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AS LEVEL

Examiners' report

CHEMISTRY A

H032

For first teaching in 2015

H032/02 Summer 2024 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Paper 2 series overview

H032/02 is one of the two examination components for AS Level GCE Chemistry A.

This synoptic 'Depth in Chemistry' paper links together content from all four modules and is worth 70 marks. Candidates answer all questions with a range of question styles including short answer (structured questions, problem solving, calculations, practical) and extended response questions, including those marked using Level of Response mark schemes.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• Demonstrated a good understanding of the fundamentals of chemistry studied in the course, making correct use of terminology in their responses. • Showed good attention to detail, e.g. added lone pairs to O in hydrogen bonding diagram (1(b)(i)); clearly drawn dot-and-cross diagram (1(c)(ii)); and included correct state symbols in IE equation (2(c)(i)). • Performed calculations showing detailed working for each step in a logical order: Calculation of mass of anhydrous zinc sulfate (1(d)); showing Ca is in excess (2(b)(ii)); enthalpy change (3(b)); and calculating concentration of peroxide required (4(b)(ii)). • Produced clear and concise responses for Level of Response questions 3(b) and 6, ensuring all aspects of the question were answered.	• Struggled to use the correct terminology in an appropriate way. • Did not appear to have read through their answers, leaving errors in the wording or contradictions by not crossing through incorrect answers. • Did not read the questions carefully to ensure they answered the question asked, e.g. redox in terms of electron transfer (2(b)(i)); adding points for 1st IE for Mg (2(c)(i)); or circling anomalous result (4(b)(i)). • Were not able to tackle calculations as they appeared unsure of which equation to use or made slips, e.g. not converting volumes to dm^3. • Made errors in drawing organic structures such as C having 5 bonds or missing hydrogens. • Did not use the data sheet to help them interpret spectra in question 6.

Question 1 (a)

1 This question is about water, H_2O, and ammonia, NH_3.

(a) Hydrogen and oxygen have different electronegativities.

What is meant by the term **electronegativity**?

....

....

.... **[2]**

Many managed to score at least one mark here but most struggled to give a comprehensive definition. A mark was often lost mark for omission of 'atom', i.e. not saying what was attracting electrons, or for saying 'element' instead. The ability to attract **an electron** was not accepted as this is describing electron affinity rather than electronegativity. Many described the formation of dipoles or partial charges across the bond due to the difference in electronegativity but didn't demonstrate a clear understanding of what electronegativity is. Lower-scoring candidates often referred to the formation of ions and/or loss of electrons.

Assessment for learning

Learning key words and terminology is an important part of understanding Chemistry.

Encourage students to make their own flash cards for each topic – this can be done on card or electronically using websites such as Quizlet.

Display key words and definitions in classrooms.

Although the current specifications place less emphasis on rote recall of definitions, students should still practice writing definitions for common terms with appropriate key words.

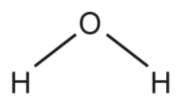
Question 1 (b) (i)

(b) H_2O is a polar molecule that has hydrogen bonding.

(i) Complete the diagram below to show hydrogen bonding between the H_2O molecule shown and another H_2O molecule.

Include relevant dipoles and lone pairs.

Label the hydrogen bond.

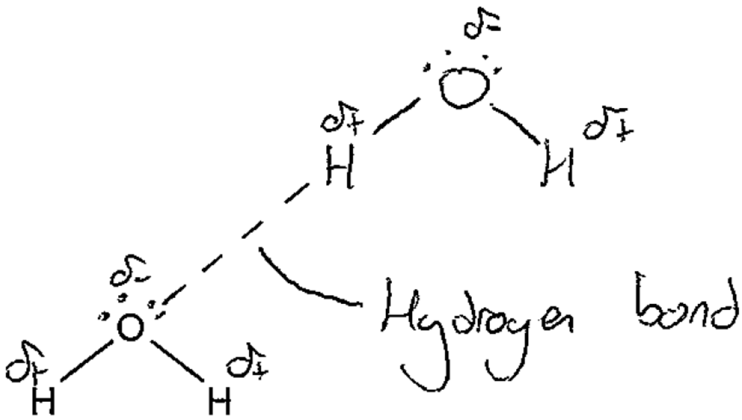


[2]

Around half of candidates scored both marks with a well-drawn diagram (such as that shown in the exemplar below). Practising drawing hydrogen bonds between different molecules is a really good way of exploring students' understanding of what they are. The most common errors were missing the lone pair or showing a hydrogen bond that didn't originate from those drawn.

Lower-scoring candidates often didn't draw a second water molecule, labelling the covalent bond between O and H as a hydrogen bond. Quite a few diagrams were seen with δ+ and δ- only on one molecule or with δ+ on one structure and δ- on the other. It was essential here to show that the O-H bond in both molecules is polar. Diagrams were often unclear so sometimes difficult to interpret.

Exemplar 1



This is an example of a good diagram for hydrogen bonding.

Question 1 (b) (ii)

(ii) Explain why molecules of H_2O are polar.

....

....

.... **[1]**

Some appropriate answers were seen, mostly discussing the asymmetrical shape of water. More than half didn't score the mark. However, many were able to describe O-H being a polar bond due to the difference in electronegativity but didn't realise that this doesn't always mean that the molecule itself is polar.

The relationship between the words electronegative, dipole and polar need more attention and how this all relates to the shapes of molecules. Some candidates said *symmetrical* when they meant *asymmetrical.*

Question 1 (b) (iii)

(iii) One unusual property of H_2O is that ice floats on water.

Explain why ice has a lower density than water.

....

....

.... **[1]**

Some good answers were seen referring to hydrogen bonds holding/keeping water molecules further apart or creating an open lattice. However, a number did not score for not mentioning hydrogen bonds or for referring to alternative intermolecular forces. For example, 'In solid state, the London forces are weaker' and 'Ice has less induced dipole-dipole forces'. Some also indicated that 'air' was in the structure and this wasn't accepted as air molecules are too large to fit in the gaps between water molecules in the ice crystal structure.

Responses often demonstrated some significant misconceptions in candidate understanding. Many felt that the length of the hydrogen bond changed, for example 'when ice freezes hydrogen bonds expand' 'Atoms are further apart so longer hydrogen bonds'. Some suggested that the strength of the hydrogen bond changed (for example, 'ice has weaker H-bonds than water'). Some recognised that ice has a crystalline structure but didn't explain how this is different from other solid structures, which would be denser than their liquid counterparts.

Lower-scoring candidates struggled to understand density (for example, 'ice is more compact' or 'molecules closer together in ice'). Terminology was also a problem with candidates often referring to 'ice' or 'particles' rather than 'molecules'.

