.

(c) Ozone can also be used in the treatment of water in swimming pools.
A swimming pool has a volume of 375 000 dm^3 and contains 15 g of ozone.

Calculate the concentration of ozone in the pool in parts per million (ppm).

[Assume the density of water in the swimming pool = 1.00 g cm^{-3}]

(2)

$375000 \times 10^3 = 375000000\ cm^3$.

$\frac{15 \times 10^6}{375000000} = 0.04\ ppm$

ResultsPlus
Examiner Comments

Here the candidate has produced a concise and fully correct calculation.

(c) Ozone can also be used in the treatment of water in swimming pools.
A swimming pool has a volume of 375 000 dm^3 and contains 15 g of ozone.

Calculate the concentration of ozone in the pool in parts per million (ppm).

[Assume the density of water in the swimming pool = 1.00 g cm^{-3}]

(2)

$n = \frac{m}{M} = \frac{15}{16 \times 3} = 0.3125$ mol

$C = n \times V = 0.3125 \times 375000 = 117000$ mol dm^{-3}

$= 117$ ppm mol dm^{-3}

ResultsPlus
Examiner Comments

Here the candidate has calculated the number of moles of ozone instead of just comparing the masses. This was a common mistake and did not score.

ResultsPlus
Examiner Tip

You need to understand that parts per million calculations involves comparing masses, not moles.

Question 20 (a)

Calculation errors in (a)(i) were extremely rare and most candidates were able to correctly work out the empirical formula. However, a small number failed to calculate the mass of oxygen so could not get a sensible empirical formula, and a very small minority inverted the mole calculation.

With the majority getting (a)(i) correct, (a)(ii) was very straightforward. However, a number did not use their empirical formula mass of 44 in their answer, so did not score.

20 An organic compound, acetoin, is one of the compounds that gives butter its characteristic flavour.

(a) Acetoin contains 54.5 % by mass of carbon and 9.1 % by mass of hydrogen. The remainder is oxygen.

(i) Calculate the empirical formula of acetoin.
You must show all your working. Assume: if there are 100g acetoin (3)

	C	O	H
m/g :	54.5	36.4	9.1
n/mol	4.542	2.275	9.1
ratio	2	1	4

$n = \frac{m}{M}$.

the empirical formula is ~~C_2OH_4~~

C_2H_4O

(ii) The molar mass of acetoin is 88.0 g mol^{-1}.

Use this information to calculate the molecular formula of acetoin.

(1)

$M = 88$ g/mol

$C_2H_4O = 12 \times 2 + 4 + 16 = 44$

$\frac{88}{44} = 2$

The molecular formula : $C_4H_8O_2$

ResultsPlus
Examiner Comments

This is a fully correct answer.

However, in (a)(i) they have not shown they have divided by the lowest number of moles to get the ratio. This was not penalised, but candidates are advised to show all their working in calculations.

In (a)(ii) they make correct use of the empirical formula mass to deduce the molecular formula.

Question 20 (b)(i)

This question proved to be quite challenging to the majority of candidates. In many responses it was clear that candidates had not read the question properly as they treated the three tests separately instead of linking them to identify the functional group. A number failed to appreciate that both alcohols and carboxylic acids gave a positive PCl_5 test, so did not score the first mark. Others, who had correctly concluded that the functional group was an alcohol then suggested it was an aldehyde because of the third test. This lack of logical progression cost marks and was evident in many scripts.

(b) Acetoin contains **two** functional groups.

(i) Some chemical tests were carried out on acetoin. These tests identify **one** of the two functional groups.

Acetoin produced steamy fumes when reacted with PCl_5.

Acetoin did **not** react with sodium hydrogencarbonate solution.

Acetoin turned hot acidified potassium dichromate(VI) solution from orange to green.

State what can be deduced from each of these three tests and hence identify this functional group.

(3)

① for first tests: it has -OH functional group

② for second tests: it is not -COOH functional group

③ for third tests: it has ~~C=O double bond~~. -OH group

~~ther~~ therefore. acetoin has -OH and ~~C=O double bond~~. group.

ResultsPlus
Examiner Comments

The candidate makes the correct deductions from test 1 and 2, but in test 3 they do not say that the alcohol has to be primary or secondary as it is oxidised.

This was a common response that scores 2 marks.

(b) Acetoin contains **two** functional groups.

(i) Some chemical tests were carried out on acetoin. These tests identify **one** of the two functional groups.

Acetoin produced steamy fumes when reacted with PCl_5.

Acetoin did **not** react with sodium hydrogencarbonate solution. No CO_2

Acetoin turned hot acidified potassium dichromate(VI) solution from orange to green.

State what can be deduced from each of these three tests and hence identify this functional group.

(3)

For the first one it show Acetoin has -OH

For the second one it shows Acetoin ~~don't has~~ is not carboxylic acid.

For the third one. it shows Acetoin can be oxidised by $K_2Cr_2O_7$ so it's primary or secondary alcohol.

ResultsPlus
Examiner Comments

This is a fully correct answer, where the candidate demonstrates their excellent deduction.

Question 20 (b)(ii)

Most candidates managed to correctly identify the infrared spectrum wavenumbers and bonds that could be used to distinguish between an aldehyde and ketone. There were very few mistakes transferring the information from the Data Booklet, but some candidates included an O-H bond, presumably as they were referring back to the previous part of the question.

(ii) Acetoin also contains the carbonyl group C=O, in the form of a ketone **not** an aldehyde.

Use page 5 of your Data Booklet to show how infrared spectra data could be used to prove that acetoin contains a ketone not an aldehyde.
Complete the table.

