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AS LEVEL

Examiners' report

CHEMISTRY A

H032

For first teaching in 2015

H032/02 Summer 2022 series

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 are 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.

Advance Information for Summer 2022 assessments

To support student revision, advance information was published about the focus of exams for Summer 2022 assessments. Advance information was available for most GCSE, AS and A Level subjects, Core Maths, FSMQ, and Cambridge Nationals Information Technologies. You can find more information on our website.

Paper 2 series overview

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

This synoptic depth in chemistry paper links together content from all 4 modules and is worth 70 marks. Candidates answer 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 did the following:	Candidates who did less well on this paper generally did the following:
• performed calculations showing detailed working for each step, with no intermediate rounding of values and gave answers to appropriate number of significant figures: Question 1 (b) (ii) calculation of mass of citric acid from titration, Question 4 (a) (ii) calculation of K_c, Question 4 (b) enthalpy change from bond enthalpy data, Question 5 (b) atom economy and Question 5 (c) (i) mass required using % yield • determined rate from gradient of tangent • produced clear and concise responses for Level of Response, e.g. Questions 4 (a) (i) and 6 • applied practical skills to a range of situations, e.g. Question 1 (c) modifying a titration method, Question 3 (b) (i) observations and Question 5 (c) (ii) purification of organic liquid • gave radical substitution mechanism propagation steps for Question 5 (a) (ii) and considered why it results in a poor yield for Question 5 (a) (iii).	• made basic errors in writing formulae. (e.g. br rather than Br or SrOH rather than $Sr(OH)_2$) • working, if given, for calculations was unclear or used rounded values, which made it difficult to follow logic • produced responses that lacked depth. For example, Question 3 (a) (i) "particles have reacted and so fewer collisions" shows some understanding but not enough to gain marks • did not plan responses for longer answer questions (such as Questions 2 (a) (iii) and 4 (a) (i)) resulting in repetition or even contradiction in answers • made errors in drawing organic structures such as C having 5 bonds or missing hydrogens • unable to fully interpret spectra in Question 6.

Question 1 (a) (i)

1 Lime is a citrus fruit containing citric acid, $C_6H_8O_7$.

(a) Citric acid is a weak organic acid.

(i) What is meant by an **acid**?

..... **[1]**

Most candidates scored this mark. Some candidates referred to acids having or containing H^+ ions rather than indicating that H^+ ions are donated or released. A small number of candidates gave simplistic responses in terms of pH only.

Question 1 (a) (ii)

(ii) What is meant by an acid that is **weak**?

.....

..... **[1]**

Again, this was well answered by most candidates. A few candidates gave responses in terms of pH or indicated that there were more OH^- ions present.

Misconception

Some candidates described a solution with a low concentration of H^+ ions, demonstrating a confusion between concepts of weak and dilute in reference to acids. Visual picture cards can be very helpful in assessing understanding of these concepts. This topic is covered at GCSE and resources can be found here: http://www.ocr.org.uk/Images/363946-ph-scale-lesson-element.doc

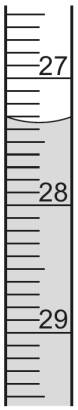
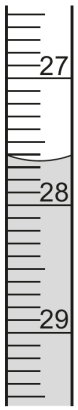
Question 1 (b) (i)

(b) A student carries out a titration to determine the mass of citric acid in a lime.
The student follows the method below:

- Squeeze the juice out of two limes.
- Transfer the juice into a 250.0 cm^3 volumetric flask and make up to the mark with distilled water.
- Pipette 25.0 cm^3 of the diluted lime juice into a conical flask and add a few drops of phenolphthalein indicator.
- Titrate this solution with 0.800 $mol\,dm^{-3}$ NaOH(aq).

The student carries out a trial titration, followed by three further titrations.

The diagram shows the burette readings for the three further titrations.
Each reading is measured to the nearest 0.05 cm^3.

Titration 1		Titration 2		Titration 3	
Initial reading	Final reading	Initial reading	Final reading	Initial reading	Final reading
					

(i) Record the student's burette readings in the table below.

Calculate the mean titre, to the nearest 0.05 cm^3, that the student should use to analyse the results.

	Titration 1	Titration 2	Titration 3
Final reading / cm^3			
Initial reading / cm^3			
Titre / cm^3			

mean titre ..... cm^3 **[4]**

Although most candidates gained some marks here, there were a significant number who did not gain all 4 marks. Some candidates need to practice reading burettes and recording their values – this can be checked during practical work. The most common errors included not recording values to 2 decimal places (especially if final number was 0), readings recorded the wrong way round in the table, and misreading 0.05 as 0.5. Most candidates were able to identify concordant results, but some still calculated the mean from all values. This led to an average that needed to be rounded to the nearest 0.05, as asked for in the question, resulting in them losing both the mean titre mark and mark for accuracy. Some had errors which lead to values which weren't concordant – this should be a flag to students that they have made a mistake.

Question 1 (b) (ii)

(ii) Citric acid, $C_6H_8O_7$, is neutralised by NaOH as shown in the equation below.

$C_6H_8O_7 + 3NaOH \rightarrow Na_3C_6H_5O_7 + 3H_2O$

Calculate the mass, in g, of citric acid in **one** lime.

Assume that citric acid (M_r = 192.0) is the only acid in lime juice.

mass of citric acid in **one** lime = ... g **[5]**

Most candidates managed to gain at least 1 mark for this question. The most common mark lost was for not multiplying by 10, having missed that only 25cm^3 of 250 cm^3 citric acid solution was used in the titration. Another mark that was often lost was for not dividing by 2 to find mass in 1 lime rather than the 2 used in experiment. Some candidates used 25cm^3 to calculate their moles of NaOH rather than the titre value from (i).

It is vital that candidates are given the opportunity to practice more complex multi-step calculations of this type, with modelling given for lower-attaining candidates. Identifying which information goes with each reactant is vital. All steps in the calculation should be separate and clearly labelled to help avoid confusion. Encourage candidates to keep full values in their calculators to avoid intermediate step rounding. When writing down intermediate values, ideally write down the full calculator value or where this is not possible the value must be given to at least 3 significant figures (correctly rounded). It is helpful to the examiner to know if calculator values are used and this could be indicated by using truncated answers followed by … , for example 0.00729… for n(A).

Exemplar 1

(ii) Citric acid, $C_6H_8O_7$, is neutralised by NaOH as shown in the equation below.

$$C_6H_8O_7 + 3NaOH \rightarrow Na_3C_6H_5O_7 + 3H_2O$$

(27.35 cm³ NaOH; 0.80 mol dm⁻³)

Calculate the mass, in g, of citric acid in **one** lime.