Question 1 (c) (i)

(c) Solid ammonia, NH_3, also contains hydrogen bonds.

(i) Suggest why solid ammonia has a lower melting point than ice.

....

....

....

.... **[2]**

Despite being told in the question that ammonia contains hydrogen bonds, many gave responses in terms of ammonia having either London forces and permanent dipole-dipole forces which are weaker than hydrogen bonds. For example, 'ammonia consists of permanent dipole-dipole interactions which are weaker than hydrogen bonding in ice' and 'NH_3 has 17 electrons and H_2O has 18 electrons. Due to NH_3 having fewer electrons, there are fewer London forces'.

Lower-scoring candidates often confused hydrogen bonds and covalent bonds, consistent with what was seen in 1(b)(i). For example, 'O-H bond is stronger than N-H bond' and 'more energy needed to break O-H bonds rather than N-H bonds'. Some of these candidates did score a mark for recognising that N is less electronegative than O.

For others they understood that ammonia has weaker hydrogen bonds but then struggled to give a reason either in terms of lone pairs or electronegativity.

Question 1 (c) (ii)

(ii) When ammonia dissolves in water, ammonium ions, NH_4^+, are formed.

Draw a 'dot-and-cross' diagram to show the bonding in an NH_4^+ ion.

Show outer electrons only.

[2]

Less than half of the candidates scored both marks. Most candidates drew 4 x N-H shared covalent bonds and therefore lost the dative bond mark. Some added an additional electron to either N or H. Some drew an additional shaped electron (e.g. using a triangle) on one of the bonding pairs, obviously not realising that both electrons in dative bond originate from N, so have the same symbol.

Many diagrams were unclear making it hard distinguish between dots and crosses especially if adding circles for electron shells. A few lower-attaining candidates attempted to draw an ionic dot-cross diagrams.

Question 1 (c) (iii)

(iii) Outline how you would test for the presence of NH_4^+ ions in a solution.

Your answer should include observations.

....

....

....

.... **[2]**

Higher-attaining candidates often gave a very detailed responses with all stages, including warming the NaOH, use of damp litmus paper and some included an ionic equation. Quite a few lost a mark as they missed the addition of hydroxide, just warmed, but they still gained mark for testing with indicator paper.

Some thought that the indicator paper would turn red or be bleached and a few gave incorrect ion test e.g. add silver nitrate, add acid.

Over a third of candidates did not score on this question, with a significant proportion not even attempting it.

Question 1 (d)

(d) A student heats 11.50 g of hydrated zinc sulfate, $ZnSO_4•7H_2O$, to remove all the water of crystallisation.

Calculate the mass of anhydrous zinc sulfate that should be obtained.

mass = ... g **[3]**

Just under half of the candidates scored all 3 marks. A range of responses were seen for this question but the most common error was to use the incorrect M_r for the hydrated which included either using the M_r for the anhydrous salt or the M_r for $ZnSO_4.H_2O$ (179.5). It was evident that candidates struggle to understand what is meant by water of crystallisation.

Some scored 2 marks for the correct M_r and finding moles but then were unsure how to proceed with the calculation. For example, some divided moles by 7 before multiplying by 161.5. Many candidates took the more complicated alternative route to find the mass of water before subtracting from mass of hydrated compound.

Low-scoring candidates often struggled to correctly work out M_r values. Their working was set out so that individual steps were unclear, often with contradictory calculations.

Question 2 (a) (i)

2 This question is about periodicity and the reaction of some Group 2 metals.

(a) Periodicity is the repeating trend in properties of elements across different periods in the periodic table.

(i) Complete the table below with the electron configurations and blocks.

	Group 2	**Group 17 (7)**
Period 2	Be $1s^2$	F $1s^2$ ....
Period 3	Mg $1s^2$	C*l* $1s^2$ ....
Block	....	....

[3]

A very well answered question with most candidates very confident in giving the correct electron configurations and blocks. Errors were rare but included: $2p^5$ or $3p^6$ ending for Cl; using mass number for number of electrons; and assigning group 17 as d block and giving orbital box diagrams rather than block.

Question 2 (a) (ii)

(ii) Use your answers to **(a)(i)** to explain why electron configuration is an example of a periodic trend.

....

....

....

.... **[2]**

Many found this question challenging despite doing well in Question 2(a)(i). The question states 'use your answers from (a)(i)' but not many candidates wrote about the electron configurations they had given. Many gave very simplistic responses in terms of the number of electrons increasing but made no reference to how those electrons are arranged (e.g. 'number of electrons increases across a period as the electron configuration gets higher' or 'atomic number increases').

Some candidates struggled with terminology, often referring to 'block' or 'orbital' instead of subshell (e.g. 'outer electrons are in same block', 'going across a period the number of orbitals increases', 'elements in same group have their highest energy electron in same block' or 'orbital').

Candidates need clarity on the terminology used for electron configurations and periodic table i.e. blocks, shells, sub-shells and orbitals.

It was rare for candidates to score both marks as this was a question that they were unfamiliar with. However, some did gain a mark for linking the number of outer shell electrons to the group number or stating that elements in the same period have the same number of shells. It was not enough to refer to the highest energy electron being in the s-subshell or p-subshell as this is the link to the block, but all groups in same block will be the same.

Some described the trend in other physical or chemical properties. Some examples included: 'Elements have same chemical and physical properties due to similar electronic configuration'; 'as you go across period, number of electrons increase and their boiling and melting points increase'; and 'electrons are more easily lost in a paired orbital, due to greater repulsion and so have lower ionisation energies'.

OCR support

We have produced a transition guide on the topic of atomic structure. It covers content from KS4 and how this is developed at KS5 with a wide range of suggested resources to support teaching. At KS4, candidates are expected to be able to explain how the position of an element in the Periodic Table is related to the arrangement of electrons in its atoms, with development at KS5 to arrangement in to s, p and d orbitals.

https://ocr.org.uk/Images/170375-atomic-structure-ks4-ks5.pdf

Question 2 (a) (iii)

(iii) Mg forms 2+ ions but C*l* usually forms 1– ions in their reactions. Explain why.

....

....

....

.... **[2]**

Generally, this question was well answered with a clear understanding of how and why ions are formed. However, approximately a quarter of students only gained 1 mark as they either didn't explain electrons being lost by Mg and gained by Cl or gave no justification. A common slip was stating Cl has one electron in its outer shell.

Some described bonding between Mg and Cl, which wasn't what the question asked, but this didn't prevent them from scoring both marks.

Question 2 (a) (iv)

(iv) Magnesium reacts with oxygen in the air.