(3)

	Bond	Wavenumber range / cm^{-1}
Absorption present in acetoin but not in an aldehyde	C=O	1720 - 1700
One absorption present in an aldehyde but not in acetoin	C=O	1740 - 1720
Another absorption present in an aldehyde but not in acetoin	~~C-H~~ C-H	2900-2820 and 2775 -2700

ResultsPlus
Examiner Comments

This is a fully correct answer.

The candidate has included both C-H ranges in the bottom row, but just one would have been sufficient.

(ii) Acetoin also contains the carbonyl group C=O, in the form of a ketone **not** an aldehyde.

Use page 5 of your Data Booklet to show how infrared spectra data could be used to prove that acetoin contains a ketone not an aldehyde.
Complete the table.

C-H

(3)

	Bond	Wavenumber range / cm^{-1}
Absorption present in acetoin but not in an aldehyde	O-H	3300-2500
One absorption present in an aldehyde but not in acetoin	C-H	2900-2820 and 2775-2700
Another absorption present in an aldehyde but not in acetoin	C=O	1740-1720

ResultsPlus
Examiner Comments

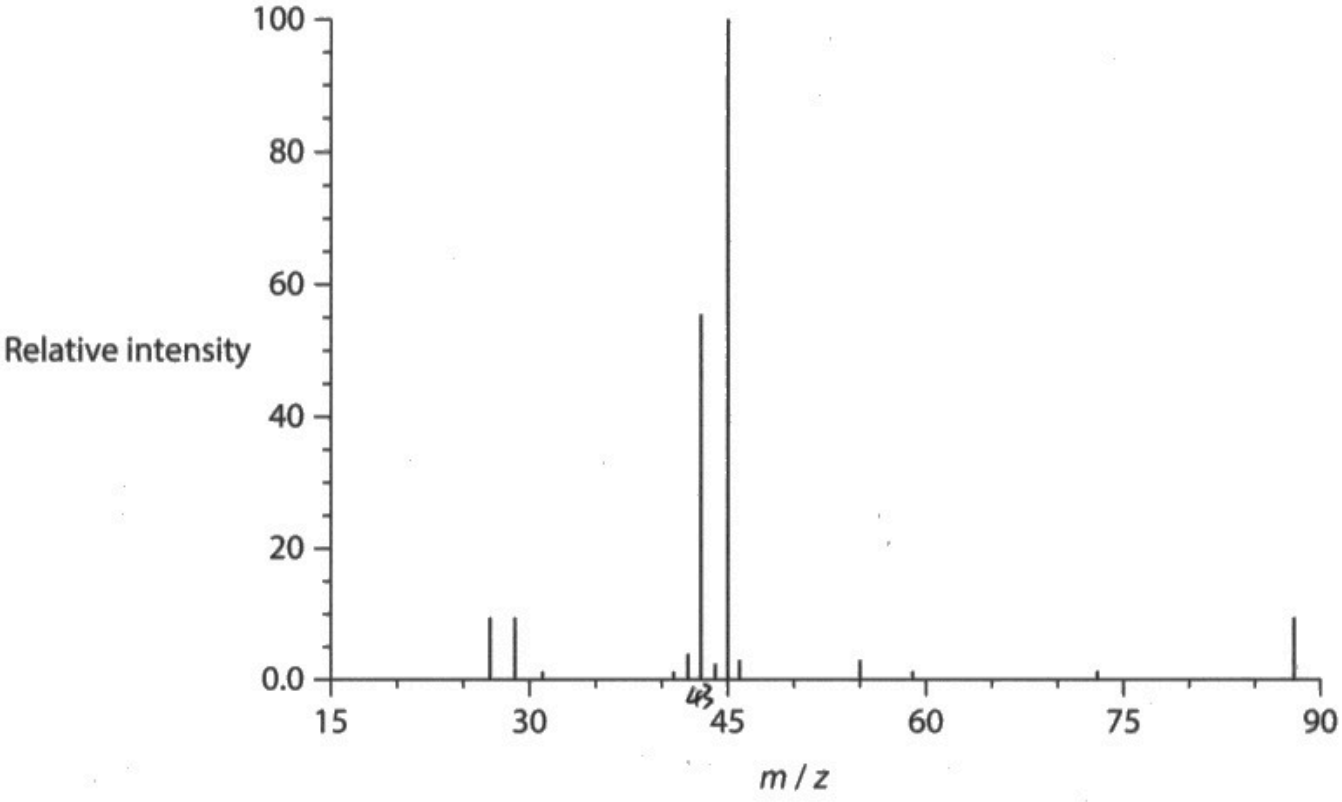
The candidate wrongly thinks the O-H bond from a carboxylic acid can be used to distinguish between a ketone and an aldehyde.

This was quite a common wrong answer, but despite this, the other bonds and wavenumber ranges are correct and 2 marks are scored.

Question 20 (b)(iii)

This question was found to be particularly challenging with many blanks with over half the candidates failing to score. Those who understood that acetoin contained an alcohol and aldehyde functional group were usually able to correctly identify the peaks and draw the structure. Although some lost a mark for omitting the positive charge. However, many candidates did not use the information from the earlier parts of the question and a number of wrong ions were seen including COOH, C_3H_7 and even metal ions.