Assume that citric acid (M_r = 192.0) is the only acid in lime juice.

mol. NaOH = $\frac{0.800 \times 27.35}{1000}$

= 0.02188 mol.

$C_6H_8O_7$: NaOH

1 : 3 ratio ∴ mol. acid

$\frac{0.02188}{3}$ = 7.293×10^{-3} mol.

7.293×10^{-3} mol. in 25cm³

∴ mol. in 250cm³ = $7.293 \times 10^{-3} \times 10$

= 0.07293 mol

M_r = 192.0

m = mol. × Mr

= 0.07293 × 192

= 14.0032

2 lime = 14.0032

1 lime = $\frac{14.0032}{2}$

= 7.0016

= 7.00 grams (3.S.f)

mass of citric acid in **one** lime = 7.00 g **[5]**

The exemplar shows a response where each step of the calculation is shown clearly. The candidate has also used pictures to aid them, recognising that the NaOH is in the burette and lime juice in the conical flask. All values are identified and there is no intermediate rounding. All 5 marks are given here.

Question 1 (c)

(c) The student's teacher thinks that there is an unnecessary safety risk in using a sodium hydroxide concentration of 0.800 mol dm^{-3} for the titration.

Suggest how the student could modify the method using a sodium hydroxide concentration of 0.200 mol dm^{-3} instead of 0.800 mol dm^{-3}.

The student should aim to have the same titre as in the original method.

Justify your answer.

.....

.....

.....

..... **[2]**

A very challenging question with very few candidates scoring both marks. The response needed a clear indication of how the method would be altered and a justification for why this would work. Lots of candidates recognised the need to dilute the citric acid to obtain the correct titre but were not able to give a method of how to do this or any indication of quantities needed. Some candidates said to use a larger volume of NaOH – not recognising that this would be the titre value, e.g. "in order to keep the same titre but lower concentration of NaOH the student should titre more NaOH". Some gave the method of how to dilute the NaOH or even just said to add water. A few suggested using a higher concentration of lime juice.

Candidates need to be given opportunities to plan practical work to fully appreciate the impact that any changes will have (specification 1.1.1).

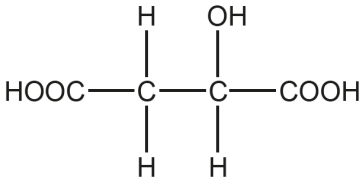
OCR support

Further information about practical skills assessed on written exams can be found in section 3 of the practical skills handbook - https://www.ocr.org.uk/Images/208932-chemistry-practical-skills-handbook.pdf. If using our suggested practicals, then encourage candidates to answer the extension opportunity questions to help develop a deeper understanding in preparation for written assessments.

Question 1 (d)

(d) Other fruits contain different organic acids.

Apple juice contains malic acid which has the following structure.



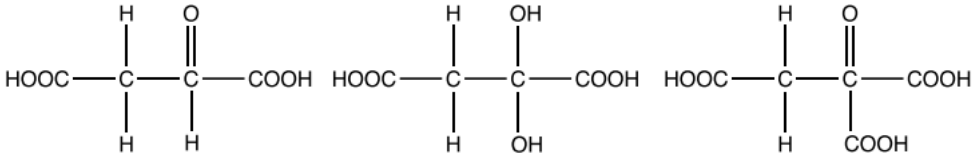
Malic acid can be oxidised by heating with acidified potassium dichromate(VI).

Write a balanced equation for the reaction, showing the structure of the organic product.

Use [O] to represent the oxidising agent.

[2]

Despite oxidation of alcohols being a topic that has been assessed many times, candidates found this question very tricky with a majority failing to score any marks. Candidates needed to correctly identify this as a secondary alcohol which, when oxidised, will become a ketone. A wide range of errors were seen, including the following:



Other errors included forming C=C or removing COOH. Approximately half of those that got the correct structure were also able to balance the equation gaining both marks. Some forgot that another product was formed or gave H_2 instead.

Candidates were given the structure and told to use [O] to represent the oxidising agent. However, some attempted to use structural or molecular formula and/or adding in dichromate to their answers.

Question 2 (a) (i)

2 This question is about some Group 2 elements and their compounds.

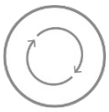
(a) Strontium and calcium both react with water.

(i) Write an equation for the reaction of strontium with water.

..... **[1]**

Around half of all candidates did not score this mark. The most common error was giving SrO as the product rather than the hydroxide. Other errors included incorrect balancing (missing 2 on H_2O, SrOH as the formula of the hydroxide and no hydrogen formed (often giving H_2O instead)).

Assessment for learning



Regular practice writing formulae and balancing chemical equations will help to consolidate these concepts, avoiding basic errors such as giving formula of group 2 hydroxide as SrOH.

Question 2 (a) (ii)

(ii) Using oxidation numbers, explain why the reaction of strontium with water is a redox reaction.

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.....

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..... **[2]**

Most candidates managed to score at least 1 mark for this question. The most common reason for losing a mark, despite demonstrating a good understanding of redox, was stating that H changed from +2 to 0 (need to give oxidation number per atom). Other errors seen included only giving change for Sr, descriptions in terms of electrons rather than oxidation numbers, Sr change from 0 to +1 (linked to SrOH), oxygen being reduced rather than H and mixing up oxidation/reduction or not specifying.

Question 2 (a) (iii)

(iii) Explain why calcium reacts more slowly with water than strontium does.

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..... **[3]**

Most candidates gained some marks here although a significant proportion were unable to score all 3 marks covering atomic radius, shielding, nuclear attraction/IE. The mark most often missed was for shielding. Some candidates did not answer the question asked and gave the trend down the group so could not be given marks unless they made it clear Sr is below Ca in the group. Care must be taken to answer question asked not similar questions they have seen before. The best responses were those with direct comparative statements, e.g. "Ca has a smaller atomic radius than Sr". It is worth noting that harder/easier to lose electrons didn't gain marks, but was seen fairly frequently, as response needs to be in terms of energy required or linked to nuclear attraction.

Question 2 (b) (i)

(b) A student adds barium oxide, BaO, to water.

A reaction takes place forming a colourless solution.

(i) Predict the approximate pH of the colourless solution.

pH = ... **[1]**

Most candidates gained this mark. The most common incorrect response was pH 7 with a few giving a pH value of less than 7.

Question 2 (b) (ii)

(ii) A student adds a few drops of dilute sulfuric acid to the colourless solution.