Write the equation for this reaction.

.... **[1]**

Many candidates correctly gave the balanced equation here. However, some didn't balance but had the correct formula. A few gave Mg_2 as a reactant or MgO_2 as a product. Some had O_2 on both sides of the equation.

Question 2 (b) (i)

(b) The reaction between calcium and hydrochloric acid is a redox reaction.

$Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$ **Equation 2.1**

(i) Explain, in terms of electron transfer, why the reaction shown in **equation 2.1** is a redox reaction.

....

....

....

.... **[2]**

Explaining redox reactions is a common question in exam papers, however here candidates needed to do it 'in terms of electron transfer'. Subsequently, many lost a mark as they identified oxidation and reduction in terms of oxidation numbers only. However, many gave responses both in terms of oxidation numbers and electrons.

It was necessary to be specific here and say Ca had lost 2 electrons, so a few lost the mark by only referring to 'Ca losing electrons'. Some lost marks for only describing oxidation of Ca and not reduction of H.

There was some evidence that candidates were not sure of Cl's role in the reaction (i.e. as a spectator ion) with some stating it was reduced and/or accepted electrons from Ca but then gave them to H.

Question 2 (b) (ii)

(ii) A student plans to add 0.0100 mol of Ca to 120 cm^3 of 0.100 mol dm^{-3} $HCl(aq)$.

When the student carries out this reaction, they are surprised that all the calcium reacts, despite being in excess of the $HCl(aq)$.

- Show by calculation that calcium is in excess of the $HCl(aq)$.
- Suggest a reason for this unexpected result.

....

....

....

....

....

.... **[3]**

Most candidates correctly calculated the amount of HCl as 0.012 mol. However, many struggled with demonstrating that Ca is in excess. Responses often highlighted misconceptions here in terms of candidates' understanding about excess and limiting reagents. For example, 'Ca has a lower concentration than HCl so becomes the limiting reagent' and 'Not all the HCl had reacted'

Many compared moles of HCl calculated (i.e. 0.012) directly to moles of Ca (i.e. 0.01) saying that HCl was in excess, despite being told otherwise in the question. Some had the 2:1 ratio of HCl to Ca the wrong way around. Some attempted to calculate mass of Ca and HCl to use for comparison.

Only a small proportion of candidates were able to access the third mark and correctly suggest that Ca was also reacting with water. Some other suggestions that were seen included:

- 'Ca reacted with oxygen or was impure'. In both cases this would mean that we would expect solid to remain.
- 'Higher concentration of HCl added', or 'HCl is a strong acid', or 'acid acts as a catalyst'.
- 'H_2 evolved' or 'Ca reacts with hydrogen formed'.
- 'Human error', 'didn't weigh Ca correctly', 'measured volume of HCl incorrectly'.

Misconception

Candidates often struggle to understand the concepts around limiting reagents and those in excess. Using a simple baking analogy can help to relate this to everyday life.

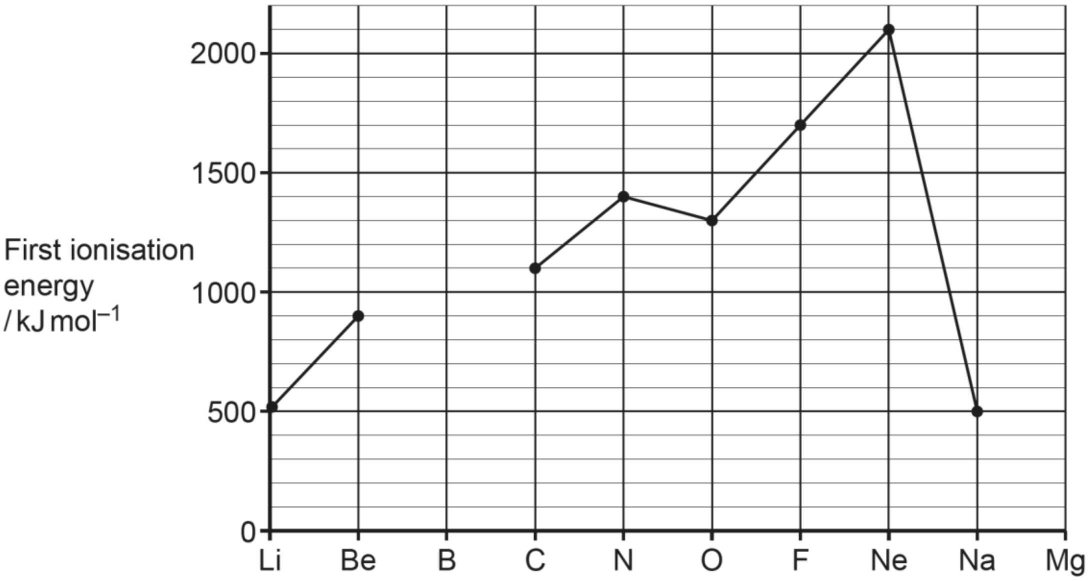
For example:

To make 10 pancakes you need 100 g flour, 2 eggs and 300 ml milk

How many pancakes can I make if I have only 50 g flour, 2 eggs and 300 ml milk?
Which is the limiting ingredient and which are in excess?
The number of pancakes we can make is the theoretical yield.

Question 2 (c) (i)

(c) The graph shows the first ionisation energies for the elements Li to Be and for C to Na.



(i) Complete the graph by adding points for the missing values of B and Mg. **[2]**

Approximately a quarter of candidates scored both marks here. Many candidates omitted to plot a point for Mg or positioned the point for Mg at 900 or above so higher than Be.

Question 2 (c) (ii)

(ii) Write an equation, including state symbols, to represent the **second** ionisation energy of B.

.... **[2]**

More than half of candidates scored both marks here. Errors seen included missing or incorrect state symbols, especially (s), but also (aq) was seen. Some had electrons on the left hand side of the equation, i.e. '$B^+ + e^- \rightarrow Be^{2+}$'. Some included negatively charged ions and occasionally the wrong element was used, e.g. Mg or Be.

Question 3 (a)

3 Enthalpy changes of reaction can be determined by experiment.

(a) What is meant by the term **enthalpy change of reaction**?

....

....

.... **[1]**

The term was not well known, with only a small proportion of candidates scoring this mark. Many gave the definition for enthalpy change of combustion or formation or bond enthalpy. Many referred to one mole of either reactants or products or bonds, or sometimes a combination of these. Lower-attaining candidates often said it was the temperature change.

Question 3 (b)*

(b)* A student carries out an experiment to determine the enthalpy change for the reaction between zinc and copper(II) nitrate solution.