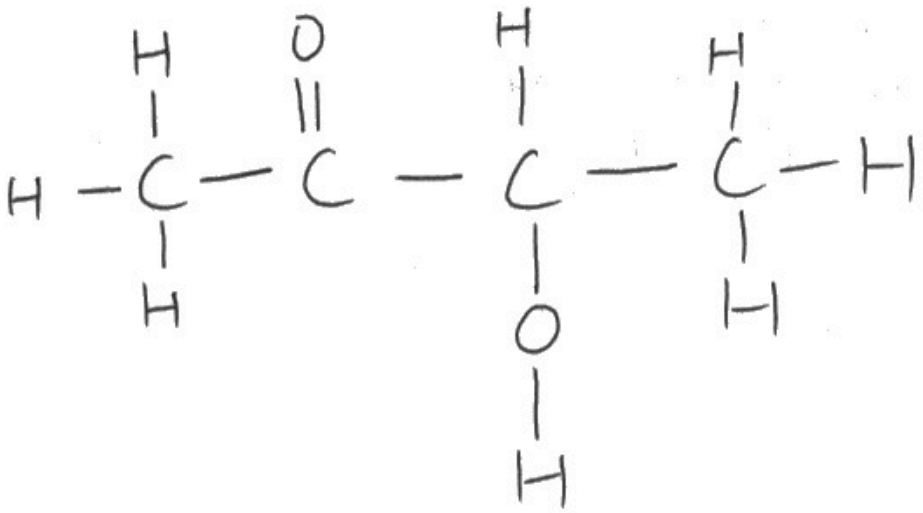
(iii) Part of the mass spectrum of acetoin is shown.



Determine a possible structure of acetoin using your answer to part (b)(i), the information given in (b)(ii) and the mass spectrum.

In your answer, identify the two ions responsible for the two peaks of highest intensity.

(3)



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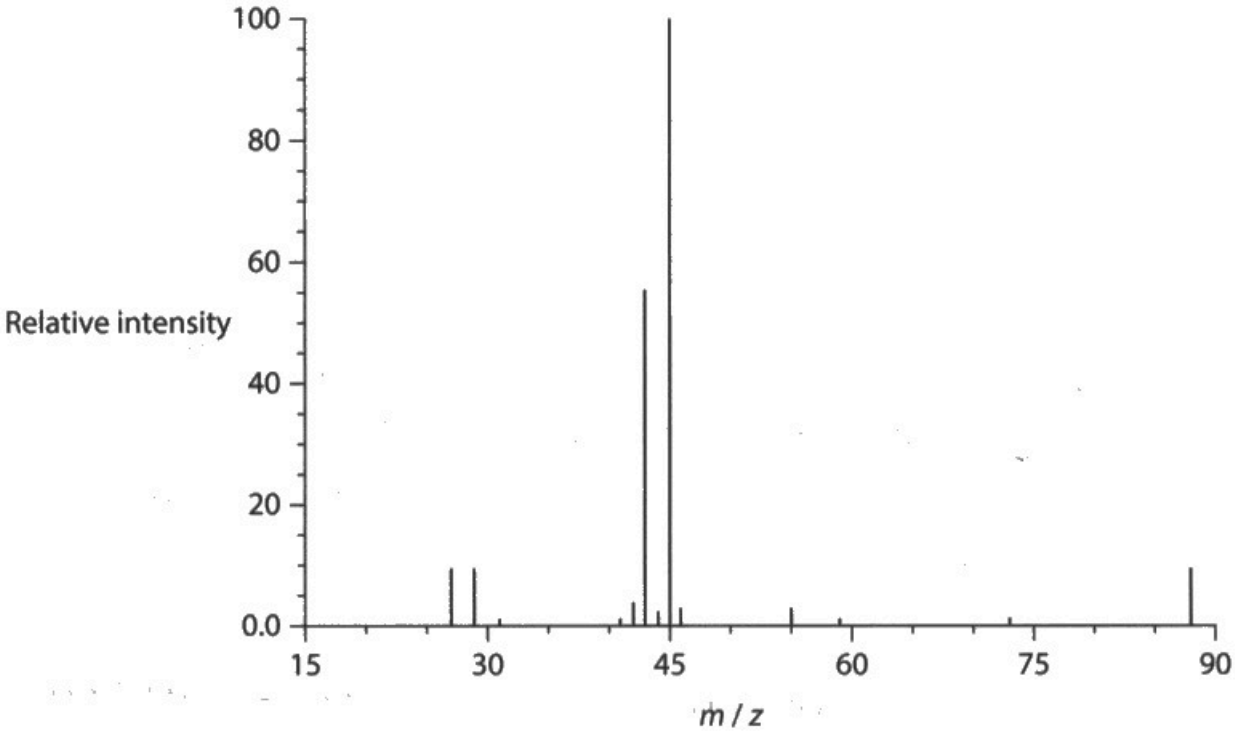
Examiner Comments

The candidate has made no attempt to identify the ions, despite drawing the correct structure and scoring a mark.

ResultsPlus
Examiner Tip

Practise fragmenting molecules to deduce possible ions that could be present in mass spectra.

(iii) Part of the mass spectrum of acetoin is shown.

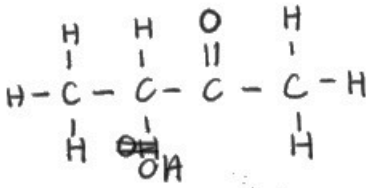


Determine a possible structure of acetoin using your answer to part (b)(i), the information given in (b)(ii) and the mass spectrum.

In your answer, identify the two ions responsible for the two peaks of highest intensity.