Describe what the student would observe, and give the formula of the barium compound produced.

Observation .....

Formula of barium compound .....

[2]

Most candidates were able to give the formula of the barium compound as $BaSO_4$. However, they did not recognise that this would cause a white ppt to be seen, presumably as not in the context of qualitative ions testing. Many candidates said they would see bubbling/fizzing. Some gave a colour change as they were possibly considering what would be seen if an indicator is present. Others mentioned a precipitate but with no colour given.

Some candidates gave the incorrect formula, such as Ba_2SO_4 or $Ba(SO_4)_2$, again showing the importance of practising writing formulae. In addition, some candidates wrote out the whole equation for the reaction.

OCR support

We have produced a topic support pack to assist with learning about the reaction of group 2 elements and their compounds: http://www.ocr.org.uk/Images/364103-chemistry-of-group-2.docx

Question 3 (a) (i)

3 A student investigates some reactions of zinc compounds and zinc metal.

(a) The student investigates the rate of reaction between zinc carbonate, $ZnCO_3(s)$, and dilute hydrochloric acid, $HCl(aq)$.

$ZnCO_3(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + CO_2(g) + H_2O(l)$

The student follows the method outlined below:

- Add 50 cm^3 of dilute $HCl(aq)$ into a conical flask at 20 °C.
- Place the flask on a top-pan balance.
- Add an excess of $ZnCO_3(s)$ to the flask.
- Record the mass of the flask and contents on the top-pan balance every 30 seconds.

The student plots a graph of mass against time, shown in **Fig. 3.1** below.

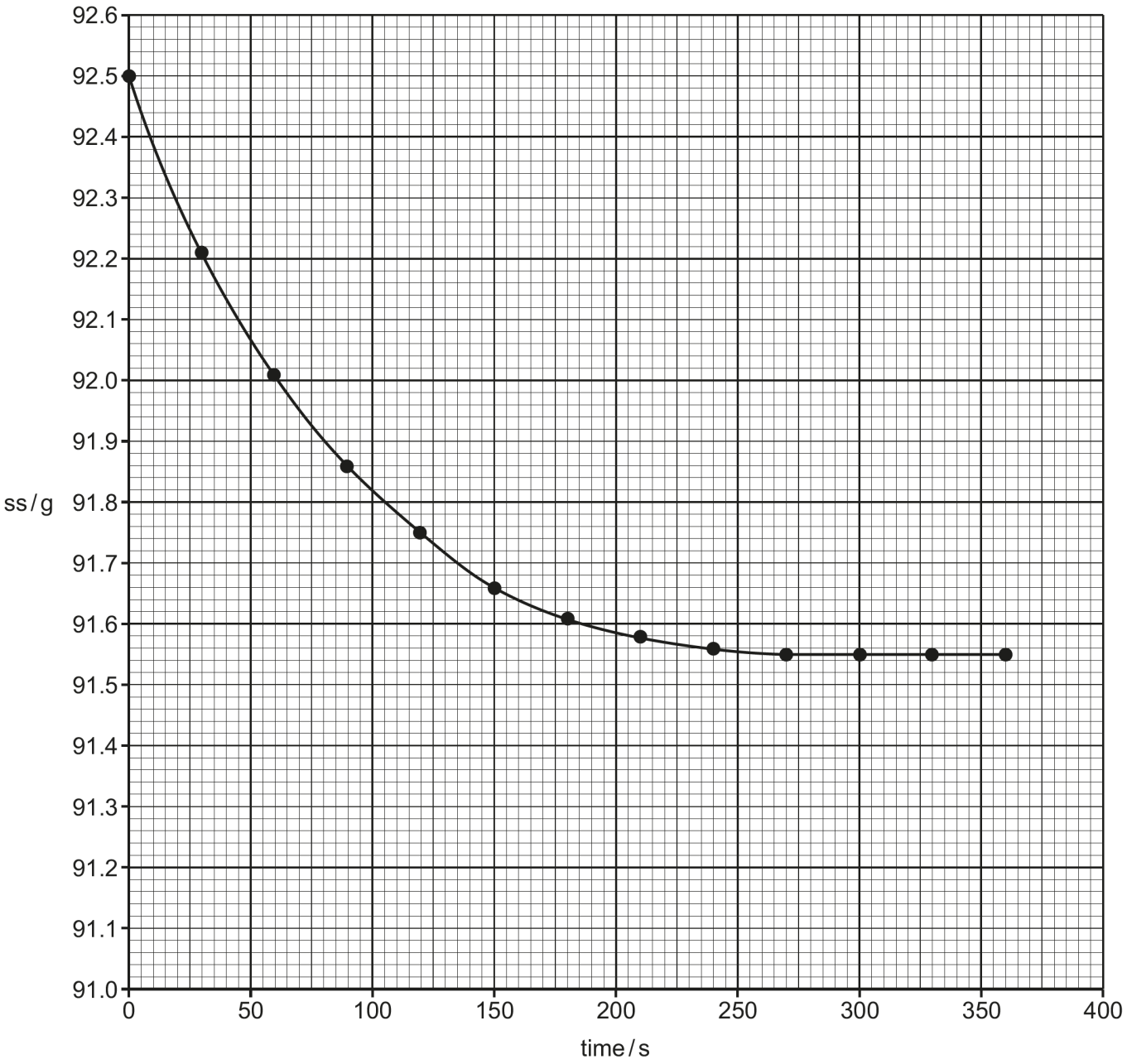

Fig. 3.1

(i) The graph shows that the reaction gets slower over time, and eventually stops.

Explain why, in terms of collision theory.

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.....

..... **[3]**

Only a small number of candidates managed to score all 3 marks for this question. Lots began their response describing why the rate is high at the start. This often filled the space available with marks being gained only in the last sentence. Very few gave descriptions with this specific reaction in mind, such as recognising that the HCl was the limiting reagent so gets used up, leaving some $MgCO_3$ remaining. Common errors included referring to "fewer collisions" but without any indication of time, or "less reactant" without considering the volume of the reaction.

Misconception

Many candidates described a decrease in energy in the reaction or gave responses related to activation energy. For example: "lose energy and start to collide less often", "reactants have less kinetic energy" and "only a certain number of particles which have enough energy above the activation energy…over time energy will decrease and less particles have enough energy".

We have produced a delivery guide on rates with some useful resources to help consolidate ideas and avoid misconceptions such as these: https://www.ocr.org.uk/Images/231742-rates-delivery-guide.pdf

Question 3 (a) (ii)

(ii) Using the graph in **Fig. 3.1**, find the rate of reaction, in $g\,s^{-1}$, at 50 seconds.