$Zn(s) + Cu(NO_3)_2(aq) \rightarrow Zn(NO_3)_2(aq) + Cu(s) \quad \Delta_r H$ **Equation 3.1**

The student follows the method outlined below.

- Add $100\,cm^3$ of $0.500\,mol\,dm^{-3}$ $Cu(NO_3)_2(aq)$ to a beaker.
- Measure the temperature of the solution.
- Add excess zinc to the beaker.
- Stir the mixture and record the maximum temperature.

The temperature of the solution changes from 19.5 °C to 38.1 °C.

Calculate $\Delta_r H$, in $kJ\,mol^{-1}$, for **equation 3.1**.

State any assumptions you have made in your calculation.

Suggest improvements for obtaining a more accurate value for $\Delta_r H$. **[6]**

The calculation of enthalpy change was generally well-answered and the majority of candidates were able to recall the equation $q = mc\Delta T$. Many candidates forgot the minus sign or gave a positive sign for final enthalpy change.

Errors in calculation were most commonly for using an incorrect mass, usually by finding the mass of copper(II) nitrate (from moles and M_r). Some also used the wrong value for the heat capacity, selecting the value for R from the data sheet instead. Many gave the final answer to an inappropriate six significant figures.

Candidates often found it challenging to give appropriate assumptions and improvements, limiting the level achieved to Level 2.

However, many candidates did correctly give the assumptions that the specific heat capacity and density of the solution was the same as water. This is usually stated for the candidates with these types of questions. The most common improvements suggested were use of a polystyrene cup, adding a lid or using a thermometer with a higher resolution. Quite a few candidates suggested using a larger volume of solution which would indeed reduce the % uncertainty in the volume measurement. However, it would lead to a smaller temperature change, increasing the % uncertainty in the temperature measurement.

Some confused the question with a calculation of enthalpy change of combustion and gave improvements accordingly, e.g. 'use a copper or bomb calorimeter', 'draft shields', 'heat for longer', 'position of flame and supplies of oxygen'.

Exemplar 2

0.5 × $\frac{100}{1000}$ = 0.05 mol

Q = mcΔT

→ Q = 100 × 4.18 × (38.1 − 19.5) = 7774.8 ~~kJ~~ = 7.77 kJ

7.77 ÷ 0.05 = 155.5 kJ mol^{-1}

→ reaction is exo ∴ ΔrH = −155.5 kJ mol^{-1} #

I assumed that the specific heat capacity of the solution is the same as ~~the~~ water. I assumed that no heat was lost to surroundings. I assumed that the mass of solution with zinc in it is ~~100 cm³~~ 100 g. I assumed the density of solution is same as water so 100 cm³ equals to 100 g. Improvements can be ~~done~~ do the experiment under standard conditions. Can also improve by using a larger mass of reactants ~~and~~ and also use a more accurate thermometer that can record to 2 decimal places. I can also improve by putting the beaker in another beaker with water to reduce heat loss to surroundings

This response achieved Level 3 - 6 marks. There is a correct calculation for ΔH, the final value has a correct negative sign and is given to 4 significant figures. Lots of valid assumptions and improvements are given.

Question 3 (c)

(c) The student modifies the experiment using 50 cm^3 instead of 100 cm^3 of 0.500 mol dm^{-3} copper(II) nitrate solution.

The value of $\Delta_r H$ for this modified experiment is the same as in **equation 3.1**.

Explain why.

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....

....

.... **[2]**

There was a lot of misunderstanding associated with this question, with many candidates failing to score any marks. Many said that nothing would change as the concentration was still the same or because the same bonds were being broken and formed.

Under a quarter of students scored 1 mark, usually for making the link between the drop in volume to a change in the q and n values. A few did state that the temperature didn't change. Only a small proportion scored both marks, usually by showing by calculation that the temperature change was the same, moles was half and energy was half. Some did believe that the temperature changed, either that it decreased as less reacted or increased as there was less volume to heat.

A wide variety of alternative responses were given including:

'Enthalpy change the same regardless of mass used'

'Number of moles doesn't impact energy required as it is the same bonds breaking'

'Energy to break and form bonds will still be the same with any volume'

'Amount of energy required to make the new bond would be the same'

'Only concentration has an effect on bond enthalpy values not volume'

'Decrease in volume increases concentration'

'$Cu(NO_3)_2$ would still run out first so enthalpy change is the same'

'Zn is in excess so it doesn't matter how much volume we use because Zn and $Cu(NO_3)_2$ still 1:1 ratio.'

'Mole ratio is still the same' or 'same molar ratio' wasn't enough.

Question 4 (a)

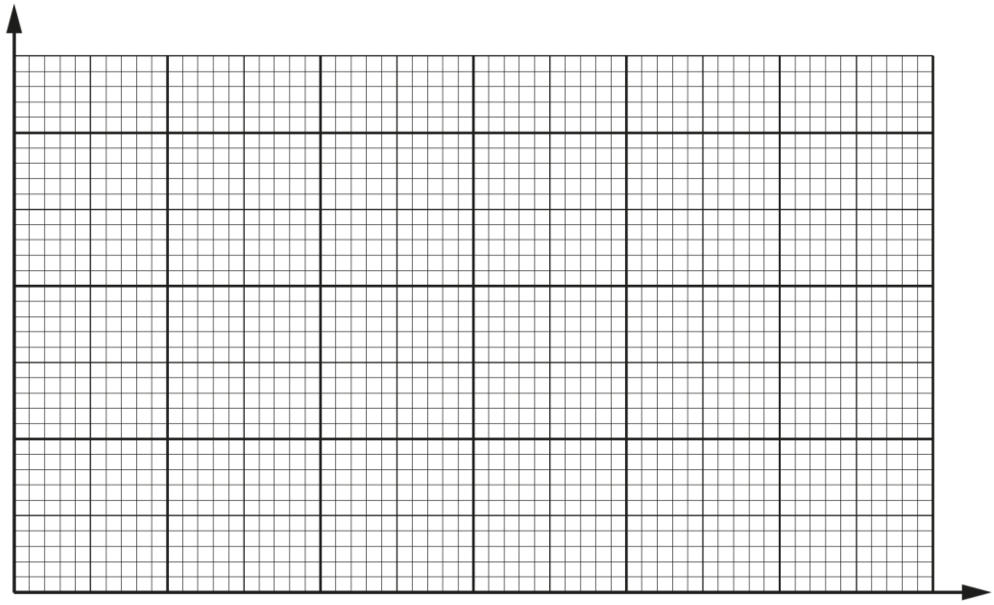
4 Aqueous hydrogen peroxide, $H_2O_2(aq)$, gradually decomposes to produce water and oxygen.