(3)

m/z 45 : CH_3CHO^+ m/z 43 : CH_3CO^+



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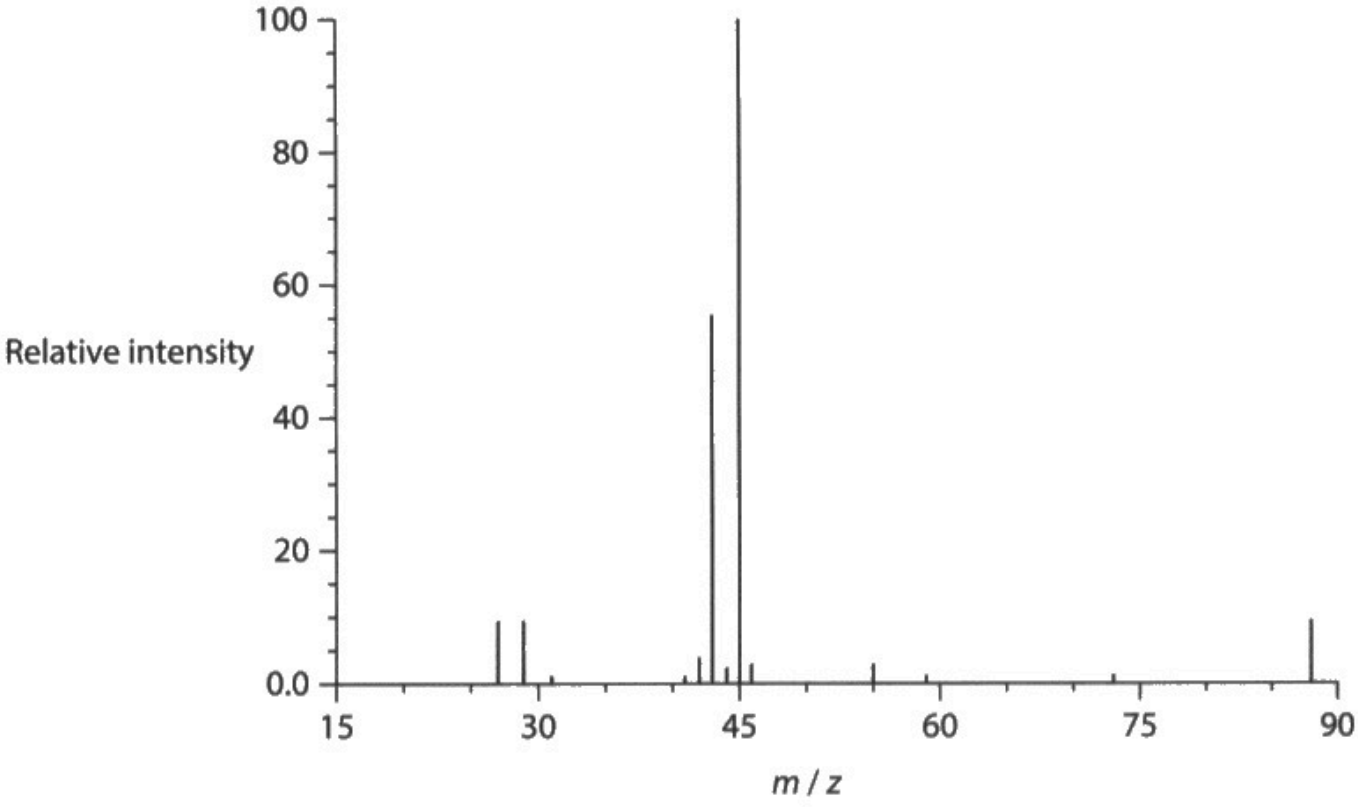
Examiner Comments

This candidate has drawn a correct structure and the ion with the mass of 43 is also correct.

However, the ion with the mass of 45 would not be produced from this molecule and its mass is 44 not 45 so only 2 marks are scored.

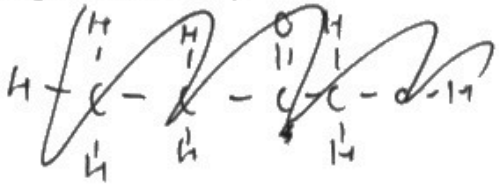
(iii) Part of the mass spectrum of acetoin is shown.



Determine a possible structure of acetoin using your answer to part (b)(i), the information given in (b)(ii) and the mass spectrum.

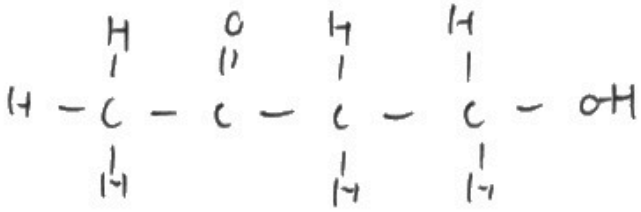
In your answer, identify the two ions responsible for the two peaks of highest intensity.

(3)



$m/z = 45 \rightarrow (CH_2CH_2OH)^+$

$m/z = 43 \rightarrow (CH_3CO)^+$



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Examiner Comments

This is an excellent answer where the candidate shows the structural formula of the ions with positive charges and a correct structure.

All 3 marks scored.

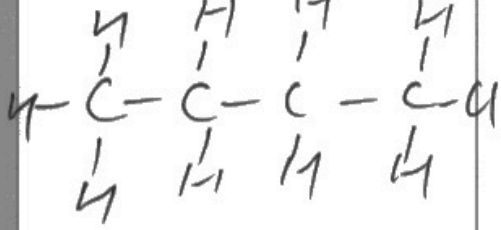
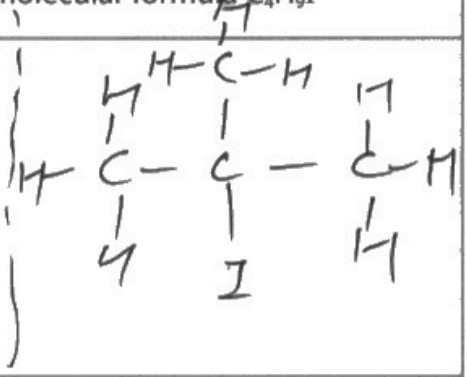
Question 21 (a)

Almost half the candidates scored all three marks on this question. Drawing the two structures was particularly well done and there were very few errors, but the naming of the compounds was more challenging.

21 This question is about halogenoalkanes.

(a) Complete the table by giving the **displayed** formula and name of each halogenoalkane.

