**Victorian Certificate of Education
Year**

Letter

STUDENT NUMBER

CHEMISTRY
Written examination

Day Date

Reading time: *. to *.** (15 minutes)**
Writing time: *. to *.** (2 hours 30 minutes)**

QUESTION AND ANSWER BOOK

Structure of book

Section	Number of questions	Number of questions to be answered	Number of marks
A	30	30	30
B	10	10	90
			Total 120

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

Materials supplied
- Question and answer book of 41 pages
- Data book
- Answer sheet for multiple-choice questions

Instructions
- Write your **student number** in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.
- You may keep the data book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

SECTION A – Multiple-choice questions

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1

Methane is a renewable energy source when it is extracted from

A.   natural gas.

B.   coal seam gas.

C.   under the sediment on ocean floors.

D.   decomposing plant and animal material.

Question 2

Which statement about petrodiesel and biodiesel is correct?

A.   Petrodiesel emits soot (small carbon particles) when burning is incomplete; biodiesel is pollutant-free.

B.   Petrodiesel is produced by distilling crude oil; biodiesel is produced by esterification of fatty acids.

C.   Petrodiesel consists of long-chain hydrocarbons; biodiesel contains benzene and its derivatives.

D.   Petrodiesel has greater viscosity and hence flows more slowly along fuel lines than biodiesel.

Question 3

Which one of the following substances present in food provides the lowest amount of energy per gram for the human body?

A.   tristearin (a triglyceride)

B.   alanine (an amino acid)

C.   cellulose (a polysaccharide)

D.   fructose (a monosaccharide)

Question 4

A substance that could be formed as a product when a polysaccharide undergoes enzyme-catalysed hydrolysis is

A. H_2O

B. CO_2

C. $C_6H_{12}O_6$

D. $CH_2OH.CHOH.CH_2OH$

Question 5

Insulin is a protein that controls a person's blood sugar level. A student tested four separate samples of pure insulin in the form of solid crystals.

In which one of the following tests would the primary structure of an insulin sample most likely be disrupted?

A.   Dissolve the crystals in hydrochloric acid, add the enzyme pepsin, then heat the solution.

B.   Dissolve the crystals in water, then blend the solution at a very high speed.

C.   Dissolve the crystals in sodium hydroxide solution, then heat the solution.

D.   Dissolve the crystals in water, then cool the solution in an ice bath.

Question 6

A group of students performed acid-base titrations to determine the mass of aspirin in some tablets. The manufacturer guaranteed that the true aspirin content was between 300 mg and 303 mg per tablet.

Which set of results for the mass of aspirin in the tablets tested would be described as of relatively high precision and relatively low accuracy?

A.   278 mg, 280 mg, 279 mg, 281 mg

B.   301 mg, 299 mg, 302 mg, 300 mg

C.   295 mg, 301 mg, 306 mg, 299 mg

D.   282 mg, 312 mg, 289 mg, 306 mg

Question 7

When hydrochloric acid, HCl, is added to aluminium sulfide, Al_2S_3, the highly toxic gas hydrogen sulfide, H_2S, is evolved. The equation for this reaction is

$$Al_2S_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2S(g)$$
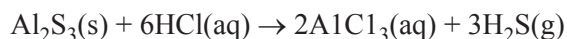
If excess hydrochloric acid is added to 0.200 mol of aluminium sulfide, then the volume of hydrogen sulfide produced at standard laboratory conditions (SLC) will be

A.   1.63 L

B.   4.90 L

C.   7.35 L

D.   14.7 L

Use the following information to answer Questions 8 and 9.

Ghim Li wishes to investigate the effect of pH on the activity of the enzyme protease.

Question 8

Ghim Li performs her tests in flasks that are placed in a water bath to keep the flasks and their contents at a constant temperature of 37 °C.

Under these conditions, the temperature at which the experiment is conducted is referred to as the

A. control.
B. dependent variable.
C. controlled variable.
D. independent variable.

Question 9

In one test, Ghim Li raises the pH of a solution containing the reactants and the enzyme to 13.0

Which one of the following will occur?

A. The rate of the reaction that the enzyme is catalysing will increase.
B. The hydrogen bonding holding the enzyme in its shape will not be disrupted.
C. Any NH_3^+ and COOH groups on the enzyme will be changed to NH_2 and COO^- groups.
D. The nature of the bonding interactions between the enzyme and the substrate will remain the same.

SECTION A – continued

Question 10

Beta-carotene is found naturally in orange and yellow vegetables. In humans, it can be converted to vitamin A_1, as shown in the flow chart below.


beta-carotene

retinal

retinol
(vitamin A_1)
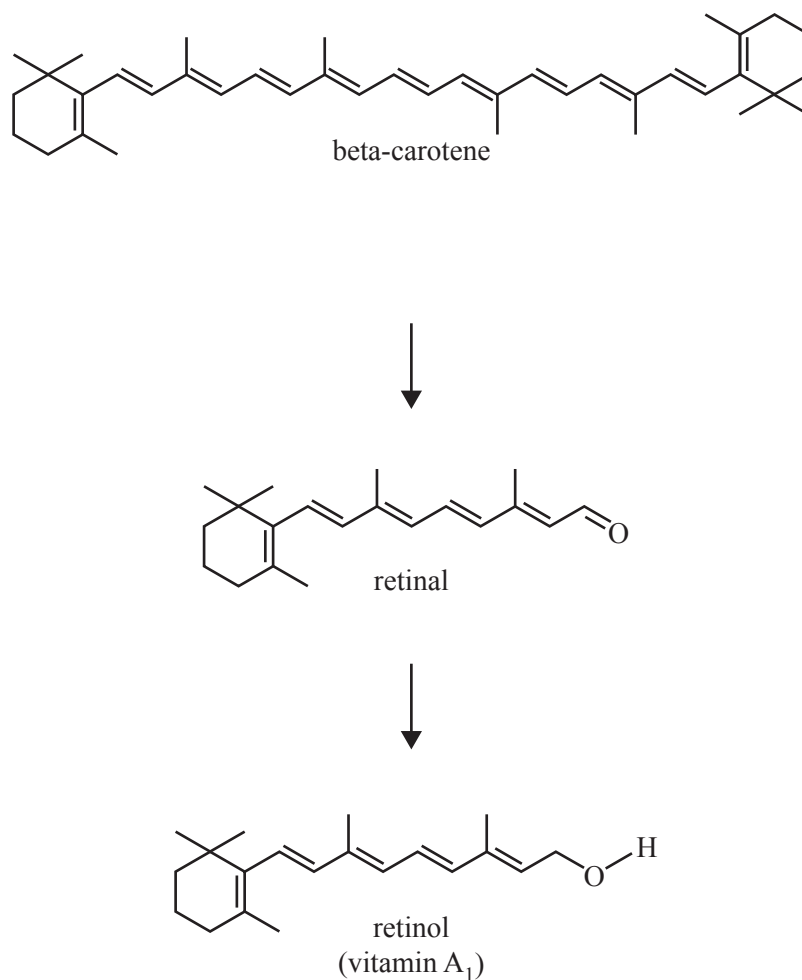
The information in the flow chart indicates that

A.   all three compounds can be distinguished by their infra-red spectra.

B.   all three compounds are classified as saturated hydrocarbons.

C.   all three compounds would be highly soluble in water.

D.   retinal is a ketone, while retinol is an alcohol.

Question 11

The mass spectrum of propanoic acid, CH_3CH_2COOH, is shown below.
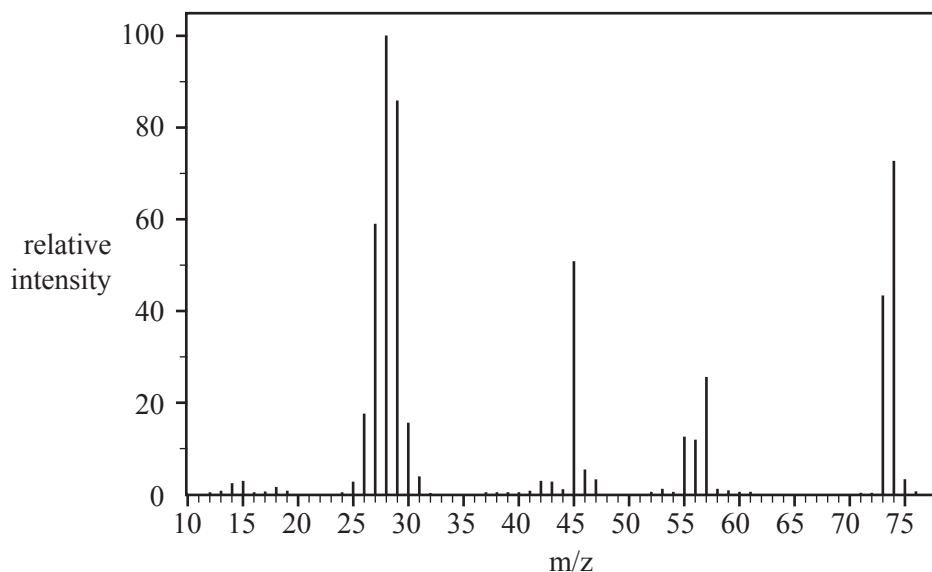
The peak at m/z 74