Show your working on the graph and in the space below.

rate of reaction = ... $g\,s^{-1}$ **[2]**

Most candidates recognised that they needed to draw a tangent. Candidates need to be instructed to draw their line clearly and make sure that it covers several large squares on the graph – preferably extending to the axes. The range given for the calculated rate from the gradient of the tangent was generous, however some did not realise that the y-axis started at 91.0 so incorrectly calculated their gradient. Some candidates used interpolation so gained no marks.

OCR support

M3 section of the Maths Skills handbook contains useful information on use of graphs in chemistry, including M3.5 on drawing and using the slope of the tangent to a curve as a measure of a rate of change: https://www.ocr.org.uk/Images/295468-chemistry-mathematical-skills-handbook.pdf

Question 3 (a) (iii)

(iii) The student repeats the experiment but heats 50 cm^3 of dilute hydrochloric acid up to 40 °C before adding the $ZnCO_3(s)$.

On **Fig. 3.1**, sketch the curve the student would obtain. **[2]**

About a third of candidates didn't score any marks here. Some did not follow the instructions to add their curve to the previous graph. The sketches produced in the blank space then usually lacked any scales on the axes so could not be given marks. Lines added were often inaccurately drawn with lines often extending below 91.55g before returning to this mass at the end. It was often difficult to interpret if a graph levelled off before the original with lots tracking the same curve with a very slightly steeper slope. Some gave a slower rate but did manage to gain marks for finishing at 91.55g.

Question 3 (b) (i)

(b) The student investigates the reaction between zinc and dilute sulfuric acid.

$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$ $\Delta H = -140\,kJ\,mol^{-1}$

Copper(II) sulfate is a catalyst for this reaction.

- The student adds a piece of zinc to each of two test tubes.
- The student adds a few drops of aqueous copper(II) sulfate to one of the test tubes, forming a pale blue solution.
- The student adds an excess of dilute sulfuric acid to each test tube.

(i) Describe **two** differences the student would observe between the test tubes.

1 .....

.....

2 .....

.....

[2]

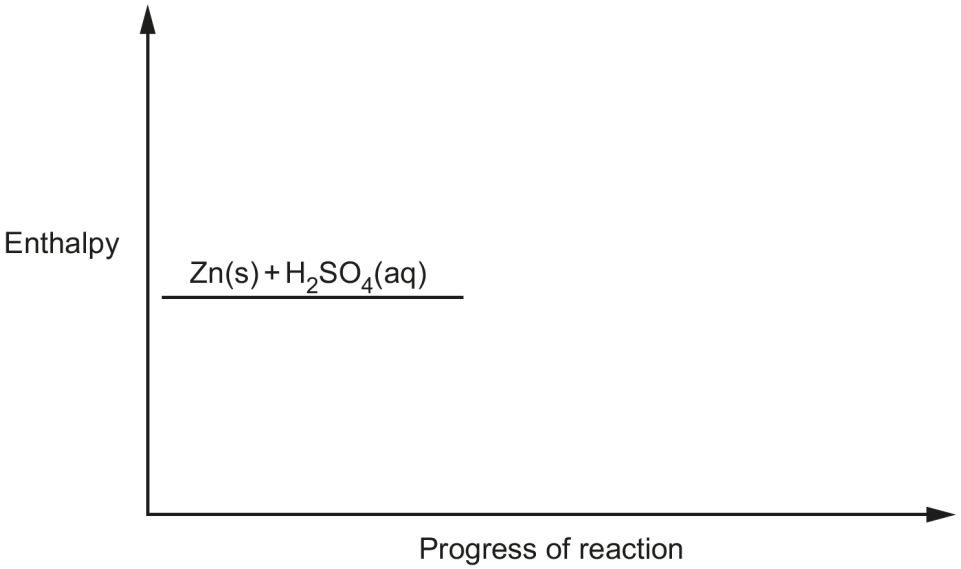
Candidates found this question very challenging. Most recognised that the addition of the catalyst would speed up the reaction but could not translate this into observations for this specific practical. For example, "reacts faster", "releases more hydrogen" or "stops reacting quicker". Giving candidates the opportunity to observe a range of both familiar and unfamiliar reactions, noting qualitative observations can help to improve their skills here. Many just noted that one tube would be blue and the other colourless rather than considering the reaction taking place. Some indicated that only 1 tube would react and the other would not. A few candidates recognised that a competing displacement reaction would take place between Zn and $CuSO_4$ so were given marks for this.

Question 3 (b) (ii)

(ii) Using the axes below, sketch an enthalpy profile diagram for the reaction with and without the catalyst.

On your diagram, include the following labels:

- ΔH, the enthalpy change
- E_a, the activation energy **without** a catalyst
- E_c, the activation energy **with** a catalyst.



[3]

Less than half of all candidates managed to gain all 3 marks giving the correct enthalpy profile diagram. Many demonstrated a lack of understanding about what an enthalpy profile diagram shows as seen by labelling of curves for E_a/E_c rather than the enthalpy change or arrows for ΔH extending to the x-axis.

Other errors also seen included, -ΔH, double headed ΔH arrow, activation energy lines starting at products, endothermic profiles, E_a and E_c the wrong way round and missing or incorrect labels.

Some candidates found it tricky to give activation lines for both catalysed and uncatalysed reactions on the same diagram, these often overlapped or did not extend to the top of the energy barrier.

Question 4 (a) (i)*

4 This question is about the manufacture of hydrogen, H_2.

(a) In industry, hydrogen is manufactured from methane, as shown in **Equilibrium 4.1**.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206\,kJ\,mol^{-1} \qquad \textbf{Equilibrium 4.1}$$

The industrial process is carried out at 15 atmospheres pressure and at a temperature of 800 °C using an excess of steam. A nickel catalyst is used.

(i)* Explain why these conditions are used industrially. **[6]**

Only a small number of candidates were given all 6 marks for their response. Many responses made little or no reference to equilibrium, considering only the rate of reaction. A clear understanding of the difference between rate and equilibrium was essential to scoring highly on this question.

Excellent descriptions were given regarding the role of the catalyst on the rate of reaction, possibly influenced by the previous question. Some gave detailed responses in terms of the impact of both pressure and temperature on the equilibrium position but then did not give the changes made by industry such as reducing temperature due to energy demand or increasing pressure to increase rate.

Some candidates indicated that 15atm was a low pressure including reference to it being "lower than normal atmospheric pressure" which suggested that they did not understand either the measurement in atmospheres and/or scale of pressure. A common incorrect response was to suggest that a higher pressure gives increased yield as more moles on right/products.