$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$ $\Delta H = -196\,kJ\,mol^{-1}$ **Equation 4.1**

The rate of decomposition of H_2O_2 can be increased by adding a small amount of manganese(IV) oxide, MnO_2, which acts as a catalyst.

(a) Explain, using a Boltzmann distribution model, why the rate of a reaction increases in the presence of a catalyst.

You are provided with the axes below, which you should label.



....

....

....

....

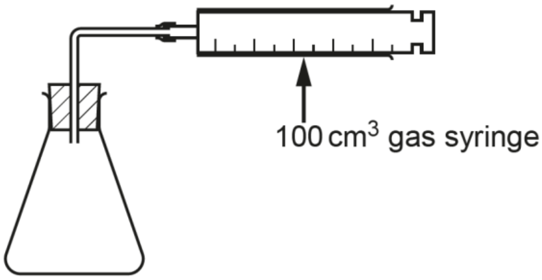
.... **[4]**

This is a familiar question with around half of candidates scoring all 4 marks. Common errors included drawing 2 lines, as you would have with different temperatures, but labelling one with catalyst and other without. Some had incorrect or missing labels on the axes. The most frequently gained mark was for knowing that the activation energy was lowered by a catalyst; this could be given by correct lines and labelling shown on the distribution, although care needed to be taken as some contradicted their answers with their diagram. Some labelled E_a and E_c lines but didn't have energy on x-axis scale.

Some struggled with the final marking point, not recognising that more molecules have the required activation energy. For example, 'more frequent successful collisions' with no reference to the activation energy, i.e. why they are successful.

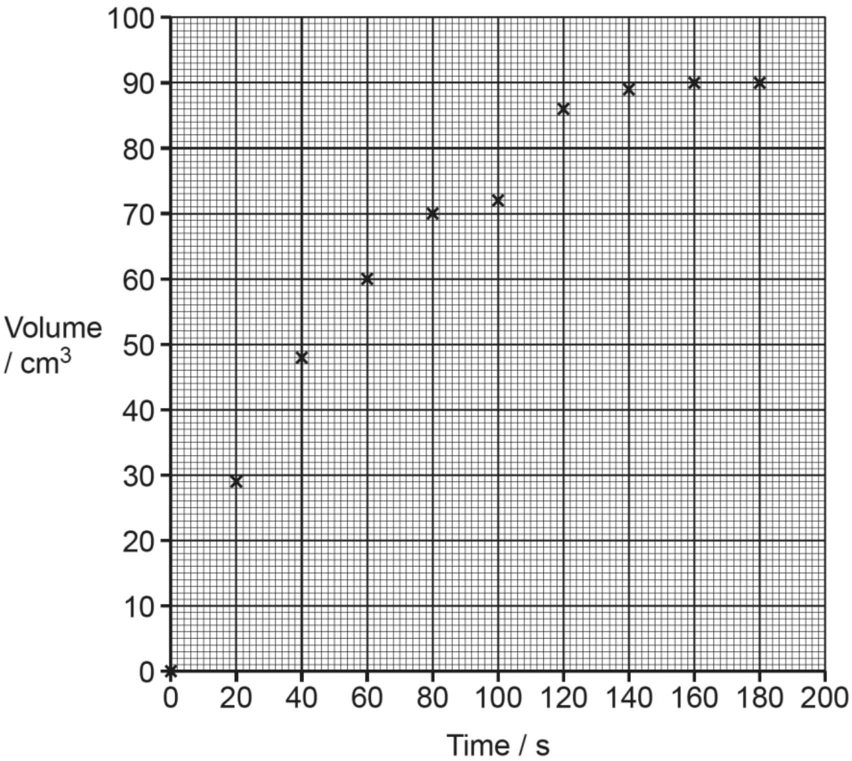
Question 4 (b) (i)

(b) A student investigates the rate of decomposition of H_2O_2, on addition of MnO_2 catalyst, using a gas syringe.



The student obtains the results shown in **graph 4.1**.

Graph 4.1



(i) On **graph 4.1**, draw a best-fit smooth curve of the results **and** circle the anomalous result. **[2]**

Most scored both marks here. Some didn't circle the anomalous result and some lost a mark for a poorly drawn curve. Candidates must ensure they have a sharp pencil and draw a single line through all the points (except the anomalous point). Some didn't start at the origin or didn't level off at around 90 cm^3.

Question 4 (b) (ii)

(ii) Use your graph to determine the rate of reaction, in $cm^3 s^{-1}$, at 50 s.

Show your working below and on the graph.

rate = ... $cm^3 s^{-1}$ **[2]**

More candidates were able to correctly draw a tangent than seen in previous years with similar questions. A generous range was given for both tangent and gradient so many scored both marks. The most common reasons for losing marks was for having a gap between the curve and the tangent or calculating the gradient incorrectly, e.g. misreading scales, dx/dy, or by using interpolation rather than a tangent.

Question 4 (b) (iii)

(iii) The student uses 50.0 cm^3 of H_2O_2 in the experiment. **Equation 4.1** shows the reaction that takes place.

$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$ **Equation 4.1**

Calculate the concentration of H_2O_2, in $mol\,dm^{-3}$, required to produce 90 cm^3 of $O_2(g)$ at RTP.

concentration = ... $mol\,dm^{-3}$ **[3]**

Over half of candidates scored all 3 marks here. However, around a quarter did not gain any credit at all. Some confused the volume of H_2O_2 for a volume for a gas and attempted to find moles using molar gas volume (i.e. used 50cm^3 rather than 90cm^3). This often lost all 3 marks as they then divided by 2 and to find concentration divided by 90/1000 instead. A few attempted to use the ideal gas equation but this rarely yielded a correct value.

Candidates must be encouraged to set out working clearly, showing logical steps and preferably labelling each step with what is being calculated and giving units. Many wrote the calculation as series of steps which all equalled the previous.

e.g. $90 \div 24000 = 3.75 \times 10^{-3} \times 2 = 7.5 \times 10^{-3} \div 0.05 = 0.15$

Misconception

Encourage students to assign information in the question to the correct chemical. One way to do this is to write out the equation and then underneath each species put correct volumes as given. It also helps to highlight ratios shown in the equation. It is important here to pay close attention to state symbols as it helps identify correct calculations to use.

For example;

$2H_2O_2$ (aq) → $2H_2O$ (l) + O_2(g)

50.0cm^3 90 cm^3

Solution Gas at RTP

Conc?

Question 4 (c)

(c) A student plans to compare the rate of decomposition of H_2O_2 using different metal oxides as the catalyst.

Suggest **two** variables which should be kept constant.

1 ....