A. represents the parent ion containing the carbon-13 isotope.

B. represents the species $[CH_3CH_2COOH]^+$.

C. represents the species CH_3CH_2COOH.

D. is commonly known as the base peak.

Question 12

Consider the following energy profile for a particular chemical reaction, where I, II and III represent enthalpy changes during the reaction.
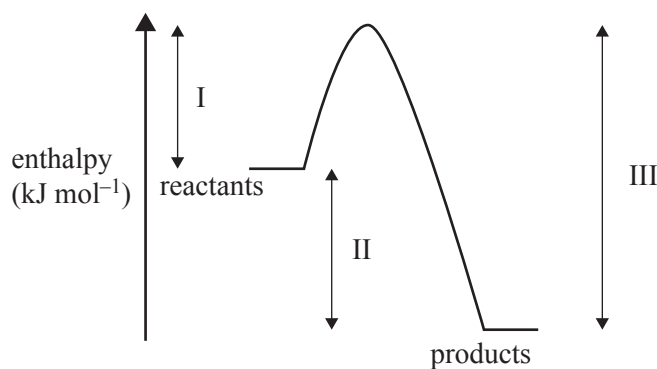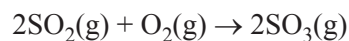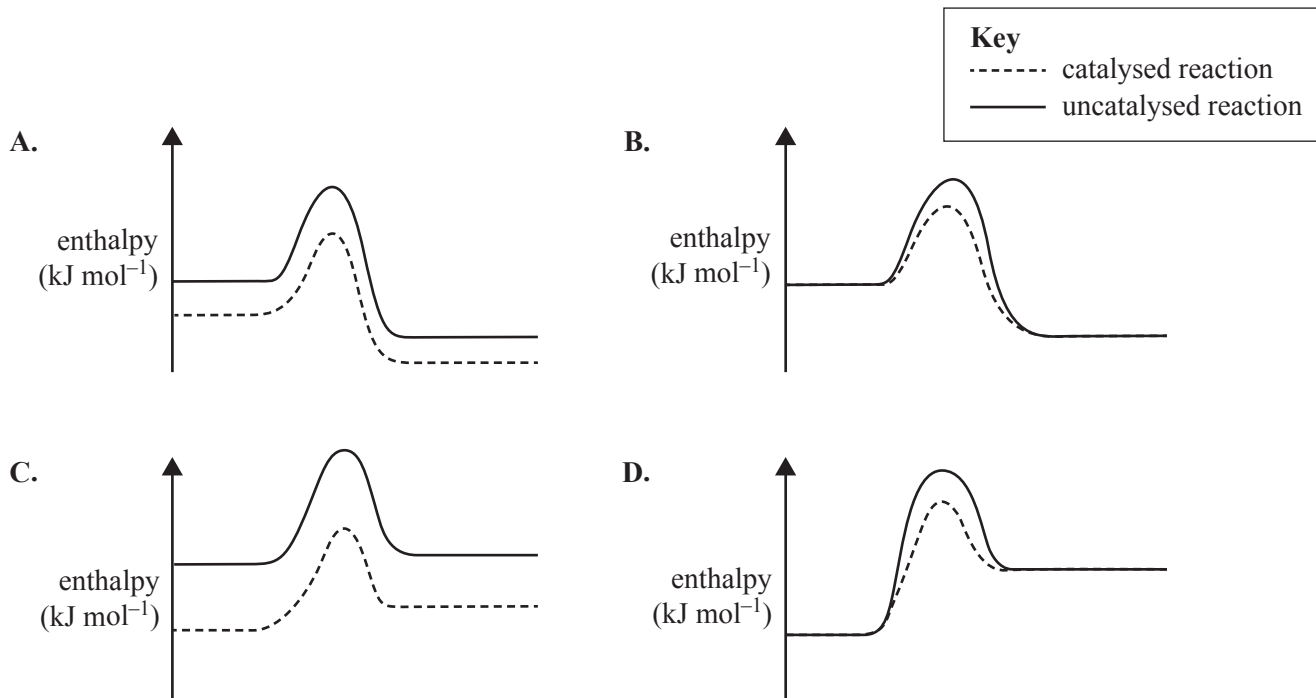

Which one of the following statements is correct?

A. The activation energy for the reverse reaction is (III–II).

B. The net energy released for the forward reaction is represented by II.

C. The energy required to break the reactant bonds is represented by II.

D. The energy released by the formation of new bonds is represented by I.

SECTION A – continued

Question 13

The oxidation of sulfur dioxide is an exothermic reaction, as shown in the equation below. The reaction is catalysed by vanadium(V) oxide.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

Which one of the following energy profile diagrams correctly represents both the catalysed and the uncatalysed reactions?

Key

------ catalysed reaction

——— uncatalysed reaction

A.

enthalpy
$(kJ\ mol^{-1})$

B.

enthalpy
$(kJ\ mol^{-1})$

C.

enthalpy
$(kJ\ mol^{-1})$

D.

enthalpy
$(kJ\ mol^{-1})$

Question 14

The equation for the fermentation of glucose, $C_6H_{12}O_6$, in the presence of yeast is shown below.

$$C_6H_{12}O_6(aq) \xrightarrow{\text{yeast}} 2C_2H_5OH(aq) + 2CO_2(g)$$

Data

Reactant or product	Concentration (g mol^{-1})
$C_6H_{12}O_6$	180.0
C_2H_5OH	46.0
CO_2	44.0

What is the percentage atom economy for the production of ethanol by this reaction?

A.   25.6%

B.   50.0%

C.   51.1%

D.   100%

SECTION A – continued
TURN OVER

Use the following information to answer Questions 15 and 16.

The number of molecules present in a sample of oxygen, O_2, gas in certain conditions has a distribution of kinetic energies shown by Curve 1 in the graph below. After one change is made to the original conditions, a second curve is drawn on the same axes (Curve 2). The areas under the two curves are the same.
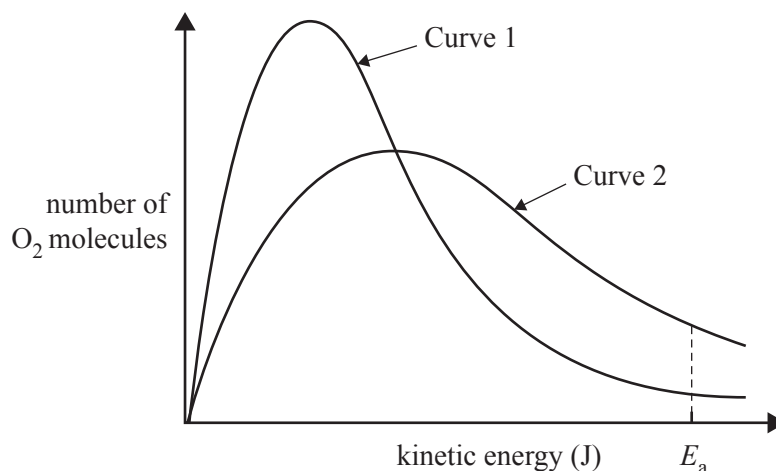
Question 15

What change was made to the original conditions shown by Curve 1, which led to the distribution shown by Curve 2?

A. The O_2 sample was heated.

B. More O_2 molecules were added to the container.

C. A powdered catalyst was blown into the container.

D. Some O_2 molecules were removed from the container.

Question 16

On the graph, E_a represents the activation energy for a reaction between O_2 and another gas.

Under its final conditions, represented by Curve 2, the number of molecules of O_2 in the sample that have sufficient energy to react is represented by the

A. area under Curve 2 to the right of E_a.

B. maximum height of Curve 2.

C. total area under Curve 2.

D. height of Curve 2 at E_a.

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Question 17

Large deposits of methane hydrate have been discovered deep under the sediment on the ocean floor. It has been suggested that methane hydrate deposits could be commercially mined to provide a clean fuel once the trapped methane is extracted.

Methane hydrate has a complex structure. The simplified formula for methane hydrate is $CH_4 \cdot 6H_2O$.

The amount of energy released by the complete combustion of methane extracted from a 1.00 kg sample of $CH_4 \cdot 6H_2O$ at SLC is

A. 8.89×10^2 kJ

B. 7.17×10^3 kJ

C. 4.30×10^4 kJ

D. 5.56×10^4 kJ

Question 18

In rechargeable batteries

A.   the anode always has a negative polarity.

B.   when the cell discharges, it acts as a galvanic cell.

C.   when the cell recharges, electrons must flow into the positive electrode.

D.   the products of the half-cell reactions migrate back and forth between the electrodes.

Question 19
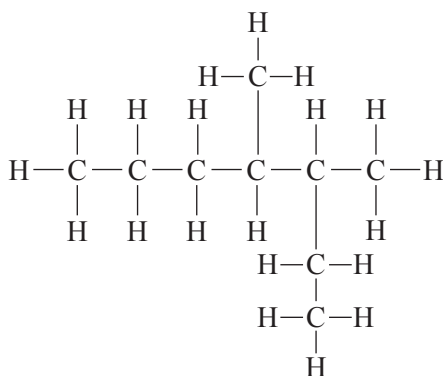
What is the correct IUPAC systematic name for the compound shown above?