Some stated that the reaction was exothermic, clearly confusing the enthalpy change signs. Some also described the "endothermic side" demonstrating a lack of understanding that enthalpy changes require a difference between products and reactants. Many did not correctly consider the use of excess of steam to increase concentration of reactant and shift equilibrium to products/right but talked in terms of limiting reagents, e.g. "This is used so all of the methane is reacted" or increased collisions.

Many were prone generalisations, e.g. "These conditions are used industrially to achieve the most hydrogen efficiently with the least amount of undesired (waste) products". Candidates need to be encouraged to plan their answers, even using subheadings to organise information and follow the key approach: point, evidence, explain. Candidates should also be encouraged to re-read their answers to check communication is clear and accurate without any contradictory statements.

Many included irrelevant or inaccurate information such as describing the toxicity of carbon monoxide, so reducing yield of that being beneficial, or "using a catalyst improves atom economy".

OCR support

This question was good at highlighting candidates understanding of the impact of different conditions on equilibrium reactions**.** We have produced a delivery guide to help with teaching about equilibrium: https://www.ocr.org.uk/Images/261544-equilibrium.pdf

Exemplar 2

A catalyst is used to lower energy costs because reactions with catalysts can be conducted at lower temperatures. Less pollutants could be produced as well as a result of using a catalyst.

The overall reaction is endothermic hence higher temperatures would produce a ~~high~~ higher maximum yield of hydrogen as the equilibrium can then shift to favour the forward reaction. However, lower temperatures should be used industrially as maintaining high temperatures are costly and if the temperature should not be too low as to avoid having a very low rate of reaction. Lower pressure should be used to to maximise the yield of hydrogen as there are more number of moles on the product side of the equation. Nevertheless, a higher pressure should be used to increase the rate of reaction and not too high as to avoid becoming to costly and creating an unsafe workplace environment.

Additional answer space if required.

Therefore temperature and pressure must reach a compromise in order to maximise the yield of hydrogen while a catalyst is used to reduce costs and pollutants produced.

This exemplar shows a candidate who achieved L3 with all 6 marks given. They have considered both the effect of temperature and pressure on equilibrium and potential compromises used industrially. They have also considered the impact of using a catalyst. Their response is logically structured and has a clear line of reasoning.

Question 4 (a) (ii)

(ii) A chemist mixes $CH_4(g)$ and $H_2O(g)$ and leaves the mixture to reach equilibrium.

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H = +206\,kJ\,mol^{-1}$ **Equilibrium 4.1**

The equilibrium mixture contains the following concentrations.

Substance	Concentration / mol dm^{-3}
$CH_4(g)$	0.111
$H_2O(g)$	0.682
$CO(g)$	0.510
$H_2(g)$	1.530

Write an expression for the equilibrium constant, K_c, for **Equilibrium 4.1** and calculate the numerical value of K_c.

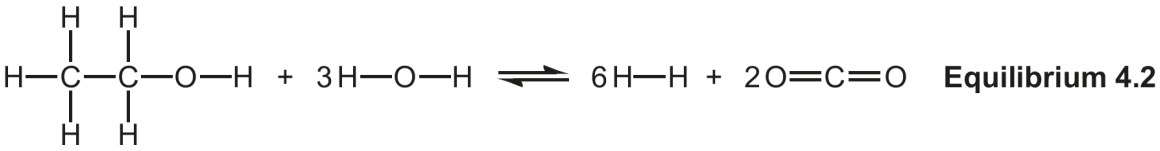
Give your answer to **3** significant figures.

K_c = ... mol^2 dm^{-6} **[2]**

This question was well answered with most candidates scoring both marks. Common errors seen included: inverse K_c expression, final answer not to 3 significant figures, adding rather than multiplying concentrations, calculator error ($[H_2]^2$ instead of $[H_2]^3$) or transcription errors (e.g. using 0.11 rather than 0.111).

Question 4 (b)

(b) Hydrogen can also be manufactured by reacting ethanol with steam, as shown in **Equilibrium 4.2**.



Equilibrium 4.2

Average bond enthalpies are shown in the table below.

Bond	C–H	C–C	C–O	O–H	H–H	C=O
Average bond enthalpy / kJ mol^{-1}	+415	+347	+358	+464	+435	+805

Calculate ΔH, in kJ mol^{-1}, for the forward reaction in **Equilibrium 4.2**.

ΔH = ... kJ mol^{-1} **[3]**

Despite the structures being drawn out with displayed formula, a significant number of candidates did not correctly count all the bonds. Common errors included missing C-C from ethanol or O-H bonds in water. Most candidates set out their working clearly, so it was easy to identify any errors in calculation steps and award ECF appropriately.

Some also had the calculation the wrong way round (made – broken) missing the essential idea that energy is needed to break bonds and released to make bonds, as well as link to endothermic changes being positive and exothermic changes being negative.

Assessment for learning

It is important to evaluate candidates understanding of enthalpy changes and build on prior knowledge from KS4. We have produced a transition guide for KS4 to KS5 on enthalpy: https://www.ocr.org.uk/Images/361305-enthalpy-changes-ks4-ks5.pdf. This includes a checkpoint task which is very useful for checking understanding of this topic, including the difference between endothermic and exothermic reaction, drawing profile diagrams, and calculating enthalpy changes from bond enthalpies.

Question 4 (c)

(c) CO_2 and H_2O molecules have different shapes.

State the bond angles in CO_2 and H_2O molecules and explain, in terms of electron pair repulsion, why the bond angles are different.

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.....

..... **[4]**

Candidates continue to find understanding of shapes of molecules a very challenging topic to grasp. Very few were able to gain all 4 marks, with most gaining little or no marks. The most common mark given was for lone pairs repelling more than bonding pairs. Many only stated a lone pair decreases bond angle by 2.5° but did not explain that this was caused by increased repulsion.

The most common error was stating that CO_2 has 2 bonding pairs – it doesn't, as it has 4 bonding pairs which are arranged as 2 double bonds. They could also state that it has 2 bonding regions. Lots stated CO_2 has no lone pairs and H_2O has 2 lone pairs but without reference to bonding pairs of electrons so lost out on 2 marks. In fact, it was fairly common that candidates indicated that only lone pairs cause repulsion, e.g. stating no repulsion in CO_2 "no lone pairs so there will be no repulsion". Though these two molecules are ones candidates will have prior knowledge of before A Level, a range of bond angles were suggested.

The most successful candidates drew out dot cross diagrams and/or displayed formula to be able to count pairs of electrons around the central atom.