2 ....

[2]

More than half of candidates achieved both marks and most scored at least 1.

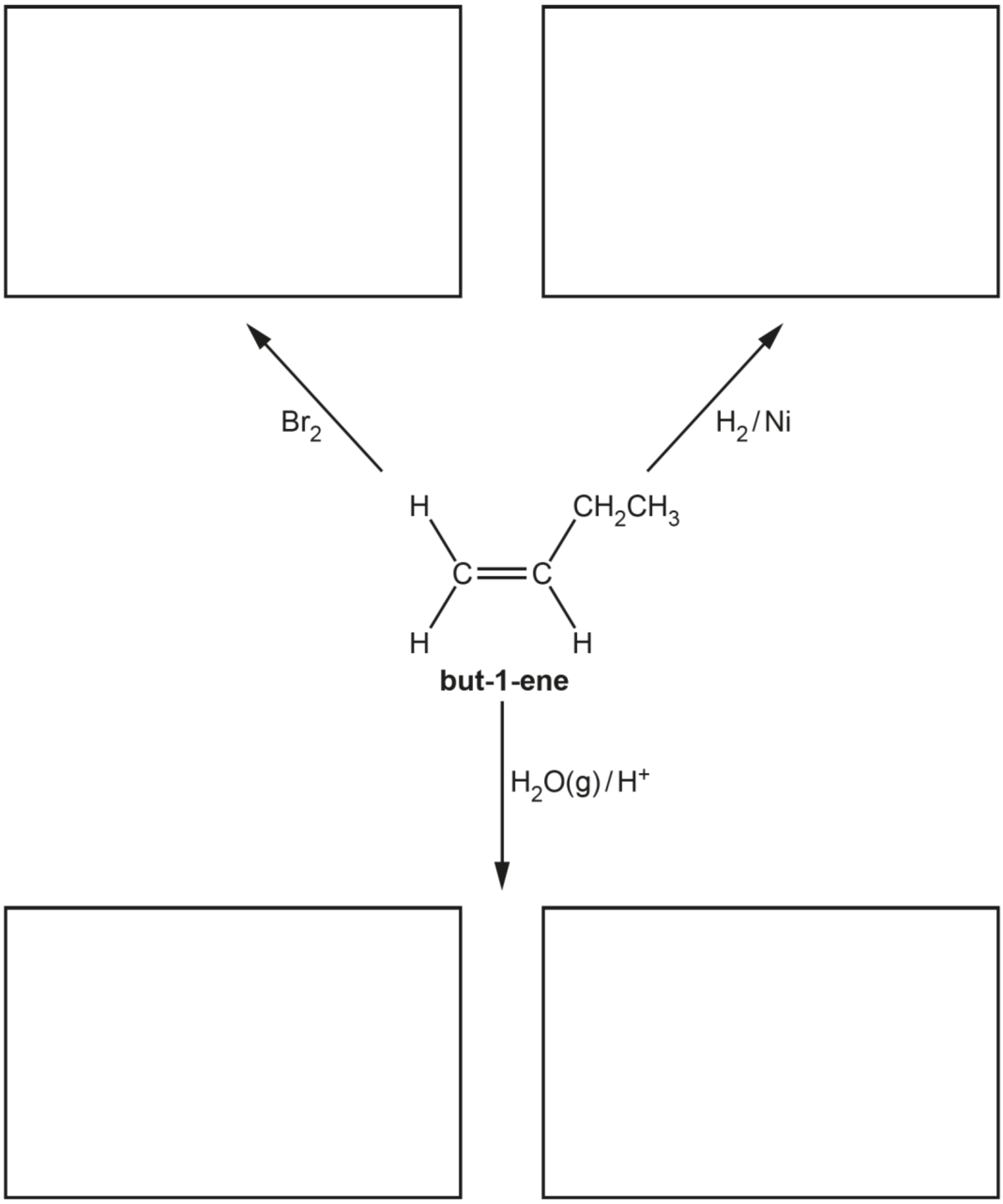
The most common reason for losing marks was for not being specific, by just saying 'concentration' or 'volume', or suggesting volume and concentration for metal oxide.

Some suggested use of the same gas syringe without realising that the apparatus used should not affect volume of gas produced, just how easy and accurate it is to measure.

Question 5 (a)

5 This question is about some reactions of alkenes.

(a) Complete the flowchart for the reactions of but-1-ene, by adding the structures of the organic products in each box.



Mixture of products

[4]

Most candidates scored all 4 marks here. Candidates seemed very knowledgeable about the addition reactions of alkenes.

Some of the most common errors seen included:

- 2,3-dibromobutane, rather than 1,2-dibromobutane

- Repeating the same alcohol in bottom boxes
- Missing H atoms from structures
- Keeping double bonds
- Missing CH_2CH_3 group (with H instead)
- H_2 as a second product on reaction with water and some gave oxidation products rather than alcohols e.g. aldehyde, ketone, carboxylic acid here
- Ni added to the organic molecule for hydrogenation

Incorrect connectivity from vertical bonds to CH_2CH_3 and OH groups was not penalised in this question but would have had a significant impact on marks if it had. Some lost the mark for incorrect connectivity for OH groups when drawn horizontally i.e. OH-C.

Drawing organic structures

Ensure students get lots of practice drawing organic structures using different types of formula including displayed, structural and skeletal. It is important to check structures carefully to ensure C has 4 bonds, O 2 bonds and H only 1 bond. Under pressure it is very easy to make slips.

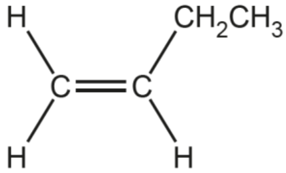
For exams, remind candidates not to draw in pencil then rub out – the structure beneath often shows up when the paper is scanned. If corrections are needed, cross out the incorrect structure and redraw clearly.

Question 5 (b) (i)

(b) HBr reacts readily with alkenes.

(i) Outline the mechanism for the reaction of but-1-ene with HBr to form **2-bromobutane**.

Include curly arrows, relevant dipoles and the structure of the product.



[4]

Approximately half of candidates scored all 4 marks. Very few scored no marks as they were able to give the correct structure of the named product (2-bromobutane). The most common reasons for losing marks included:

- Adding dipoles to C=C
- Missing dipoles on H-Br or reversed dipole on H-Br (i.e. δ+ Br)
- Missing charge on bromide ion or adding δ-
- Arrows the wrong way round or not coming from a bond or lone pair (or negative charge for bromide ion)

Some attempted a radical mechanism.