A.   4,5-dimethylheptane

B.   3,4-dimethylheptane

C.   4-methyl-5-ethylhexane

D.   2-ethyl-3-methylhexane

Question 20

Coenzyme Q10 is a substance produced by the human body. It is involved in the process of cellular respiration, which is the primary source of energy in body cells.

In which one of the following processes is coenzyme Q10 most likely involved?

A.   favouring the forward reaction of cellular respiration

B.   acting as an antioxidant to remove electrons from the cell

C.   enabling the transport of carbon dioxide away from the cell

D.   changing the orientation of atoms at the active site of the substrate

Use the following information to answer Questions 21–23.

Potassium metal, K, was discovered in 1807 in England by Sir Humphry Davy. Small, shiny beads of molten potassium were produced when an electric current from an early battery was passed through molten potassium hydroxide, KOH.

The electrolytic cell is shown in the diagram below.
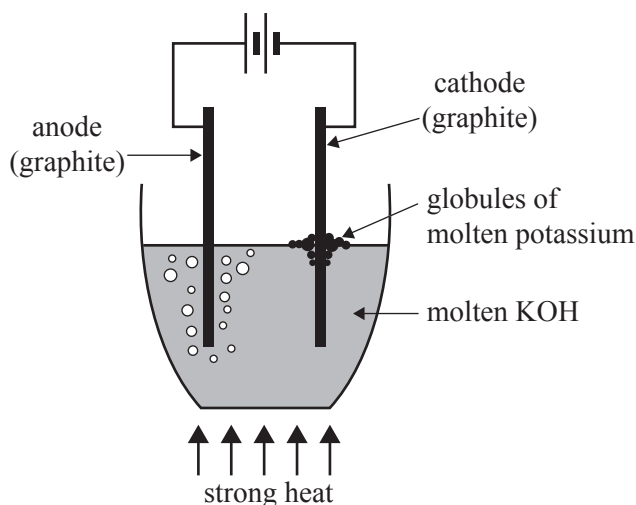
Question 21

What current was flowing through the cell if 0.152 g of molten potassium was produced in the first minute?

A. 4.00×10^{-8} A

B. 2.42×10^{-6} A

C. 6.25 A

D. 375 A

Question 22

If instead Davy had electrolysed a 1.0 M KOH solution at 25 °C, still using graphite electrodes, what main products would be observed at the anode and cathode, respectively?

A. carbon dioxide gas, hydrogen gas

B. oxygen gas, molten potassium

C. carbon dioxide gas, oxygen gas

D. oxygen gas, hydrogen gas

Question 23

Today, some metals are still extracted from their molten compounds using electrolytic cells. Aluminium is extracted from its molten oxide, Al_2O_3, by electrolysis.

If 0.60 mol of electrons are passed through molten Al_2O_3, what amount of aluminium will be produced?

A. 0.20 mol

B. 0.30 mol

C. 0.60 mol

D. 0.90 mol

Use the following information to answer Questions 24 and 25.

Titanium is a widely used metal that is extracted from its ore, titanium dioxide, TiO_2, in two stages.

Stage 1   The impure oxide is converted to titanium(IV) chloride, $TiCl_4$, at 1000 °C.
The equation for this reaction is

$$\text{Reaction 1}\quad TiO_2(s) + 2Cl_2(g) + 2C(s) \rightarrow TiCl_4(g) + 2CO(g)$$
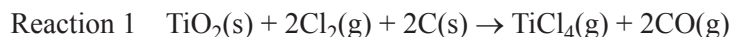
The $TiCl_4$ is then purified in an atmosphere of argon gas.

Stage 2   The pure $TiCl_4$ vapour is reacted with molten magnesium, Mg, in an atmosphere of argon gas at 1000 °C.
The equation for this reaction is

$$\text{Reaction 2}\quad TiCl_4(g) + 2Mg(l) \rightarrow Ti(s) + 2MgCl_2(l)$$

This reaction takes about two days. The titanium metal produced is then processed to purify it.

Question 24

Which statement about the two reactions is correct?

A.   The conjugate oxidising agent of $TiCl_4$ in Reaction 2 is Ti.
B.   The conjugate reducing agent of C in Reaction 1 is CO.
C.   Both the carbon and magnesium act as reducing agents.
D.   In Reaction 1, chlorine gas oxidises TiO_2 to $TiCl_4$.

Question 25

In the two reactions, the most likely role of argon gas is to

A.   reduce the risk of an explosion occurring at high temperatures.
B.   drive the reactions forward to increase the percentage yield.
C.   exclude oxygen and hence prevent Ti from forming oxides.
D.   act as a catalyst to lower the cost of production.

Question 26

Hydrogen, H_2, is produced on an industrial scale from methane, CH_4. The equation for the reaction is

$$2H_2O(g) + CH_4(g) \rightleftharpoons CO_2(g) + 4H_2(g)$$
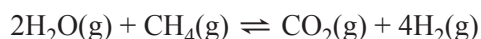
If an inert gas is added to the equilibrium system at a constant temperature and a constant volume, the concentration of H_2 will
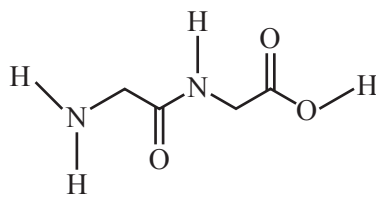
A.   increase.
B.   decrease.
C.   not change.
D.   decrease then increase.
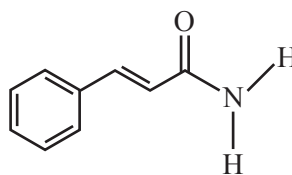
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Question 27

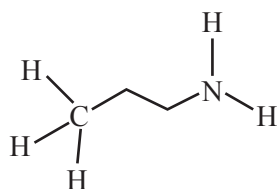Which one of the following skeletal structures represents a primary amide?

A.

B.

C.

D.

Question 28

$$\boxed{X} \xrightarrow{\text{HCl, solid AlCl}_3 \text{ catalyst}} \boxed{Y} \xrightarrow{\text{NH}_3 \text{ (dissolved in ethanol)}} \boxed{Z}$$

Y $\downarrow$ NaOH(aq)
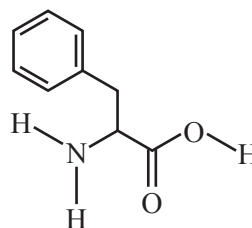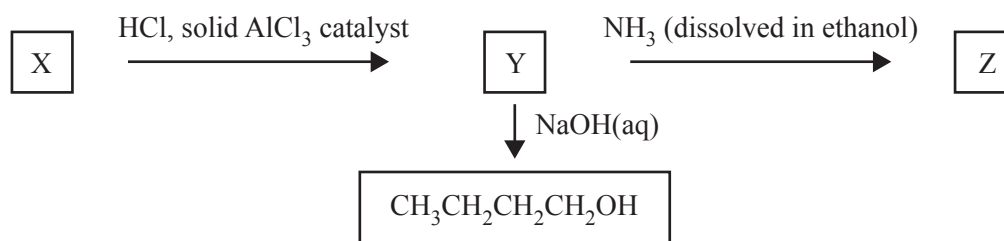
$$\boxed{CH_3CH_2CH_2CH_2OH}$$

What are the semi-structural formulas of X, Y and Z for the reaction pathway shown above?

	X	Y	Z
A.	$CH_3CH_2CH_2CH_3$	$CH_3CH_2CH_2CH_2Cl$	$CH_3CH_2CH_2CH_2NH_2$
B.	$CH_3CH_2CHCH_2$	$CH_3CH_2CHClCH_3$	$CH_3CH_2CHNH_2CH_3$
C.	$CH_3CH_2CH_2CH_3$	$CH_3CH_2CH_2CHCl_2$	$CH_3CH_2CH_2CONH_2$
D.	$CH_3CH_2CHCH_2$	$CH_3CH_2CH_2CH_2Cl$	$CH_3CH_2CH_2CH_2NH_2$

Use the following information to answer Questions 29 and 30.

Ruby standardised a citric acid, $C_6H_8O_7$, solution against a previously standardised sodium hydroxide, NaOH, solution. The equation for the titration reaction was

$$C_6H_8O_7(aq) + 3NaOH(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(l)$$
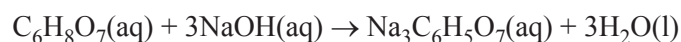
Question 29

Ruby's results are shown in the table below.

Quantity	Measurement
volume of NaOH solution	20.00 mL
molarity of NaOH solution	0.125 M
mean titre of $C_6H_8O_7$ solution	23.6 mL

What was the concentration of citric acid in the solution?

A. 0.035 M

B. 0.049 M

C. 0.105 M

D. 0.316 M

Question 30

Unknown to Ruby, the NaOH solution supplied had absorbed some carbon dioxide, CO_2, from the air. CO_2 is weakly acidic and reacts with NaOH.

What type of error will this contamination of the NaOH lead to in this analysis, and what will be its likely effect on the mean titre of citric acid?