(3)

	A straight chain primary chloroalkane with the molecular formula C_4H_9Cl	A tertiary iodoalkane with the molecular formula C_4H_9I
Displayed formula		
Name	1-chloro butane	2. iodo-2, methyl pentane

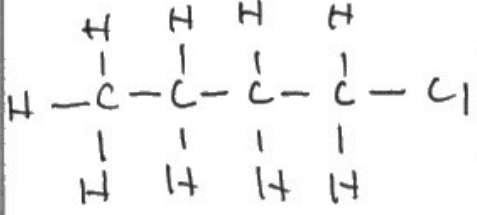
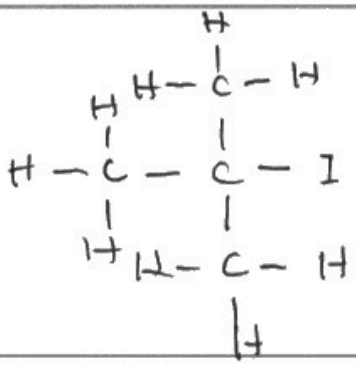
ResultsPlus
Examiner Comments

Both structures are drawn correctly but the candidate has used the wrong stem when naming the tertiary iodoalkane. This was quite a common mistake.

21 This question is about halogenoalkanes.

(a) Complete the table by giving the **displayed** formula and name of each halogenoalkane.

(3)

	A straight chain primary chloroalkane with the molecular formula C_4H_9Cl	A tertiary iodoalkane with the molecular formula C_4H_9I
Displayed formula		
Name	Chloro butane	~~methyl~~ 2-iodo-2-methyl propane

ResultsPlus
Examiner Comments

Both structures are drawn correctly but the candidate has omitted the number (1) to show the position of the chlorine when naming the primary chloroalkane. This was also quite a common mistake.

Question 21 (b)

Most candidates recognised the weaker carbon – iodine bond strength was one reason why the iodoalkane reacted faster than chloroalkane. However, the second reason was much more elusive with a large number comparing the relative stability of primary and tertiary carbocations. This information was not asked for in the question and resulted in many candidates overlooking the simple fact that tertiary haloalkanes react faster than primary haloalkanes.

(b) The two halogenoalkanes in part (a) react with aqueous potassium hydroxide to produce alcohols.

Give **two** reasons why the rate of reaction of the iodoalkane is faster than that of the chloroalkane.

(2)

Reason 1 C-I is weaker than C-Cl

Reason 2 ~~Tertiary~~ Tertiary reacts faster

ResultsPlus
Examiner Comments

This candidate's response is concise but fully correct and scores both marks.

(b) The two halogenoalkanes in part (a) react with aqueous potassium hydroxide to produce alcohols. KOH

Give **two** reasons why the rate of reaction of the iodoalkane is faster than that of the chloroalkane.

(2)

Reason 1 C-I bond is weaker than C-Cl bond.

Reason 2 2-iodo-2-methylpropane is formed from tertiary carbocation and 1-chlorobutane is formed from primary carbocation. Tertiary carbocation is more stable.

ResultsPlus
Examiner Comments

Reason 1 is correct but in Reason 2, the candidate comments on the stability of the carbocations. Although the information is correct, it does not answer the question and this was a common wrong response.

Question 21 (c)

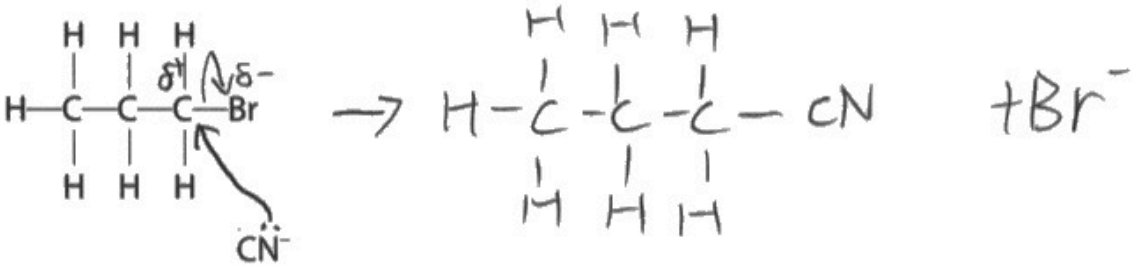
This mechanism was well understood with large numbers of totally correct, well-presented answers seen. However, marks were sometimes lost as curly arrows did not start or end precisely in the expected positions, in particular, the curly arrow from the CN^- often failed to originate from the lone pair on the C. Other common errors included omitting the Br^- and some candidates showed the bonding between the C and N in the nitrile as a single bond.

(c) Halogenoalkanes react with cyanide ions, CN^-, in alcoholic solution to form nitriles. The cyanide ions act as nucleophiles.

Complete the mechanism for the formation of butanenitrile, $CH_3CH_2CH_2CN$.

Include curly arrows, and relevant lone pairs and dipoles.

(3)



ResultsPlus
Examiner Comments

This candidate has made one mistake with the lone pair on the CN^-. They have put it on the N, but it should be on the C.

This was quite a common error.

ResultsPlus
Examiner Tip

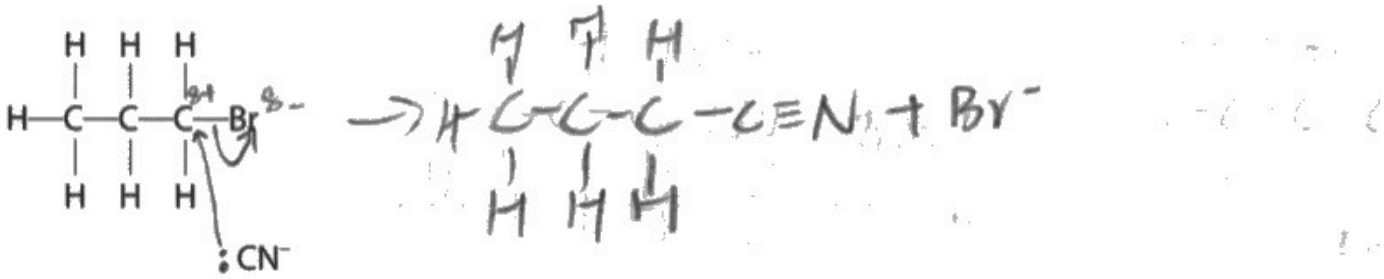
When answering mechanism questions, pay careful attention to the origin and destination of the curly arrows.