OCR support

For ideas on teaching this topic please look at our Topic Exploration Pack: Electrophilic Addition and Markownikoff's rule:
https://teachcambridge.org/item/b4220e86-bc04-492c-b354-8103687ce594

Question 5 (b) (ii)

(ii) During this reaction, a small amount of **1-bromobutane** is also produced.

Explain why **2-bromobutane** is the major product.

....

....

....

.... **[2]**

Over half of candidates didn't gain any credit for their response here. Answers often focused on Markownikoff's rule, i.e. adding H to C with most H atoms already attached, or described the stability of the product. Students need more support in understanding that the more stable carbocation will be formed in preference and result in forming more product. Many referred to the 'secondary haloalkane' being more stable, rather than the 'secondary carbocation'. Some stated that 2-bromobutane is a 'secondary carbocation', showing some misunderstanding about the terminology used here.

OCR support

We have a useful PowerPoint Presentation for teaching about Markownikoff's rule and carbocation stability: https://ocr.org.uk/Images/250388-markownikoff-s-rule-presentation.ppt

Question 6*

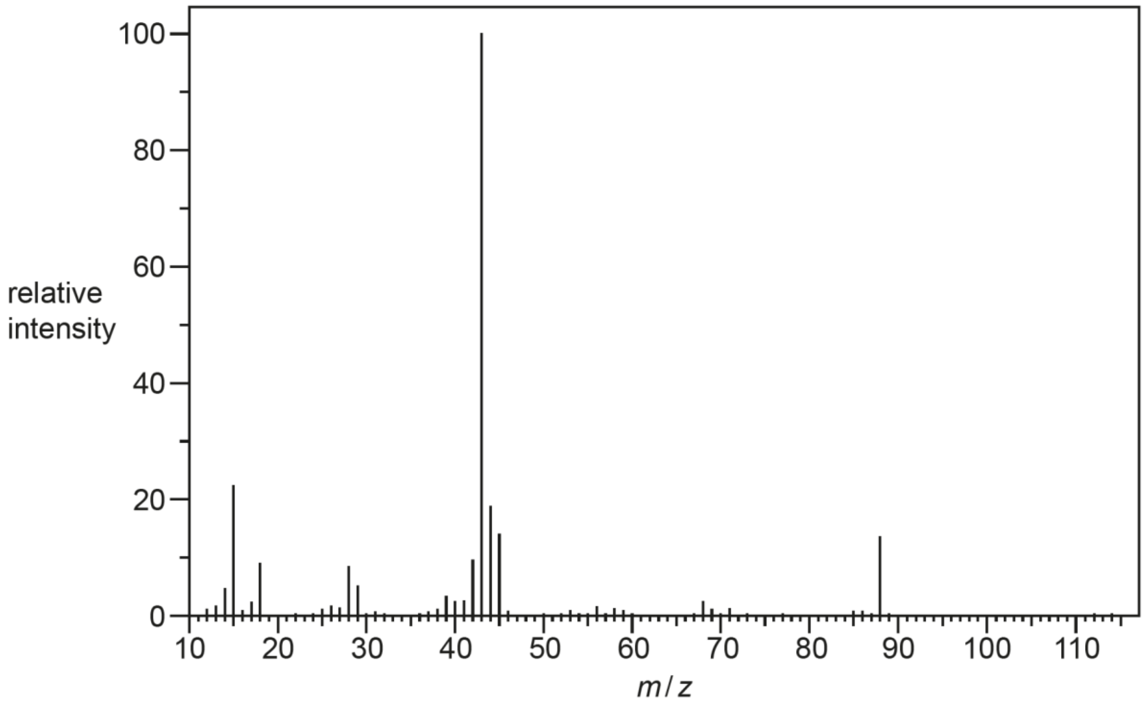
6* Compound **X** is an organic compound with **two** functional groups.

Compound **X** has the percentage composition by mass:
C, 40.91%; H, 4.54%; O, 54.55%.

Compound **X** does **not** decolourise bromine water.

A scientist analyses compound **X** using mass spectrometry and infrared spectroscopy.

Mass spectrum of X



Over a third of candidates achieved Level 3, gaining 5 or 6 marks. A correct structure (either aldehyde or ketone) alone was not enough to award Level 3 and candidates were expected to give a comprehensive description of how the evidence helped them determine the structure.

The biggest challenge for many candidates was finding the correct empirical formula. The ratio worked out to 1:1.33:1 so many incorrectly rounded this to either 1:1:1 or 1:2:1, which meant they struggled to find a molecular formula that worked and added up to 88. Incorrect molecular formulas seen included $C_3H_3O_3$, which adds to 87 (often the extra H was just added to make it fit), or $C_4H_8O_2$, which does add to 88.

Most candidates could analyse the IR spectrum, identifying peaks corresponding to C=O or O-H. Candidates should identify bonds present before making conclusions about the functional groups.

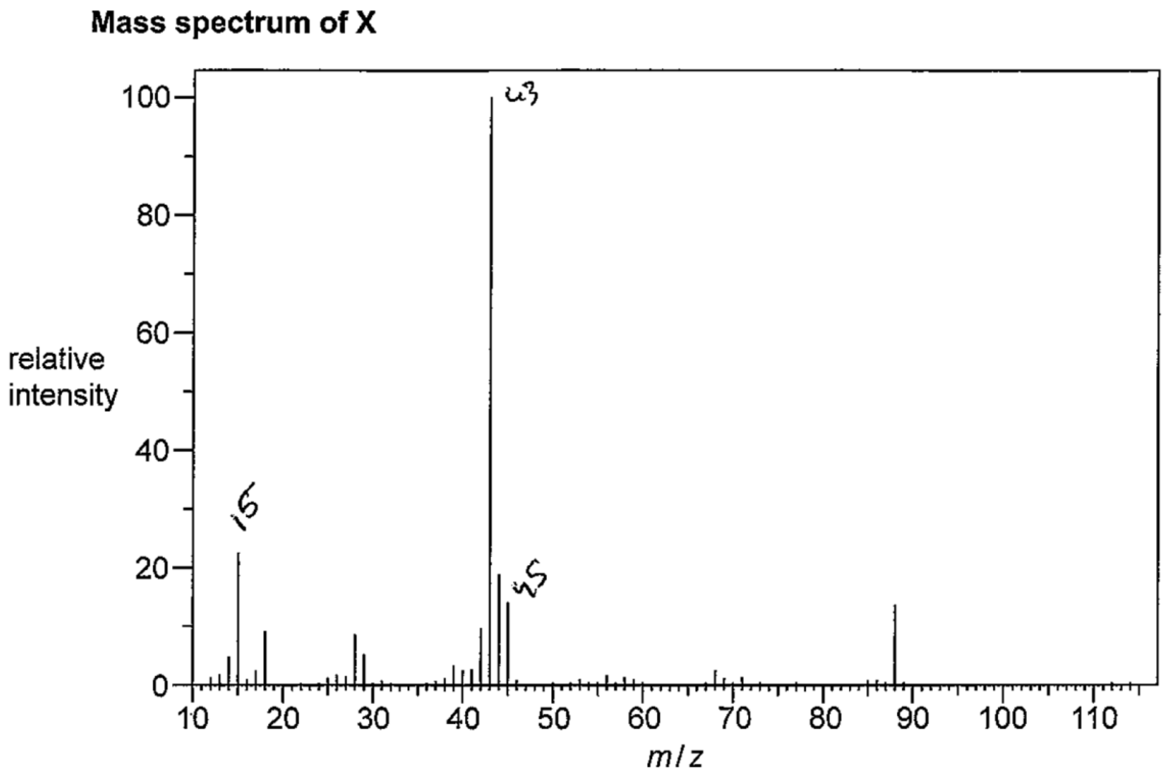
Many were able to use mass spectra to determine the M_r value from the M+ peak. Some did go on to make use of other peaks, identifying fragments and confirming whether the structure was an aldehyde or ketone depending on analysis. For example, CHO^+ at m/z = 29 suggests an aldehyde, or conversely CH_3^+ at m/z = 15 suggests a ketone.