Question 5 (a) (i)

5 2-Bromobutane, $CH_3CH_2CHBrCH_3$, can be prepared by three different methods.

The relative molecular mass, M_r, of 2-bromobutane is 136.9.

(a) 2-Bromobutane can be prepared by reacting butane with bromine (**Reaction 5.1**).

$CH_3CH_2CH_2CH_3 + Br_2 \longrightarrow CH_3CH_2CHBrCH_3 + HBr$ **Reaction 5.1**

The reaction is initiated by the formation of bromine radicals from bromine.

(i) State the conditions for the formation of bromine radicals from bromine.

..... **[1]**

Most candidates gave the correct response to this question. Incorrect responses included use of high temperatures and/or catalyst.

Question 5 (a) (ii)

(ii) Write **two** equations for the propagation steps in the mechanism for **Reaction 5.1**.

Use structural formulae for organic species and dots (•) for unpaired electrons on radicals.

$CH_3CH_2CH_2CH_3$ + ... → ..... + ...

..... + ... → ..... + ...

[2]

Candidates always find radical mechanisms tricky and this one had the added complexity of forming 2-bromo isomer. However, a majority of students still gained marks. Many candidates formed the incorrect radical removing H from C-1 i.e. $CH_3CH_2CH_2CH_2^{\bullet}$ therefore scoring only 1 mark. Some responses were a little messy making it very easy to miss off a dot or H or Br. Many candidates reacted with $Br^{\bullet}$ in the first step but added Br to the radical intermediate (as well as forming HBr). Candidates should always check equations so that they balance in terms of atoms.

Question 5 (a) (iii)

(iii) The yield of $CH_3CH_2CHBrCH_3$ is only 30%.

Suggest **two** reasons why the yield of $CH_3CH_2CHBrCH_3$ is so low.

1 .....

.....

2 .....

.....

[2]

Candidates found this question very challenging and few scored both marks. Many responses considered only the formation of HBr (other product) and/or general statements about other products with no indication of how they were formed. Some described losses due to the purification method or incomplete reaction (due to conditions such as T and P) or low atom economy. Some referred to the stability of the radical intermediate, showing possible confusion with electrophilic addition.

Candidates who understood the mechanism were more confident in answering this question, at least recognising that further substitution was possible.

Question 5 (b)

(b) 2-Bromobutane can also be prepared by reacting but-2-ene, $CH_3CH=CHCH_3$, with hydrogen bromide, HBr (**Reaction 5.2**).

$CH_3CH=CHCH_3 + HBr \longrightarrow CH_3CH_2CHBrCH_3$ **Reaction 5.2**

Explain, in terms of atom economy, why **Reaction 5.2** is more sustainable than **Reaction 5.1**.

Include calculations to justify your answer.

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..... **[2]**

Despite the question asking for calculations to be included, many candidates didn't include them and so lost both marks. Some gained one mark as recognised that 5.1 has 100% atom economy but either didn't or incorrectly calculated for 5.2 (30% was seen frequently). Care needs to be taken with rounding of final values.

Question 5 (c) (i)

(c) 2-Bromobutane can also be prepared by reacting butan-2-ol, $CH_3CH_2CHOHCH_3$, with sodium bromide and sulfuric acid (**Reaction 5.3**).

$CH_3CH_2CHOHCH_3 + H^+ + Br^- \longrightarrow CH_3CH_2CHBrCH_3 + H_2O$ **Reaction 5.3**

2-Bromobutane is a liquid with a boiling point of 91 °C and does not mix with water.

(i) A student plans to prepare 10.0 g of 2-bromobutane using **Reaction 5.3**.

The percentage yield is 67.0%.

Calculate the mass of $CH_3CH_2CHOHCH_3$ needed for this preparation.

Give your answer to **3** significant figures.

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

The most common errors were omitting the yield or inverting the yield, as given on mark scheme, resulting in 2 marks. Clear working was vital here to help marks to be given even if the final answer was incorrect. Many candidates did not gain the final mark due to incorrect significant figures. As with other multi-step calculations, rounding of intermediate values could also cause marks to be lost.

Question 5 (c) (ii)

(ii) The student mixes butan-2-ol, sodium bromide and sulfuric acid in a pear-shaped flask, and refluxes the mixture.

After 1 hour, the mixture in the flask has separated into two layers: an aqueous layer and an organic layer.

Describe the procedures the student would need to carry out to obtain a pure, dry sample of 2-bromobutane from this mixture.

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..... **[3]**

This question was not answered well with over half the candidates failing to score any marks. While some candidates seemed familiar with the techniques required, describing the process to separate the layers, they often struggled to name the separating funnel. Common approaches were to attempt to 'filter' the layers or to use heat (via evaporation or distillation) to drive off the water. Some attempted to use Na_2CO_3 or NaOH to dry the organic layer – perhaps confusing neutralisation of any remaining acid. Although distillation appeared frequently many did not give the temperature so did not gain marks. The order of the procedure was also not always clear with distillation before using a drying agent. Some described attempts to crystallise the organic layer. The range of answers suggests students may need more practical experience with separating organic liquids.