(c) Halogenoalkanes react with cyanide ions, CN^-, in alcoholic solution to form nitriles. The cyanide ions act as nucleophiles.

Complete the mechanism for the formation of butanenitrile, $CH_3CH_2CH_2CN$.

Include curly arrows, and relevant lone pairs and dipoles.

(3)



ResultsPlus
Examiner Comments

This is a fully correct mechanism.

Although it was not necessary to show the bonding in the nitrile, if it is present, it must be correct, as it is here.

Question 22 (a)

The majority of candidates were able to identify Method 2 as being more sustainable, but many did not explain why. There also appeared to be some confusion about what was required in terms of evaluating the two methods. Some candidates said that solar was good for the environment or was sustainable without explaining why or using the word renewable. However, most understood carbon dioxide produced in Method 1 was a greenhouse gas so scored at least one mark.

22 Ammonia, ammonium nitrate and urea are nitrogen-based fertilisers.
The nitrogen in the fertiliser is taken up by the roots of plants and promotes growth.

Ammonia, NH_3, is manufactured by the reaction between nitrogen and hydrogen.
The nitrogen is obtained from the air.

Hydrogen can be obtained by two methods.

Method 1

The hydrogen is usually obtained by reacting methane gas with steam.

$$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$$

Method 2

Hydrogen can also be obtained using solar power to split water into hydrogen and oxygen.

$$2H_2O \rightarrow O_2 + 2H_2$$

(a) Evaluate which of these two methods used to obtain hydrogen is more sustainable.

(3)

method 2

Because method 1 produce CO_2 will ~~ease~~ cause global warming.

method 1 need use CH_4 that is non-renewable resource.

ResultsPlus
Examiner Comments

This candidate's concise answer covered all three marking points and scored full marks.

22 Ammonia, ammonium nitrate and urea are nitrogen-based fertilisers.
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Method 2

Hydrogen can also be obtained using solar power to split water into hydrogen and oxygen.

$$2H_2O \rightarrow O_2 + 2H_2$$

(a) Evaluate which of these two methods used to obtain hydrogen is more sustainable.

(3)

the method 2 is more sustainable, because H_2O is easy to obtain and produce O_2, it's not green house gas, for method 1, CH_4 is ~~ex~~ ~~not~~ it's produced CO_2, it's a green house gas may ~~can~~ cause global warming.

ResultsPlus
Examiner Comments

The candidate has correctly selected Method 2 as being more sustainable but has not mentioned Method 1 using methane/ fossil fuels, so the mark is not scored.

They have also made no reference to the renewable nature of solar power or the finite nature of methane/fossil fuels.

But they have related carbon dioxide to being a greenhouse gas so 1 mark is scored.

Question 22 (b)(ii)

Most candidates managed to score at least one mark for this question as they correctly stated that ammonia had a high % of nitrogen as the advantage. However, a number commented on the higher yield or higher atom economy or lower cost of making ammonia which did not score. Many found identifying a disadvantage more challenging as some did not recognise that ammonia was a gas.

(ii) Give **one** advantage and **one** disadvantage of applying ammonia directly into the soil as a fertiliser.
Use information in the table and your knowledge of ammonia.

(2)

Advantage

the precentage ~~of~~ by mass of nitrogen is highest

Disadvantage

NH_3 may be escape

ResultsPlus
Examiner Comments

Both scoring points are made in this script. The advantage is correct and the candidate has scored the disadvantage by an allow on the mark scheme.

Question 22 (c)(i)

Although the majority of candidates were able to write this equation correctly, the incorrect formula of nitric acid or the lack of water were the most common errors seen.

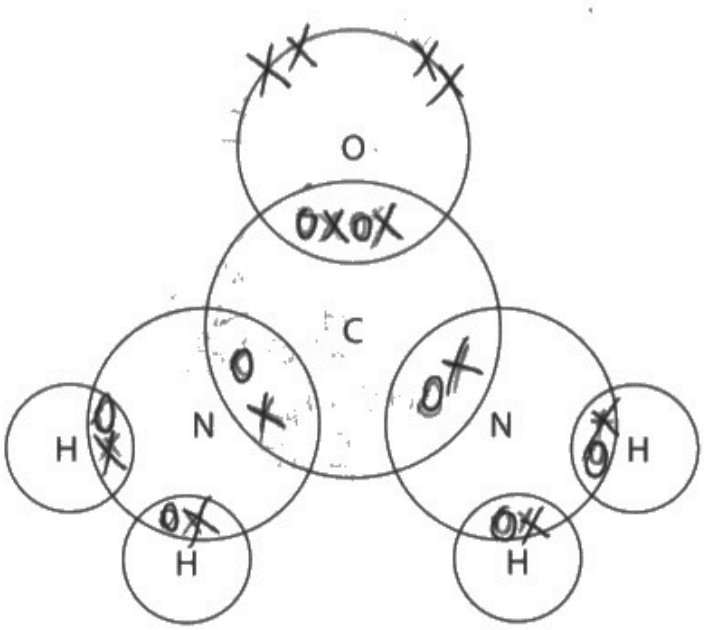
Question 22 (d)

Many candidates scored both marks on this question. Where mistakes were made, the most common ones were leaving out the lone pair of electrons on the nitrogen and only showing a single bond between the carbon and oxygen.