	Type of error	Likely effect on the mean titre of citric acid
A.	random	greater than would be if no contamination had occurred
B.	random	lower than would be if no contamination had occurred
C.	systematic	greater than would be if no contamination had occurred
D.	systematic	lower than would be if no contamination had occurred

END OF SECTION A
TURN OVER

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SECTION B

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Instructions for Section B

Answer **all** questions in the spaces provided. Write using blue or black pen.

Give simplified answers to all numerical questions, with an appropriate number of significant figures; unsimplified answers will not be given full marks.

Show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working.

Ensure chemical equations are balanced and that the formulas for individual substances include an indication of state, for example, $H_2(g)$, $NaCl(s)$.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

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Question 1 (7 marks)

When making salad sandwiches, Tom prefers homemade mayonnaise on his bread, while Gita prefers a soft, solid spread that is made from hydrogenated vegetable oil.

Tom makes his mayonnaise with olive oil. When olive oil is metabolised, one fatty acid that is produced is linoleic acid. Its skeletal structure is shown below.
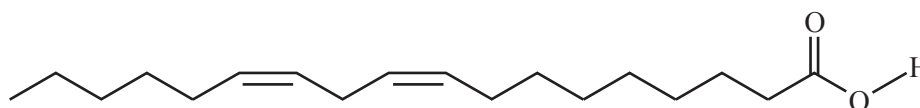
linoleic acid

Gita's favourite vegetable oil spread is manufactured from canola oil. When canola oil is metabolised, one fatty acid that is produced is elaidic acid. Its skeletal structure is shown below.
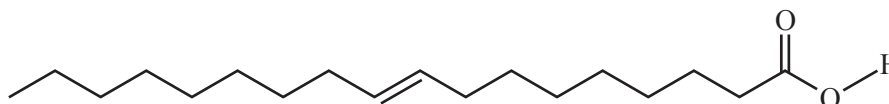
elaidic acid

a. On both of the skeletal structures above, circle all C=C double bonds that show a cis configuration.   1 mark

b. Is linoleic acid classified as an omega-3 fatty acid or as an omega-6 fatty acid? Justify your answer.   2 marks

_____

_____

c. Choose **one** of the fatty acids below by ticking (✓) the box beside it and indicate if it is saturated, monounsaturated or polyunsaturated. 1 mark

☐ linoleic acid _____

☐ elaidic acid _____

d. Consider a triglyceride that contains three linoleic acid tails and a triglyceride that has three elaidic acid tails.

Predict which of these two triglycerides would have the higher melting point. Justify your answer. 3 marks

_____

_____

_____

_____

_____

Question 2 (5 marks)

Amylase is an enzyme that catalyses the hydrolysis of starch and sugars into glucose.

There are two models that explain how enzymes work: the lock-and-key model and the induced fit model.

a. Apply your understanding of the lock-and-key model to draw and annotate a set of simple diagrams to explain how amylase catalyses the hydrolysis of a disaccharide.　　　3 marks

b. If instead the amylase catalyses the hydrolysis of a disaccharide according to the induced fit model, in what way(s) would the interaction be different? You may use labelled diagrams to explain your answer.　　　2 marks

_____

_____

_____

_____

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Question 3 (6 marks)

The following table lists a student's summary notes about food chemistry. It contains some correct and incorrect statements.

Statement number	Statement
1	The monomers of starch are bonded by glycosidic links and the monomers of proteins are bonded by peptide links.
2	The hydrolysis of a protein requires the presence of both an enzyme and a coenzyme.
3	An enzyme can only catalyse a specific biochemical reaction once, since it is consumed in the reaction.
4	Sucrose is a disaccharide formed by a condensation reaction between the monomers glucose and fructose.
5	Fats have lower melting points than oils but they are both classified as triglycerides.
6	When an oil is hydrolysed, glycerol and three fatty acids are produced.
7	Oxidative rancidity occurs when a saturated triglyceride is exposed to oxygen. This causes the saturated triglyceride to form compounds such as aldehydes and ketones.
8	Antioxidants are reducing agents that slow down the rate of oxidative rancidity.
9	The denaturation of a protein is the breaking down of its secondary and tertiary structures.
10	Zwitterions are ions that are produced when a protein is broken down by heat.

a. Identify two **correct** statements by writing the statement numbers in the boxes provided below.   2 marks

Statement number [ ]   Statement number [ ]

b. Identify two **incorrect** statements by writing the statement numbers in the table provided below. Explain why each statement is incorrect.   4 marks

| Statement number	Explanation

Question 4 (6 marks)

Claire is analysing a sample of paint to determine the organic solvents that are present. She separates the different compounds and analyses each one using infra-red (IR) spectroscopy, and ^{13}C and ^1H NMR spectroscopy.

Claire finds that one of the compounds that she isolates has a molecular formula of $C_5H_{10}O$. The results for this compound for each type of spectroscopy used are shown in the spectra on pages 18–20. Use the information provided to answer the questions on page 21.
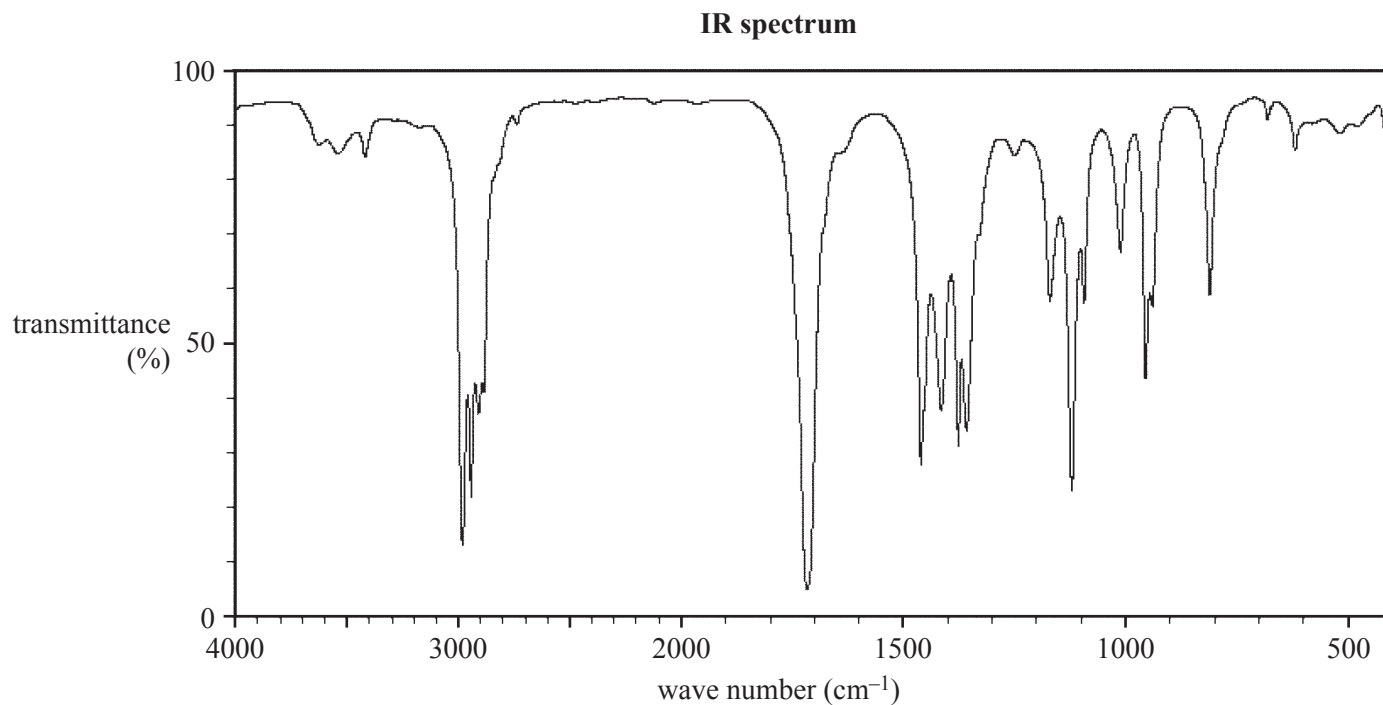
IR spectrum

Data: SDBSWeb; http://sdbs.db.aist.go.jp,
National Institute of Advanced Industrial Science and Technology
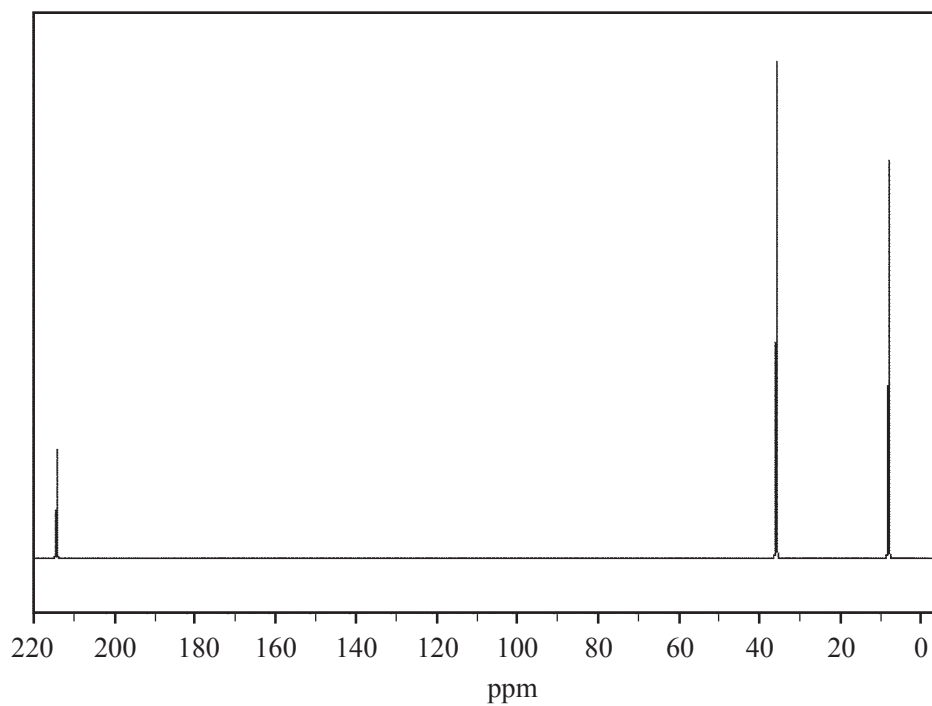
^{13}C NMR spectrum