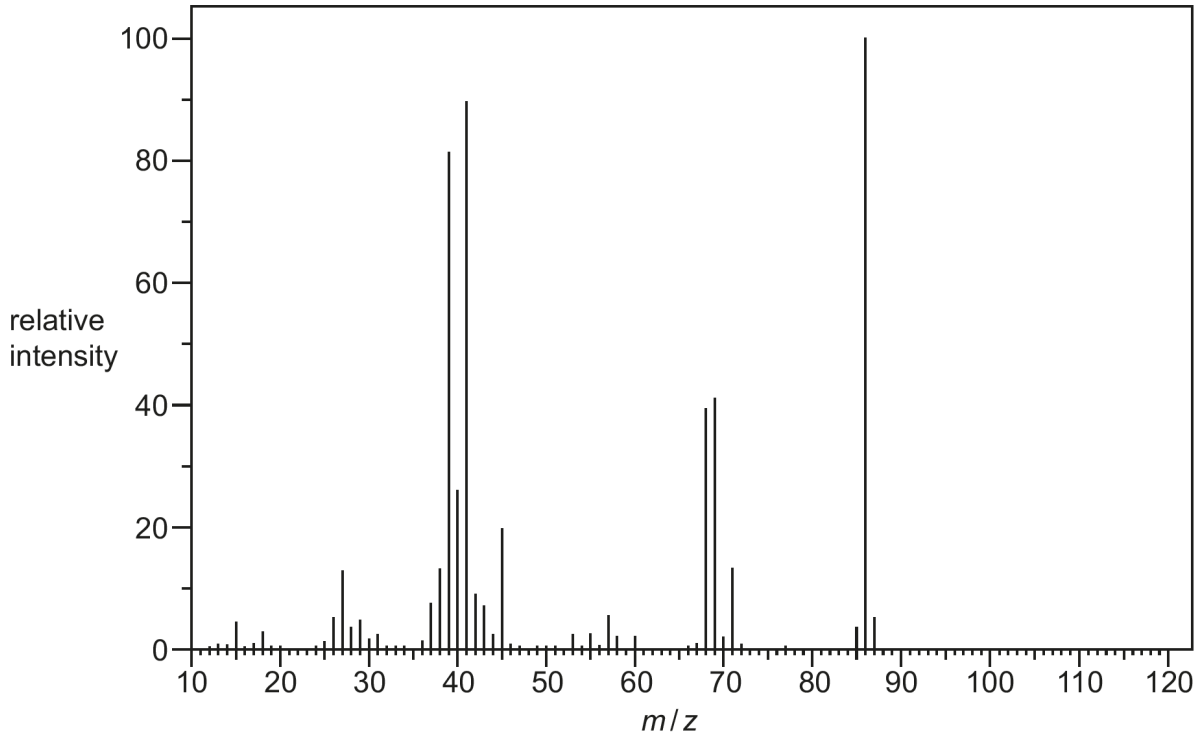
Question 6*

6* The organic compound **A** is unsaturated and is a *trans* stereoisomer.

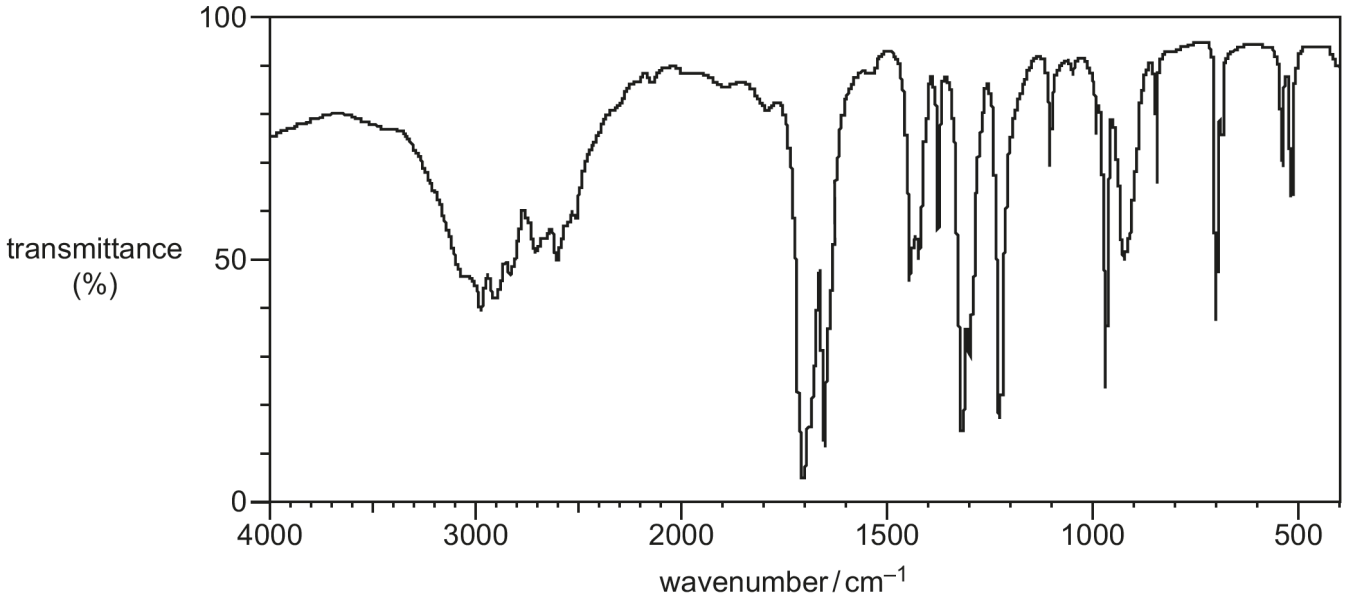
Compound **A** has the following composition by mass: C, 55.8%; H, 7.0%; O, 37.2%.

The mass spectrum and the infrared spectrum of compound **A** are shown below.

Mass spectrum



Infrared spectrum



Use the information to determine the structure of compound **A**.

Explain your reasoning and show your working. **[6]**

About a third of candidates were given Level 3 for this question. The key to answering this style of question well is to make sure all the information provided is used and to avoid contradictory statements, e.g. "structure contains carboxylic acid from IR" but then not present in final structure drawn, or a structure that doesn't match the molecular formula given. A significant number of candidates did not include C=C despite being told in the question that it was "unsaturated and is a trans stereoisomer", plus the C=C bond is shown in the IR and molecular formula needed unsaturation. The M+1 peak did confuse some candidates who then tried to add an extra H to final structure. It is very important that any structure given is feasible in terms of bonding; many candidates gave structures with C with 5 bonds (with both C=C and C=O attached), limiting them to achieving only L1. Some candidates gave a *cis* structure rather than trans.

Other candidates ignored the O-H peak (from the carboxylic acid) in the IR spectrum, attributing this to a C-H bond as it was not as smooth or as prominent as they may have seen in other spectra. Some listed the bonds observed in the IR without linking to their position – this can easily be done by annotating the spectra.