(d) Urea, NH_2CONH_2, can also be made from ammonia.

Complete the dot-and-cross diagram for the urea molecule.

(2)



ResultsPlus
Examiner Comments

Unfortunately, the candidate has missed out the lone pair of electrons on each of the nitrogen atoms and so only scores 1 mark.

ResultsPlus
Examiner Tip

When drawing dot and cross diagrams, check the number of outer electrons carefully and, if you are unsure, use your Periodic Table.

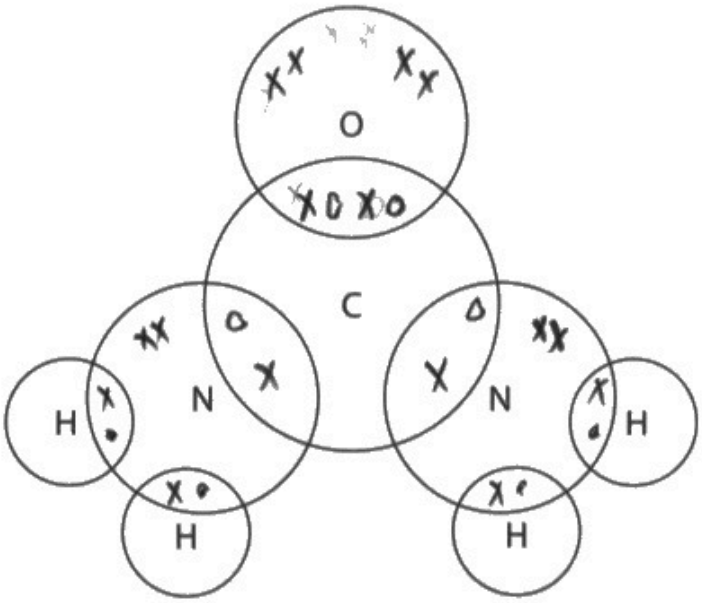
(d) Urea, NH_2CONH_2, can also be made from ammonia.

Complete the dot-and-cross diagram for the urea molecule.

(2)

C 4

N 5



ResultsPlus
Examiner Comments

This is a fully correct diagram. The candidate has put the lone pairs within the circles which is fine.

Question 22 (e)

This question was the most challenging on the paper and there were a number of blank scripts. Whilst most were able to correctly identify hydrogen bonds forming between urea and water, many diagrams were poorly drawn and only a small number of candidates were able to compare the hydrogen bonding between urea and water to the individual molecules.

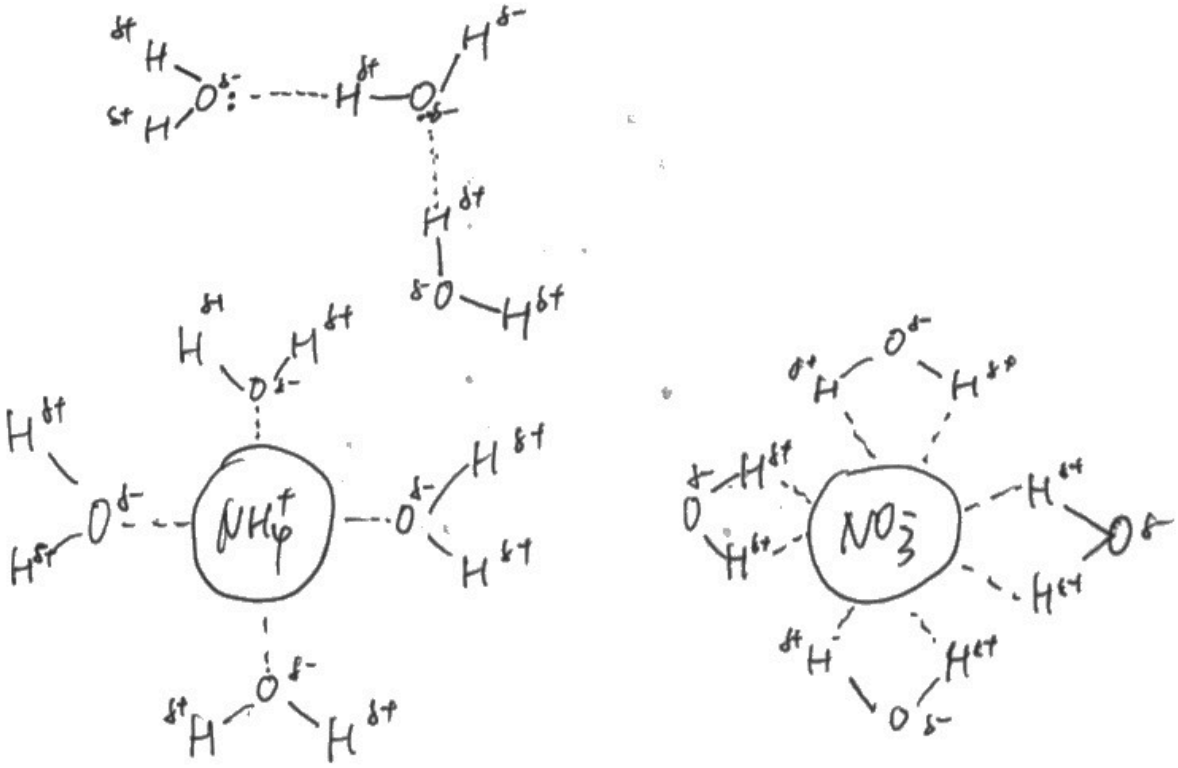
Unfortunately, a significant number of candidates thought that hydrogen bonds or London forces were formed between ammonium nitrate and water and so their diagrams could not score. Those that drew ammonium nitrate as separate ions usually showed the correct interaction with water molecules, but generally the hydration of ions and ion-dipole interactions was not well understood.