DO NOT WRITE IN THIS AREA

^{1}H NMR spectrum
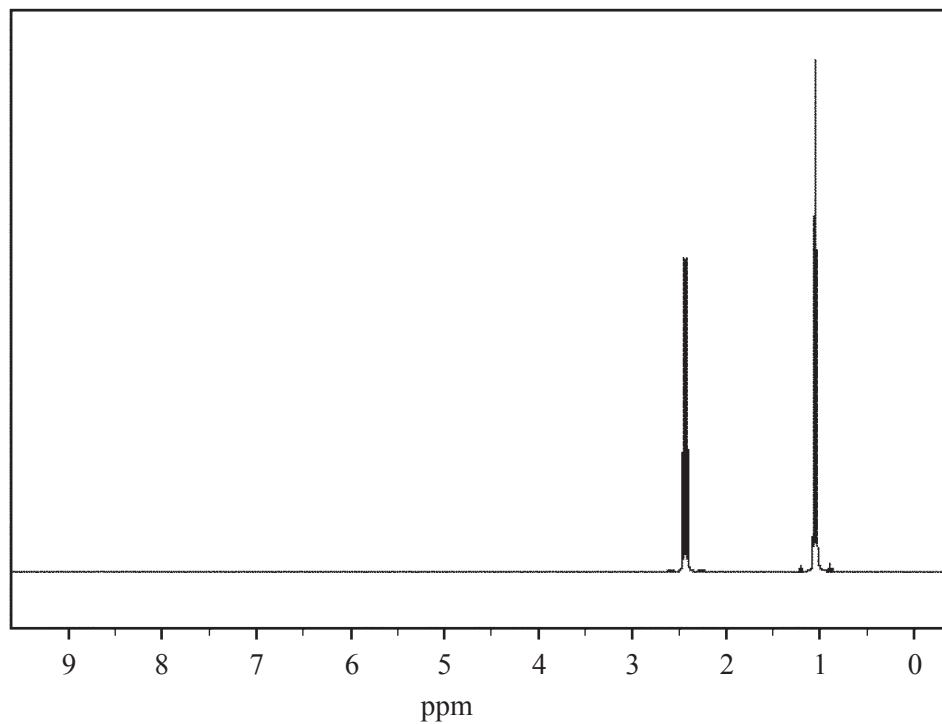
Data: SDBSWeb; http://sdbs.db.aist.go.jp,
National Institute of Advanced Industrial Science and Technology

^{1}H NMR data

Chemical shift	Splitting pattern
1.0	3
2.4	4

DO NOT WRITE IN THIS AREA

a. From the IR spectrum of the compound, identify the organic family to which this compound belongs. Justify your answer by referring to the relevant wave number. 2 marks

b. Draw a structural formula for this compound that is consistent with the data provided. Explain your reasoning by referring to this data. 4 marks

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Question 5 (12 marks)

Ascorbic acid, also called vitamin C, is an organic acid that plays a vital role in human health. Its molecular formula is $C_6H_8O_6$.

Citrus fruit are a common source of vitamin C. In the following experiment, the concentration of vitamin C present in the juice from a batch of freshly squeezed lemons was determined by carrying out a direct redox titration against the tri-iodide ion.

The tri-iodide ion is produced when iodine solution, I_2, and iodide solution, I^-, are mixed together.

$$I_2(aq) + I^-(aq) \rightarrow I_3^-(aq)$$
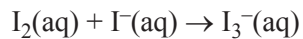
The overall redox reaction occurring is

$$C_6H_8O_6(aq) + I_3^-(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 3I^-(aq)$$
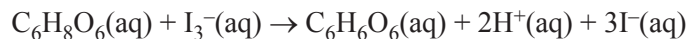
a.   Identify the oxidising agent in this titration reaction.   1 mark

For the titration, a 20.00 mL sample of pure lemon juice was made up to 250.00 mL with de-ionised water in a 250 mL volumetric flask.

Then, 25.00 mL aliquots of the diluted lemon juice were transferred to conical flasks and titrated against a previously standardised 2.000×10^{-4} M I_3^- solution, which was light brown in colour. To detect the end point, starch was added when the mixture became a very pale brown. This starch indicator turned from deep blue to colourless at the end point.

The average titre was found to be 15.65 mL.

b.   **i.**   Calculate the amount, in moles, of I_3^- present in the average titre.   1 mark

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ii.   Calculate the amount, in moles, of $C_6H_8O_6$ present in each 25.00 mL aliquot of diluted lemon juice.   1 mark

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iii.   Calculate the molarity of $C_6H_8O_6$ in the original sample of pure lemon juice. Hence, state the concentration of vitamin C in the lemon juice.   3 marks

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c. The skeletal structures of vitamin C and vitamin D$_3$ are shown below.
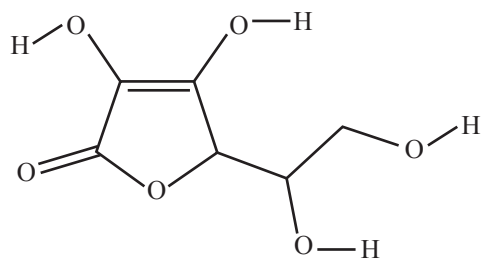
vitamin C　　　　　　　　　　　　　　　　　vitamin D$_3$

i. As with most organic compounds metabolised by the human body, vitamins exist as pairs of optical isomers. Only the optical isomer of vitamin C, which is shown in the skeletal structure above, occurs naturally.

On the skeletal structure of vitamin C, circle the two chiral carbons.　　　　　2 marks

ii. In humans, the enzyme known as L-ascorbate oxidase can break down only the naturally occurring optical isomer of vitamin C.
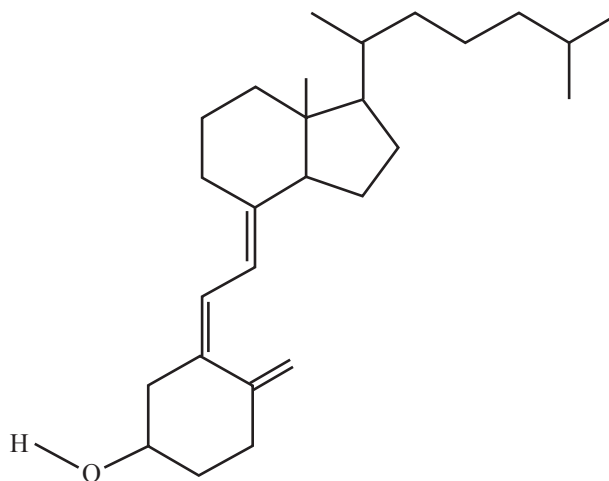
Explain why this enzyme would not break down the other optical isomer.　　　　2 marks

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iii. The analysis of the lemon juice in **part b.** was possible because vitamin C is water-soluble.

In terms of its structure, explain why vitamin C is water-soluble while vitamin D$_3$ is not.　　　　2 marks

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SECTION B – continued

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Question 6 (6 marks)

The glycaemic index (GI) is a value assigned to foods based on how slowly or quickly the carbohydrates in foods are broken down to cause an increase in blood sugar levels. The GI of pure glucose is assigned a value of 100. Foods may be classified as having a low, medium or high GI according to the values given in the table below.

Glycaemic index (GI)	Value
low	≤ 55
medium	56–69
high	≥ 70

Carbohydrates with low GI values are more slowly digested, absorbed and metabolised, and cause a lower and slower rise in blood glucose levels than carbohydrates with higher GI values.

In 2016, a research team at Tufts University undertook a study to determine whether GI values are accurate and reproducible. Sixty-three volunteers were recruited for the study that involved six testing sessions over 12 weeks. Each session involved the volunteers randomly being given a food sample of white bread (a simple carbohydrate that was used as the test food) or a glucose drink (used as a reference control). Each food sample contained 50 grams of available carbohydrate. Blood glucose levels were measured at multiple points for five hours after eating and the GI value was calculated using standard formulas.