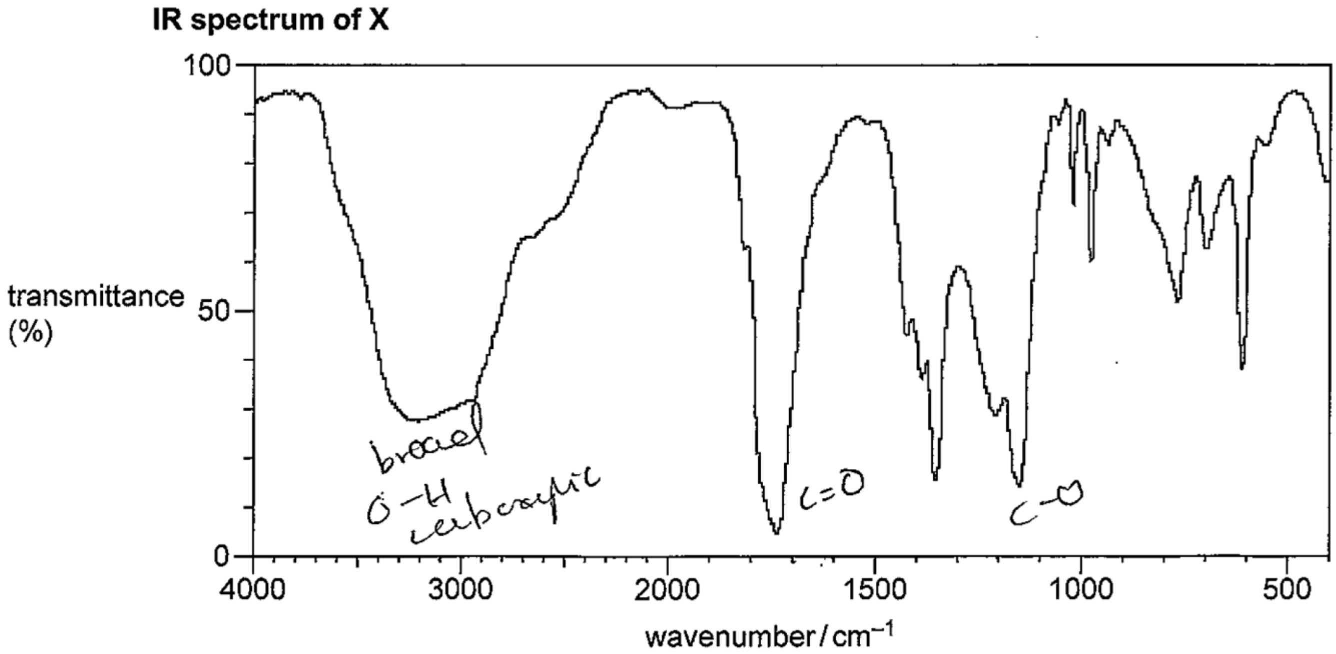
Candidates should always be encouraged to comment on all the data provided. This can be through good annotation of the spectra and notes added to the first page of the question. Many candidates didn't mention the evidence from the bromine test.

If candidates pieced together information to give a structure that is chemically feasible containing either a C=O or COOH group then they could achieve Level 2. Without a structure they were limited to Level 1.

The most common incorrect structures seen included butanoic acid, 2-hydroxypropenoic acid or structures with 2 × C=O and an alcohol OH.

Exemplar 3





no aldehyde ketone

Emperical formulae:

	C	H	O
mass	40.91	4.54	54.55
Mr	12	1	16
moles	3.41	4.54	3.41
ratio	1	1.3	1

CHO = 29 = 44 = C_2H_4O

Molecular Formulae

m/z = 88 (molecular mass) = 88

$C_4H_8O_2$

mass spectroscopy = (fragment ions)

m/z 15 = CH_3^+

m/z 43 = $C_3H_7^+$

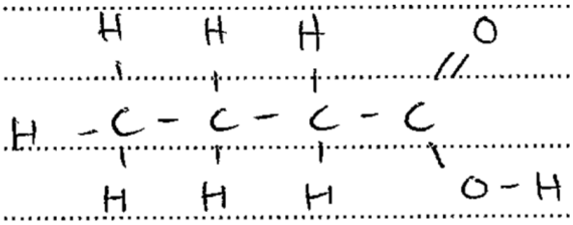
m/z 45 = $CH_3CH_2O^+$

IR spectroscopy

Extra answer space if required

shows a broad peak of key absobtion at 2500 – 3300 suggesting O–H of carboxylic acid
shows an absorbtion at 1630 – 1820 for C=O of carboxylic acid, alhedyde etc.
C–O (1000 - 1300) carboxylic acid.

Q6) Compound X



butanoic acid

This response achieved Level 2 - 4 marks. Despite a correct calculation for empirical formula, they rounded incorrectly to CHO. They then state that molecular formula is $C_4H_8O_2$ which matches the M_r value determined from the mass spectrum but not their empirical formula. They demonstrated good analysis of the IR spectrum and have even looked at potential fragments from the mass spectrum. The response meets the Level 2 descriptor as they have a feasible structure with a COOH group and have some analysis of all three scientific points. The communication is good with a clearly laid out calculation and bonds identified from IR and MS fragments have a positive charge.

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