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Chemistry

Question and Answer Book

2024 Insight Publications Trial Examination

- Reading time is **15 minutes**
- Writing time is **2 hours 30 minutes**

Materials supplied

- Question and Answer Book of 35 pages
- Multiple-Choice Answer Sheet

Instructions

- Follow the instructions on your Multiple-Choice Answer sheet.

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

Students should refer to the VCAA Data Book available at https://www.vcaa.vic.edu.au/assessment/vce-assessment/past-examinations/Pages/Chemistry.aspx as needed.

Contents pages

Section A – Multiple-choice questions

Instructions

- Answer **all** questions in pencil on the Multiple-Choice Answer Sheet.
- 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

Select the correct statement about cellular respiration.

A. Energy from the Sun is used to combine carbon dioxide and water to form glucose.

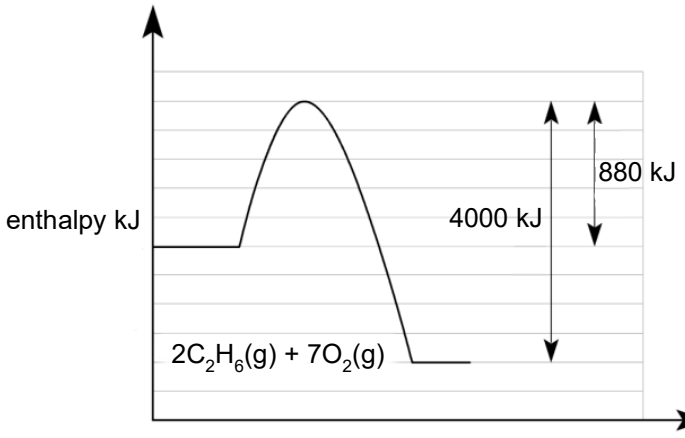
B. Respiration occurs in the lungs, where glucose is hydrolysed to smaller molecules.

C. 6 moles of glucose reacts with 1 mole of oxygen gas, absorbing significant amounts of energy.

D. 1 mole of glucose reacts with 6 moles of oxygen gas, releasing significant amounts of energy.

Question 2

An energy profile diagram is shown below for the complete combustion of ethane gas to form $CO_2(g)$ and $H_2O(l)$.



The thermochemical equation for the reaction shown is

A. $C_2H_6(g) + 3.5O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$ $\Delta H = -880$ kJ

B. $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l)$ $\Delta H = -1560$ kJ

C. $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l)$ $\Delta H = -3120$ kJ

D. $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l)$ $\Delta H = -4000$ kJ

Question 3

Select the correct statement about bioethanol.

A. The energy density of bioethanol is less than the energy density of ethanol formed from ethene.

B. 1.0 kg of bioethanol releases less energy than 1.0 kg of petrol.

C. Bioethanol is blended with water to make a fuel that can be used in place of petrol.

D. Bioethanol does not produce carbon dioxide during combustion.

Question 4

24.8 mL of butane is reacted with 200 mL of oxygen gas, with both volumes measured at SLC. The equation for the reaction is

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$$

In grams, the mass of carbon dioxide formed in this reaction will be

A. 0.044

B. 0.088

C. 0.176

D. 176

Question 5

A 2.0 g sample of cooking oil is burnt under 1.6 kg of water. The temperature of the water increases by 8.0 °C.

The percentage efficiency of the energy transfer to the water is closest to

A. 13%

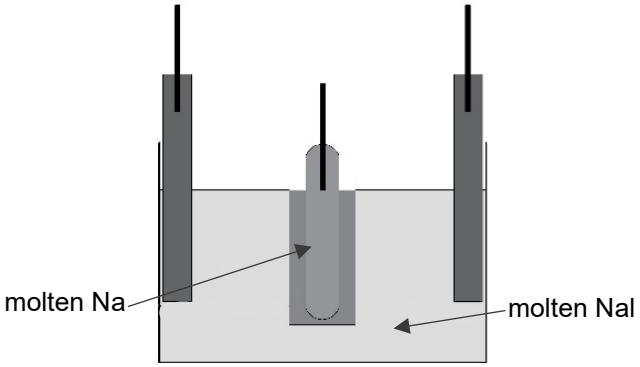
B. 36%

C. 55%

D. 72%

Use the following information to answer Questions 6 and 7.

A type of rechargeable battery that continues to attract interest uses molten sodium as one of the reactants. Sodium is a relatively abundant element, and the cell produces a high energy density. The sketch below is of a sodium/salt cell, featuring a cylindrical molten sodium electrode inside an electrolyte of molten sodium iodide, NaI.



The electrochemical series shows the two half-equations as

$I_3^- + 2e^- \rightarrow 3I^-$ 0.53 V

$Na^+ + e^- \rightarrow Na$ –2.71 V

Question 6

Which of the following correctly identifies the anode reactant and the voltage produced during discharge?