The team found that the mean GI value of white bread for the study population was 62, placing it in the category of foods with a medium GI value. However, deviations averaged 15 points in either direction, effectively placing white bread in all three GI categories. The team found that variations in GI values differed across individuals as well as within the same individual between trials, but biological factors such as gender, body mass index and physical activity had only a minor effect on the variability of GI values.

a. Why is glucose used as the standard for determining GI values? 1 mark

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b. What is meant by the term 'available carbohydrate'? 1 mark

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c. Glucose is used as the main fuel by the brain and nervous system, and is the preferred source of fuel for most organs and muscles during exercise.

Suggest why athletes may prefer to include foods with high GI values in their diet.   2 marks

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d. With reference to the findings of the study, comment on a food label claim that a product has a low GI value.   2 marks

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Question 7 (10 marks)

A car manufacturer is planning to sell hybrid cars powered by a type of hydrogen fuel cell connected to a nickel metal hydride, NiMH, battery.

A representation of the hydrogen fuel cell is shown below.
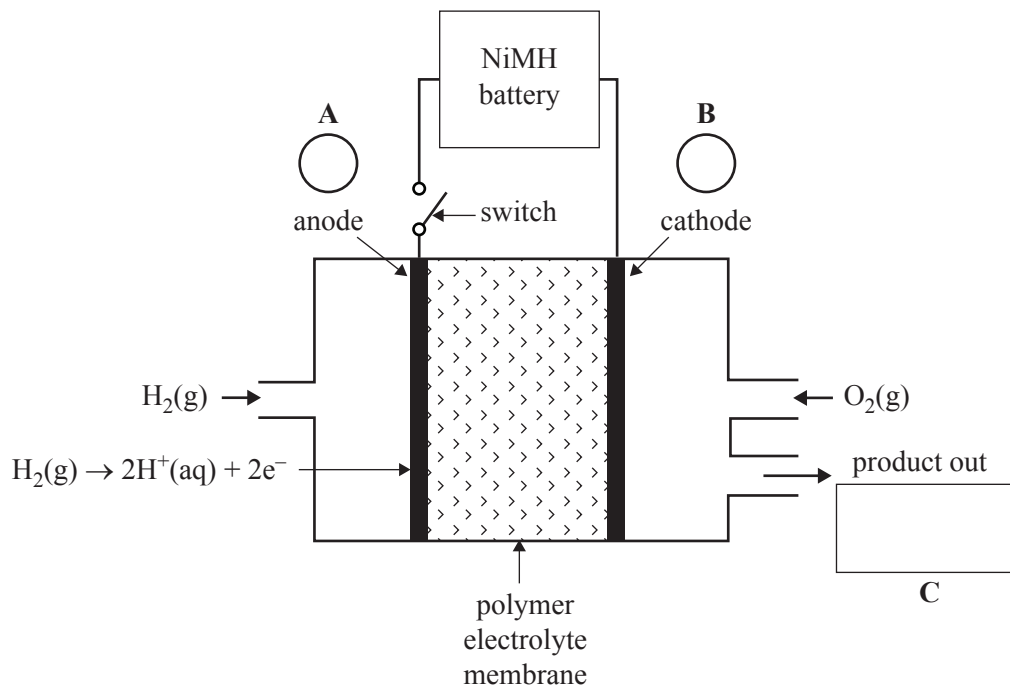
The overall cell reaction is

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$
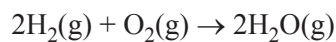
a. **i.** On the diagram above, indicate the polarity of the anode and the cathode in circles A and B, and identify the product of the reaction in box C. 2 marks

ii. Write an equation for the reaction that occurs at the cathode when the switch is closed. 1 mark

Cathode reaction _____

iii. Give **one** advantage of using a hydrogen fuel cell to supply energy rather than using petrol, which is made from crude oil. 1 mark

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DO NOT WRITE IN THIS AREA

b. The storage battery to be used in the hybrid cars comprises a series of NiMH cells. MH represents a metal hydride alloy that is used as one electrode. The other electrode contains nickel oxide hydroxide, NiOOH. The electrolyte is aqueous KOH.
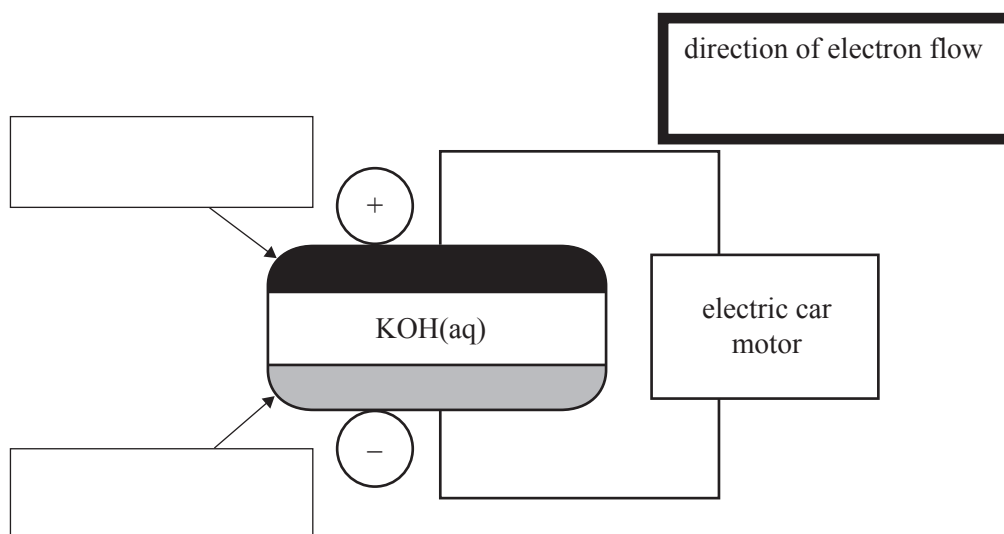
The simplified equation for the reaction at the anode while **recharging** is

$$Ni(OH)_2(s) + OH^-(aq) \rightarrow NiOOH(s) + H_2O(l) + e^-$$
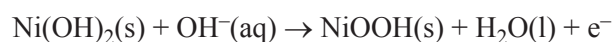
The simplified equation for the reaction at the cathode while **recharging** is

$$M(s) + H_2O(l) + e^- \rightarrow MH(s) + OH^-(aq)$$
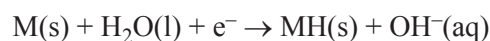
i. What is the overall equation for the **discharging** reaction? 1 mark

ii. In the boxes on the diagram above, indicate which is the MH electrode and which is the NiOOH electrode. 1 mark

iii. In the bold box provided above the cell diagram, use an arrow, $\rightarrow$ or $\leftarrow$, to indicate the direction of the electron flow as the cell is discharging. 1 mark

iv. The battery discharged for 60 minutes, producing a current of 1.15 A.

What mass, in grams, of NiOOH, would be used during this period? 3 marks

Question 8 (10 marks)

Carbon monoxide, CO, reacts with ammonia, NH_3, to produce highly toxic hydrogen cyanide, HCN, as well as carbon dioxide, CO_2, and hydrogen, H_2. This reaction is endothermic and the equation for this reaction is shown below.

$$2CO(g) + NH_3(g) \rightleftharpoons HCN(g) + CO_2(g) + H_2(g)$$

a.   **i.**   Write the expression for the equilibrium constant for this reaction.   1 mark

ii.   In one experiment, a mixture of CO and NH_3, together with a suitable catalyst, was injected into a sealed 100 mL gas syringe and allowed to come to equilibrium.

When the equilibrium mixture was analysed at a particular temperature, the following concentrations were determined.

$$[CO] = 0.0025 \text{ M} \qquad [NH_3] = 0.00125 \text{ M} \qquad [HCN] = 0.0042 \text{ M}$$

Calculate the equilibrium constant for the reaction at this temperature.   2 marks

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b.   Analysts then investigated the effect of two different changes on the equilibrium system by monitoring the amount of HCN (in moles) present in the gas mixture over a period of time.

i.   Tick (✓) the appropriate box in the table below to show the expected effect on the amount of HCN (in moles) present in the gas mixture as a result of each change.   2 marks

Change investigated	Expected effect on the amount of HCN		
	Increase	**Decrease**	**No effect**
Halve the volume of the gas mixture, keeping the temperature constant.			
Return the volume of the gas mixture to 100 mL, then inject some powdered palladium into the gas syringe. (Palladium absorbs H_2 gas onto its surface.)			