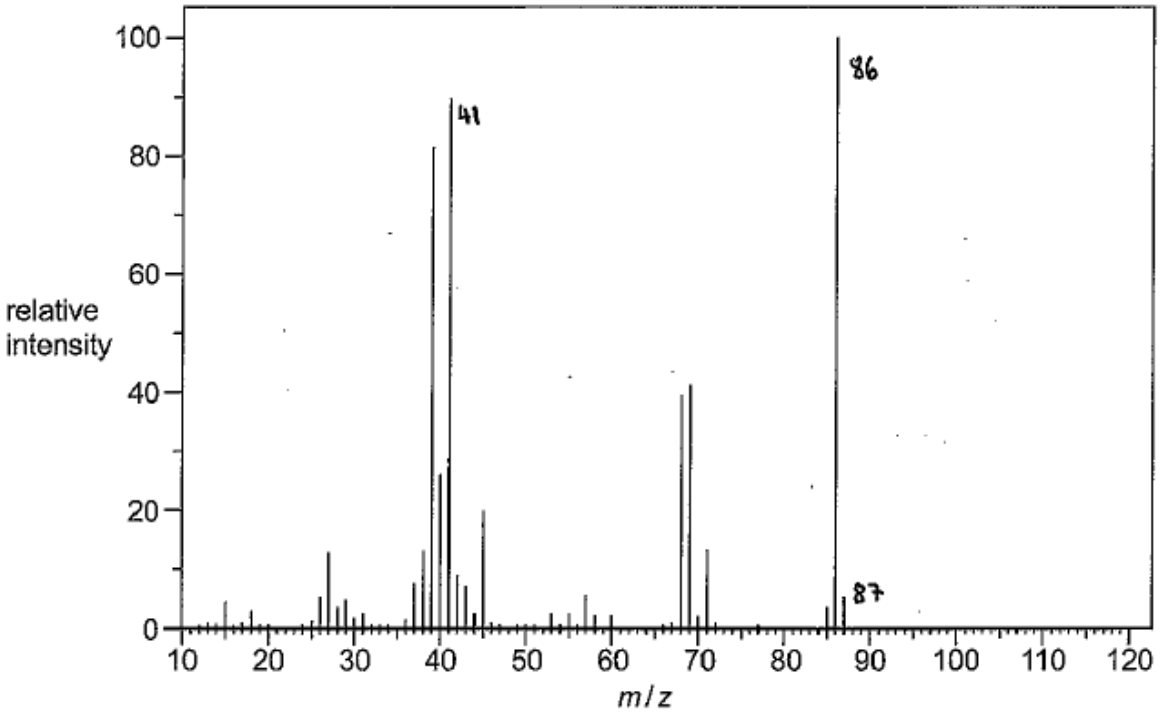
Many candidates had messy answers with lots of rough working which was then not crossed out – this made their answer very confusing. Note that no marks were given for just the empirical formula calculation and some attempted to produce a structure from the empirical formula without determining the M_r from the M^+ peak in mass spectrum.

OCR support

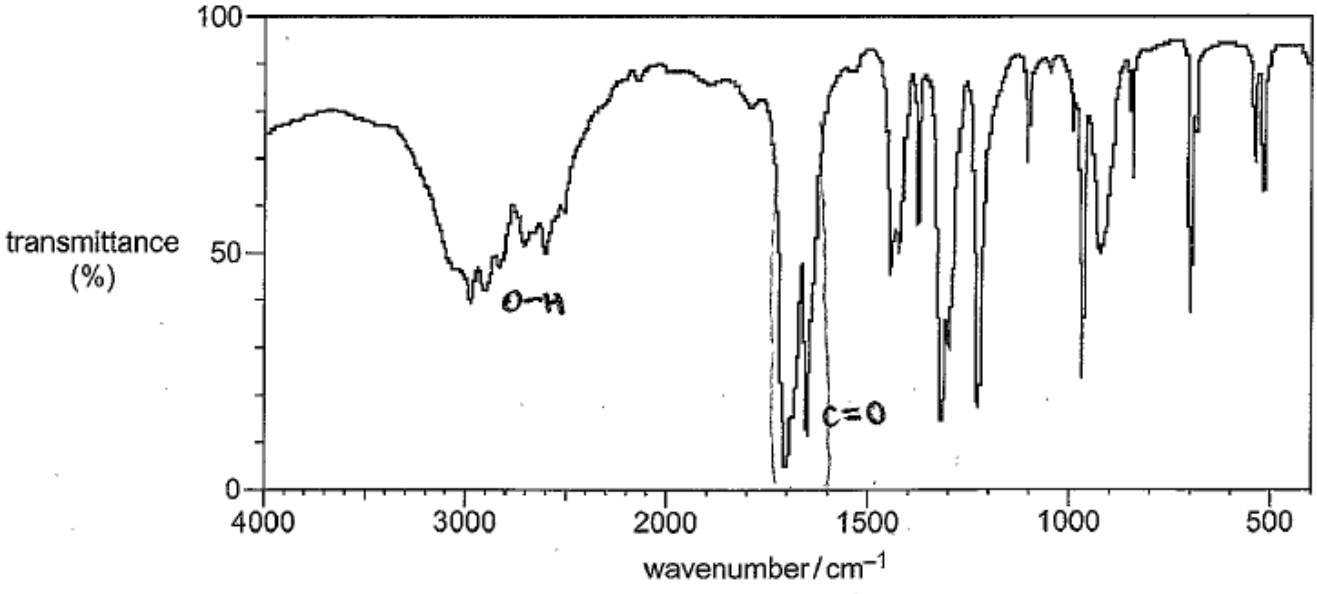
We have put together a range of online resources to support teaching of organic chemistry: https://www.ocr.org.uk/qualifications/as-a-level-gce-chemistry-a-h032-h432-from-2015/delivery-guide/module-cam04-module-4-core-organic-chemistry/delivery-guide-cadg012-organic-chemistry-as

Exemplar 3

Mass spectrum



Infrared spectrum

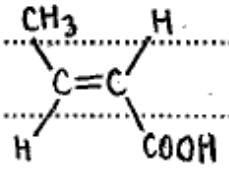


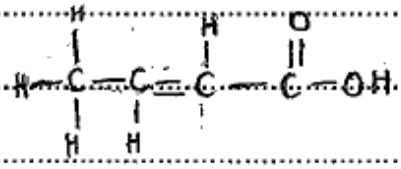
C	H	O
55.8	7.0	37.2
12	1	16
4.65	7.0	2.325
2.325	2.325	2.325
2	3	1

Emperical formula : C_2H_3O

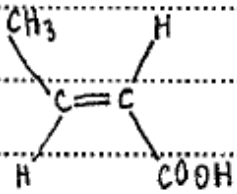
$\frac{86}{43} = 2$

Molecular formula : $C_4H_6O_2$





Compound A has an emperical formula of C_2H_3O but the relative molecular mass is 86 so the molecular formula is $C_4H_6O_2$. It is a trans stereoisomer so it has a c=c double bond. Compound A has an O-H peak between 2500-3300 and a c=o peak between 1630-1820. Therefore it is a carboxylic acid. The most stable ion of compound A is $C_3H_5^+$ which has a m/z of 41. Therefore compound A is :



This is an example of a good response which achieved L3 6 marks. Empirical and molecular formula are determined. Spectra have been annotated to aid their interpretation, but they have also included the key IR peaks as well as a MS fragment in their response. The correct structure for A is clearly drawn out. The response is clear and concise, with all information presented being relevant.

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