	Anode	Voltage (V)
A.	triiodide I_3^-	2.18
B.	iodide I^-	3.24
C.	sodium metal	3.24
D.	sodium ions	2.18

Question 7

The overall equation occurring during recharge will be

A. $2Na^+ + 3I^- \rightarrow 2Na + I_3^-$

B. $3Na^+ + 3I^- \rightarrow 3Na + I_3^-$

C. $Na + I_3^- \rightarrow Na^+ + 3I^-$

D. $2Na + I_3^- \rightarrow 2Na^+ + 3I^-$

Question 8

Electrolysis of a liquid is found to produce a colourless gas at the positive electrode and a grey metal deposit at the negative electrode.

The electrolyte used could be

A. 0.1 M $Pb(NO_3)_3$

B. 0.1 M $Al(NO_3)_3$

C. 0.1 M $CuSO_4$

D. 0.1 M NiI_2

Question 9

A rechargeable battery has zinc metal reacting at its negative electrode during discharge.

When this cell is connected to a recharger

A. the polarity of the zinc electrode will become positive.

B. the polarity of the electrode will change but the reaction at the electrode will still be oxidation.

C. a voltage equal to the voltage produced during discharge will need to be applied.

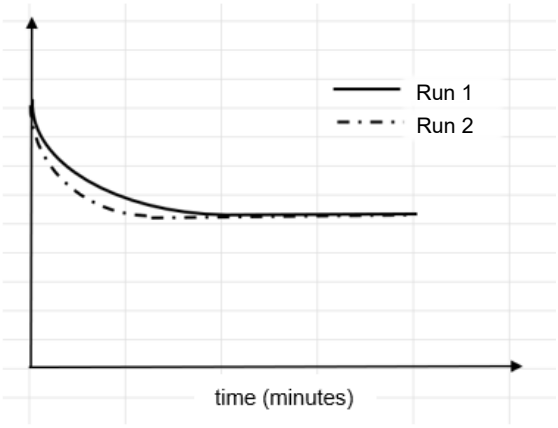
D. the zinc electrode needs to be connected to the negative terminal of the recharger.

Use the following information to answer Questions 10 and 11.

Hydrogen peroxide decomposes with time to form water and oxygen gas. The equation for the reaction is

$$2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$$

A student investigating this reaction used their results to draw the graph shown below. The student has not labelled the vertical axis.



Question 10

The quantity on the vertical axis could be

A. the volume of gas evolved from the flask used.

B. the mass of gas evolved from the flask used.

C. the mass of the flask that the reaction is conducted in.

D. the pH of the hydrogen peroxide during the reaction.

Question 11

The graph shows two different runs of this reaction. It is likely that the only difference between the two runs was that

A. the volume of H_2O_2 was greater in Run 2.

B. the concentration of H_2O_2 was greater in Run 2.

C. Run 2 was conducted without a catalyst.

D. Run 2 was conducted at a higher temperature.

Use the following information to answer Questions 12 and 13.

The decomposition of nitrogen tetroxide is an endothermic reaction, with the equation

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

K_1 = equilibrium constant at 200 °C

K_2 = equilibrium constant at 300 °C

Question 12

A sample of N_2O_4 is added to an empty reactor at 200 °C and sufficient time is allowed for an equilibrium mixture to form. The temperature is then increased to 300 °C.

When the temperature is increased

A. the forward reaction is favoured until the value of Q increases to K_1.

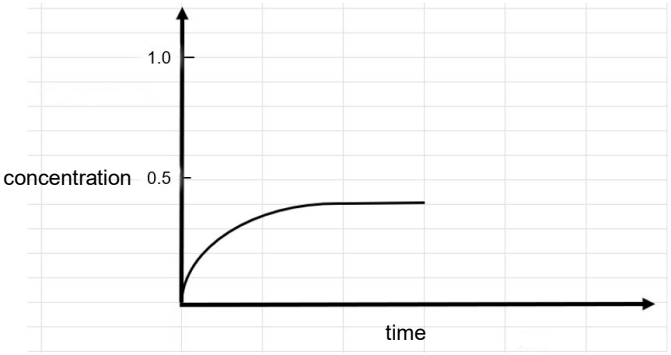
B. the forward reaction is favoured until the value of Q increases to K_2.

C. the back reaction is favoured until the value of Q decreases to K_1.

D. the back reaction is favoured until the value of Q increases to K_2.

Question 13

1.0 mol of N_2O_4 is added to an empty 1.0 L reactor. The concentration of NO_2 formed is shown on the graph below.