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ii. Complete the concentration–time graph on the axes provided below, to show what will happen to the concentrations of HCN and NH_3 in an equilibrium mixture when the volume of the gas mixture is suddenly halved at a constant temperature. 2 marks

Concentration–time graph for the equilibrium system

concentration $(mol\ L^{-1})$

0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0

time (s)

Key
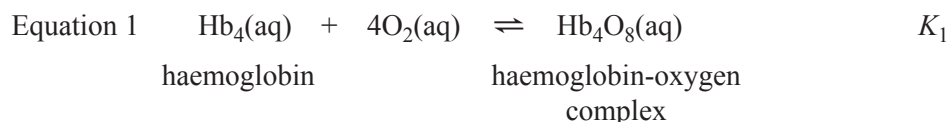——— HCN
- - - - - NH_3

volume halved
at this point
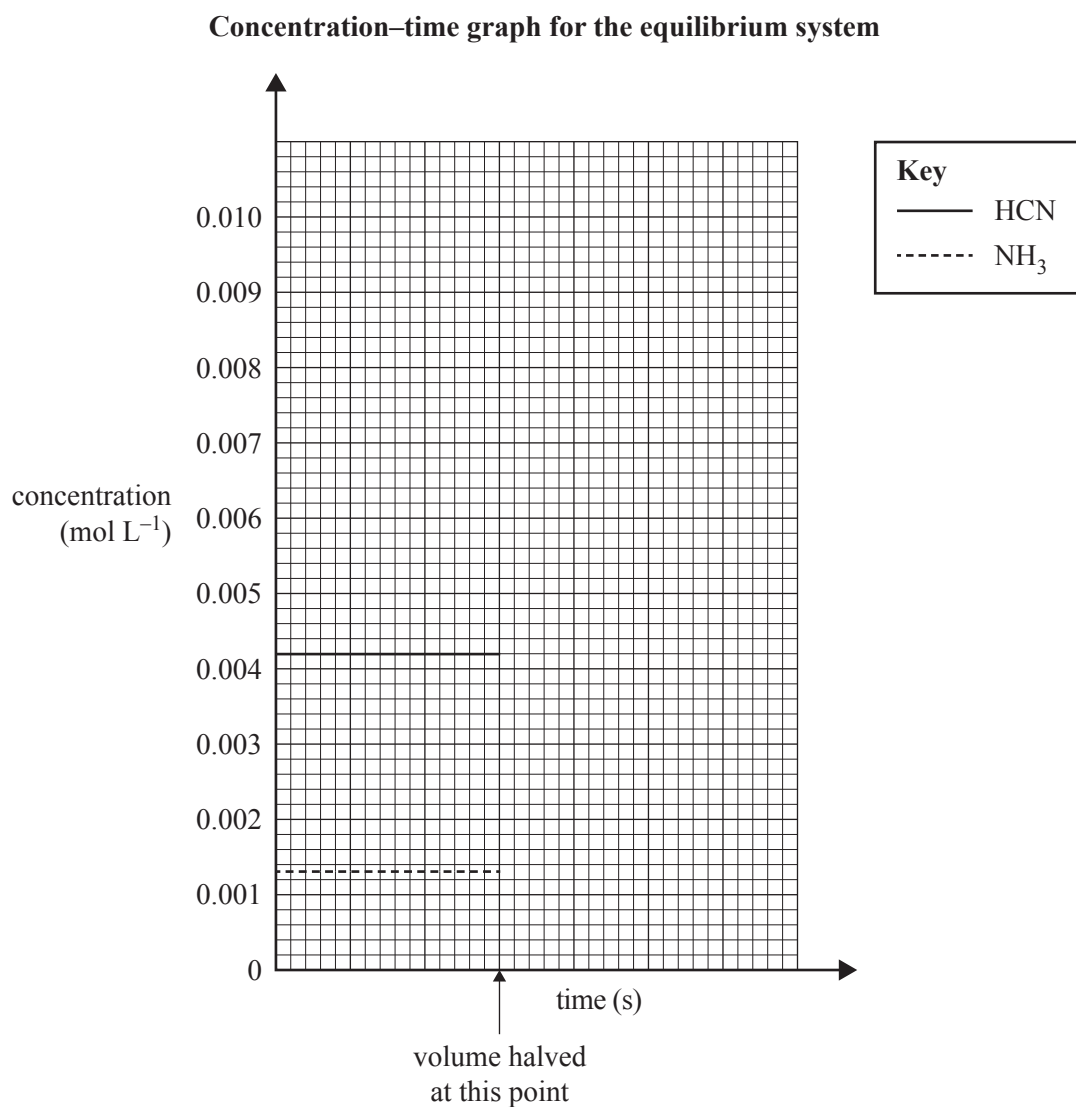
c. CO gas is produced when a hydrocarbon fuel, such as butane, C_4H_{10}, is burnt in a limited air supply.

Write the balanced equation for the combustion of C_4H_{10} in a limited air supply, assuming that CO is the only carbon-based oxidation product. 1 mark
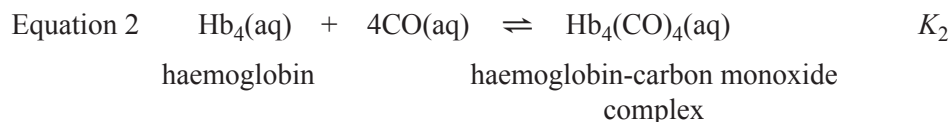
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d. CO poisoning is one danger faced by rescuers entering a burning building, so it is essential that rescuers wear appropriate breathing apparatus.

Haemoglobin in red blood cells takes up O_2 from the air in an equilibrium reaction represented by Equation 1.

$$\text{Equation 1} \qquad Hb_4(aq) \;+\; 4O_2(aq) \;\rightleftharpoons\; Hb_4O_8(aq) \qquad\qquad K_1$$

$$\text{haemoglobin} \qquad\qquad \text{haemoglobin-oxygen complex}$$

CO molecules can also attach to haemoglobin molecules. The equilibrium reaction involved is represented by Equation 2.

$$\text{Equation 2} \qquad Hb_4(aq) \;+\; 4CO(aq) \;\rightleftharpoons\; Hb_4(CO)_4(aq) \qquad\qquad K_2$$

$$\text{haemoglobin} \qquad\qquad \text{haemoglobin-carbon monoxide complex}$$

If the concentration of CO in the air inside a burning building increases to 800 ppm, anyone who is exposed to this will quickly lose consciousness, even if oxygen is present. To revive them, they must be given pure oxygen.

What conclusions can be made about the relative values of equilibrium constants K_1 and K_2? 2 marks

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Question 9 (14 marks)

A group of students was set the task of investigating the molar heat of combustion of glucose using primary and secondary data that was obtained from two different experimental techniques.

The first experimental technique used to find the molar heat of combustion of glucose involved collecting primary data. The students set up the apparatus as shown below. They weighed out a sample of pure glucose powder into the crucible, ready for the combustion. They also weighed out 150.0 g of water into the copper calorimeter pot and measured the initial temperature of the water.

Experimental technique 1
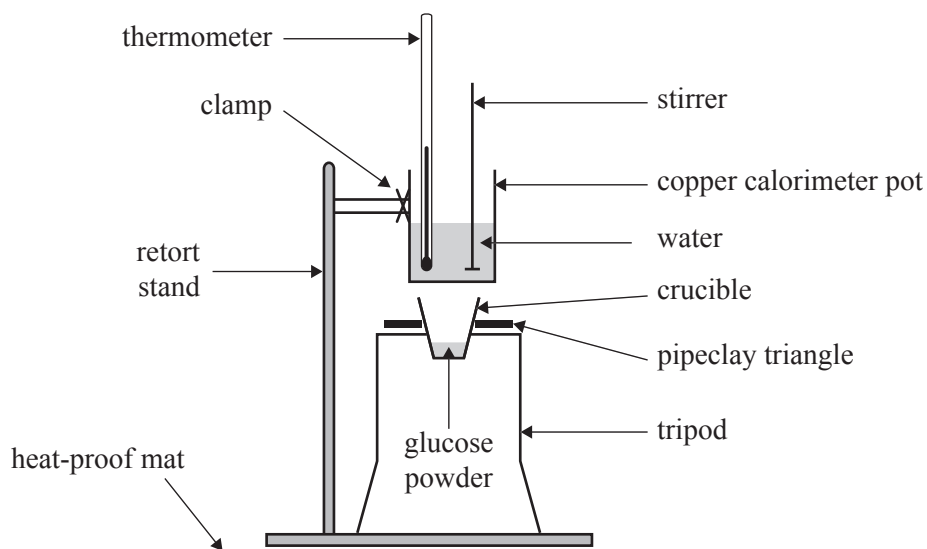
Before burning the glucose to determine an experimental value of its heat content, the students decided to calculate the predicted maximum temperature rise of the water. The set of data they used is shown in Table 1.

Table 1. Data for determining the predicted maximum temperature rise of the water

Quantity	Measurement
mass of glucose powder	2.002 g
mass of water	150.0 g
specific heat capacity of water	4.182 J g^{-1} °C^{-1}
initial temperature of water	21.3 °C
published molar heat of combustion of glucose	2805 kJ mol^{-1}
molar mass of glucose	180.0 g mol^{-1}

a.   **i.**   Use the data from Table 1 to calculate the predicted maximum temperature rise of the water.   3 marks

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ii.   The students then safely ignited the glucose powder. When the powder stopped burning, the students recorded the actual temperature rise of the water. They determined that the final temperature of the water was 48.5 °C.

Compare the experimental temperature rise with the value that the students predicted and hence comment on the accuracy of the value of the heat of combustion of glucose that the students would have obtained using this experimental technique.   2 marks

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The second experimental technique for finding the molar heat of combustion of glucose involved using a typical commercial bomb calorimeter. The apparatus set up by the students is shown below.