*(e) Both urea and ammonium nitrate are soluble in water.

Discuss the differences in the interactions of water molecules with both urea and ammonium nitrate.

Include **three** diagrams showing these interactions.

(6)



~~water~~ H_2O has hydrogen bond and can form ion-dipole force with NH_4NO_3.

ResultsPlus
Examiner Comments

This candidate has drawn and correctly named the ion-dipole interactions.

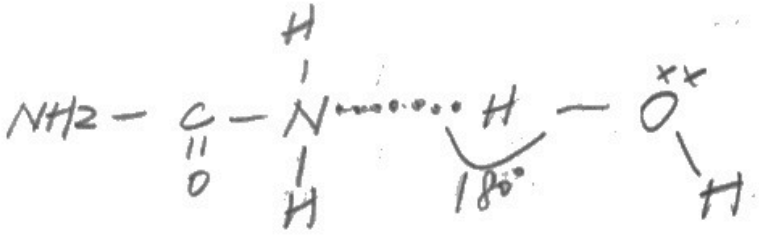
However, they made no attempt at drawing or describing the interactions between water and urea so 3 marks were scored.

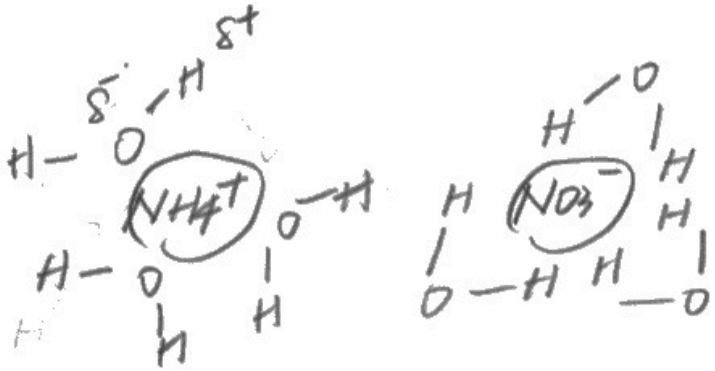
*(e) Both urea and ammonium nitrate are soluble in water. H_2O. NH_2CONH_2.

Discuss the differences in the interactions of water molecules with both urea and ammonium nitrate. NH_4NO_3.

Include **three** diagrams showing these interactions.

(6)





Urea forms H-bond with H_2O. because great difference between N and O. so great attraction. and N contains Lone pair of electrons.

ammonium nitrate is ionic compound. & hydration occurs. energy released during hydration > energy needed to break ionic bonds. so reaction occur. can be dissolved

ResultsPlus
Examiner Comments

This is an excellent answer. The candidate has drawn three correct diagrams and described the interactions taking place, namely hydrogen bonds between water and urea and the hydration of the ions by water.

This scored 5 marks.

Question 22 (f)

Despite this slightly novel calculation at the end of the paper, many candidates got full marks and the average score was just over 2 out of 4. Calculating the number of hectares and the mass of nitrogen seemed to be the most accessible parts of the question, but a number then used the percentage of nitrogen in urea (46.7) incorrectly in the final part of the calculation.

A sizable number also lost the last mark for not giving their answer to 2 or 3 significant figures.

(f) A field needs 160 kg of N per hectare to be applied using urea fertiliser.
The field size is 500 m × 640 m.

[1 hectare (ha) = 10 000 m^2, molar mass of urea = 60 g mol^{-1}]

Urea contains 46.7 % N by mass.

Calculate the mass of urea, in tonnes, that needs to be applied to the field.

Give your answer to an appropriate number of significant figures.

(4)

$500 \times 640 = 320000\ m^2 = 32$ hectare,

so need $160 \times 1000 \times 32 = 5120000$ g N

need $\frac{5120000}{46.7\%} = 10963597.4$ g urea

$= 11.0$ tonnes

ResultsPlus
Examiner Comments

This is an excellent well set out answer scoring full marks.

(f) A field needs 160 kg of N per hectare to be applied using urea fertiliser.
The field size is 500 m × 640 m.

[1 hectare (ha) = 10000 m^2, molar mass of urea = 60 g mol^{-1}]

Urea contains 46.7% N by mass.

Calculate the mass of urea, in tonnes, that needs to be applied to the field.

Give your answer to an appropriate number of significant figures.

(4)

$V = 500 \times 640$

$= 320000\ m^2$

$\frac{320000\ m^2}{10000\ m^2} = 32\ ha$

$m_N = 32 \times 160$

$= 5120\ kg$

$= 5120000\ g$

$n_N = \frac{5120000}{14}$

$= 365714.29\ mol$

$n_{Urea} = 365714.29 \div 46.7\%$

$= 783114.1\ mol$

$m_{Urea} = 24984846.13\ g$

$= 46.99\ tons$

(Total for Question 22 = 20 marks)

ResultsPlus
Examiner Comments

This candidate has scored the first two marks by calculating the number of hectares and then the mass of nitrogen required.

They then go wrong and calculate the number of moles of nitrogen instead of the mass of urea required.

Paper Summary

In order to improve their performance, candidates should:

- always read the information in the question carefully, noting any instructions in bold type
- learn the qualitative tests to identify organic groups
- practise multi step qualitative organic questions and ensure each step is not treated in isolation
- show all working when carrying out calculations and think carefully about units, significant figures and rounding
- learn how ions interact with water when they dissolve
- when drawing mechanisms be very careful with the starting and end point of curly arrows, paying particular attention if the arrow comes from a pair of electrons
- practise fragmenting patterns of organic compounds when placed in a mass spectrometer.

Grade boundaries

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

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

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