Experimental technique 2
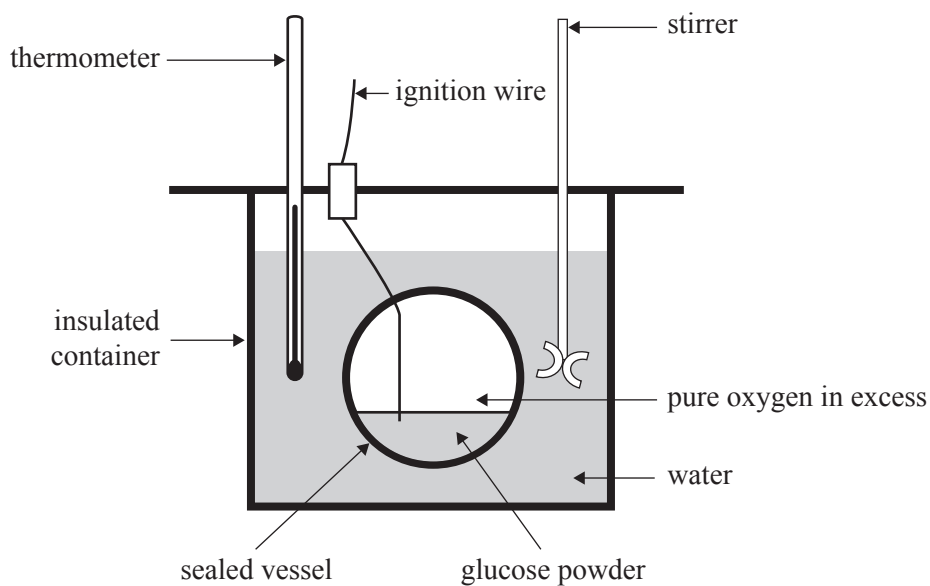
The students were able to obtain the following secondary data from a commercial food analysis laboratory.

Table 2. Electrical calibration of bomb calorimeter

Quantity	Measurement
current	1.78 A
potential difference	5.65 V
time current passed	135 s
temperature rise of water	1.150 °C

Table 3. Combustion of glucose

Quantity	Measurement
mass of glucose	1.324 g
temperature rise of water	17.32 °C

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b. **i.** Show by calculation that the calibration factor of the bomb calorimeter obtained by the students is 1180 J °C^{-1}.

2 marks

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ii. Using 1180 J °C^{-1} as the calibration factor of the bomb calorimeter, calculate the molar heat of combustion of glucose in J mol^{-1}.

3 marks

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iii. Compare the experimental value from **part b.ii.** with the published value of the molar heat of combustion of glucose given in Table 1.

1 mark

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c. **i.** Identify **one** of the design faults of Experimental technique 1 that would have contributed to its less accurate results.

1 mark

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ii. Explain how the design features of Experimental technique 2 overcame the design fault identified in **part c.i.** to obtain more accurate results.

2 marks

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Question 10 (14 marks)

For his extended VCE Chemistry experimental investigation project, Chris decided to investigate whether there is a relationship between the rate of the reaction between magnesium, Mg, and hydrochloric acid, HCl, and the concentration of the acid.

The following is an extract from the scientific poster that Chris produced.

Question under investigation: Is there a relationship between the rate of the reaction between magnesium, Mg, and different concentrations of hydrochloric acid, HCl?

Equation for the reaction: $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$

Experimental design: Four different concentrations of HCl were tested. The rate of each reaction was investigated by measuring the volume of hydrogen, H_2, gas produced at 60-second intervals.

Hypothesis: The greater the concentration of the acid, the faster the reaction will be. I expect this because, for a reaction to occur, H^+ ions must collide with Mg atoms. The greater the concentration of the acid, the more frequently the H^+ ions will collide with the surface of the Mg and so the greater the amount of H_2 gas that will be produced.

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a. In his hypothesis, does Chris demonstrate an understanding of the chemistry that is relevant to this experimental investigation? Explain your reasoning.   2 marks

In his poster, Chris outlined how the experimental investigation was conducted. An extract from his methodology is shown in the table below.

Methodology: First, the variables were identified. The decisions I made are shown in Table 1.

Table 1. The variables identified

Variable	Classification	Details
mass of Mg	controlled variable	The first piece of Mg ribbon was weighed and measured, then the same length of Mg was used for each concentration of HCl tested.
concentration of HCl	dependent variable	0.5 M, 1.0 M, 1.5 M and 2.0 M solutions of HCl were tested.
volume of HCl	controlled variable	50.0 mL was used for each test, measured using a graduated measuring cylinder.

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b. Is Chris's identification of the concentration of HCl as the dependent variable correct? Give a reason for your answer.   1 mark

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Chris's poster included a diagram of the experimental set-up, supported by short notes, as shown below.

The experimental set-up:

- syringe for injecting HCl
- H_2 gas collecting in graduated measuring cylinder
- stopwatch
- tablet device to record results
- sealed reaction flask
- magnetic stirrer to keep reactants evenly mixed
- piece of Mg
- beehive shelf
- water trough

Notes:

- Timing began the instant I started injecting the acid from the syringe above the flask onto the piece of Mg.
- The stopwatch was mounted next to the graduated measuring cylinder, and the volume and time were recorded using a video app on a tablet device and replayed in slow motion to allow the results to be obtained.
- The injection of 20.0 mL HCl into the sealed reaction flask immediately pushed 20.0 mL of air out of the flask and into the measuring cylinder. I recorded only the net volume of H_2 gas produced.

c. Identify **one** feature of Chris's experimental set-up and notes above that was designed to improve the accuracy of the results. Explain how this feature could improve accuracy.   3 marks

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Chris also recorded his observations on his poster.

Observations: For the 2.0 M HCl, initially there was very rapid bubbling in the flask. The bubbling slowed over time. All Mg appeared to have dissolved. The flask became very hot.

For the 1.5 M and 1.0 M HCl solutions, the bubbling was not as rapid as for the 2.0 M HCl, and for the 0.5 M HCl it was much slower. The solutions were still bubbling when timing stopped. The flasks became hot, although not as hot as the flask containing 2.0 M HCl.

d.   Comment on Chris's observations, including the differences in the rate of bubbling and how well the experiment had been controlled.   3 marks

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Chris replayed his video in slow motion, recorded his experimental results in his logbook and produced a graph for his poster. The graph is shown below.

Results:

Graph of volume of H_2 gas produced against time

volume of H_2 gas (mL)

Key
- ◆ 2.0 M
- ☐ 1.5 M
- ▲ 1.0 M
- ■ 0.5 M

time (s)
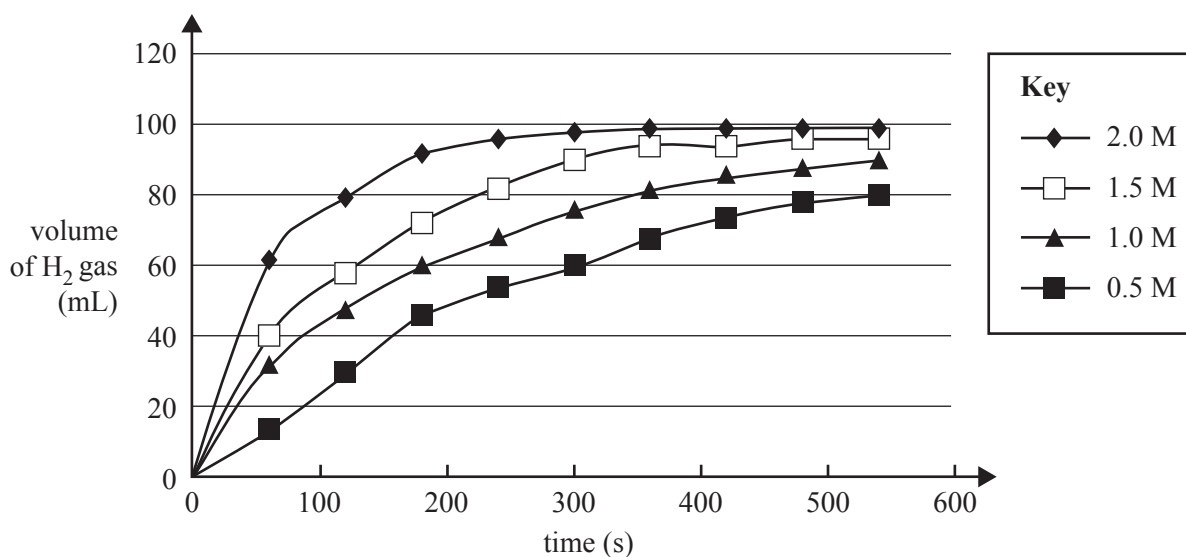
e. What conclusions might Chris have stated, given his results for the question under investigation and his hypothesis?   2 marks

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f. Suggest **one** other question Chris could ask to extend this experimental investigation and briefly outline an experimental design that would enable Chris to answer this question. You may present your answer as a list of main steps or as a simple flow chart.   3 marks

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END OF QUESTION AND ANSWER BOOK

Answers to multiple-choice questions

Question	Answer
1	D
2	B
3	C
4	C
5	A
6	A
7	D
8	C
9	C
10	A
11	B
12	B
13	B
14	C
15	A

Question	Answer
16	A
17	B
18	B
19	B
20	D
21	C
22	D
23	A
24	C
25	C
26	C
27	B
28	D
29	A
30	D