The value of K at this temperature is

A. 0.10 M

B. 0.20 M

C. 0.50 M

D. 5.00 M

Question 14

One of the steps in the production of sulfuric acid is the conversion of SO_2 gas to SO_3. The equation for the reaction is

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -ve$$

Consider the following options to answer this question.

I. lowering the temperature

II. adding a catalyst

III. increasing the pressure

IV. adding an inert gas

Of the changes I to IV made to an equilibrium mixture of the gases in the reaction, which will increase the amount of SO_3 present when equilibrium is re-established?

A. I only

B. I and II only

C. I and III only

D. I, III and IV

Question 15

Select the correct procedure to follow when preparing a standard solution in a volumetric flask.

A. Rinse the flask with a solution of similar concentration to the solution being prepared.

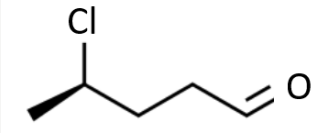
B. Fill the flask to the required mark with deionised water, then add the required mass of solid.

C. Add the required mass of solid to the flask, then heat the flask to remove any moisture.

D. Add the required mass of solid, add enough deionised water to dissolve the solid and then fill to the required mark.

Question 16

The correct IUPAC name for the following compound is



A. 2-chloropentanoic acid.

B. 2-chloropentan-4-al.

C. 4-chloro-1-pentanal.

D. 4-chloropentanal.

Question 17

The strongest form of intermolecular bonding in butan-2-one is

A. dipole–dipole bonding.

B. hydrogen bonding.

C. dispersion forces.

D. covalent bonding.

Question 18

A triglyceride made from only linolenic acid is warmed with methanol and concentrated KOH.

The molecular formula of the biodiesel molecules formed is

A. $C_{17}H_{30}O_2$

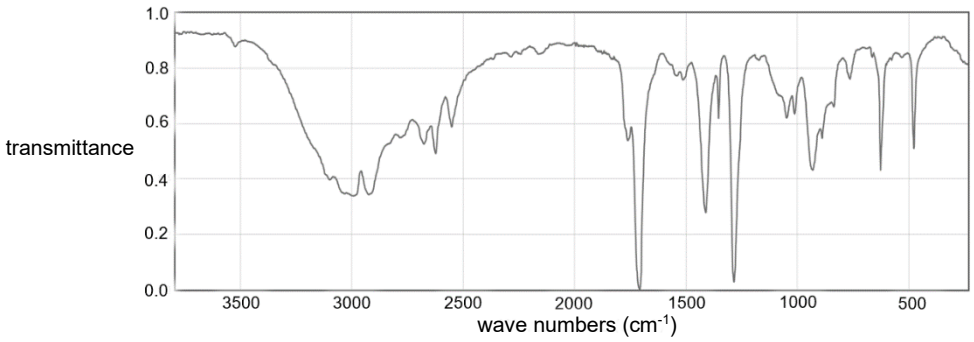
B. $C_{18}H_{30}O_2$

C. $C_{19}H_{32}O_2$

D. $C_{19}H_{34}O_3$

Question 19

A university chemistry student reacts two liquids to produce the ester ethyl propanoate. The student then distils the reaction mixture and condenses the first gas evolved. She then has an infrared spectrum conducted on this fraction. The spectrum obtained is shown below.



The infrared spectrum suggests that

A. the liquid tested might contain ethanol.

B. the liquid tested might contain propanoic acid.

C. the liquid tested is a mixture of ethanol and propanoic acid.

D. the liquid tested is pure ethyl propanoate.

Use the following information to answer Questions 20 and 21.

Some steel wool left outside for several weeks has noticeable signs of rust. A student washes a 1.00 g sample to remove the rust and then dissolves the remaining steel wool in sulfuric acid to convert the iron to Fe^{2+} ions.

The student then places the iron solution under a burette filled with acidified 0.200 M solution of potassium permanganate, $KMnO_4$. The purple permanganate solution turns colourless as the permanganate ions are converted to Mn^{2+} ions. The $KMnO_4$ titre is found to be 15.0 mL.

Question 20

The overall equation for the titration reaction is

A. $MnO_4^-(aq) + 2Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 2Fe^{3+}(aq) + 4OH^-(aq)$

B. $MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$

C. $MnO_4^-(aq) + 5Fe^{2+}(aq) + 4H_2O(l) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 8H^+(aq)$

D. $MnO_4^-(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 5Fe(s) + 4H_2O(l)$

Question 21

In grams, the mass of iron in the 1.00 g sample is

A. 0.164

B. 0.419

C. 0.837

D. 1.67

Question 22

The human body can produce the enzyme caseinase, which acts on casein consumed in dairy products to form amino acids. Some of these amino acids are used in the formation of the protein keratin, a structural material in fingernails and hair.

The reactions involved in the breakdown of casein and the formation of keratin are, respectively

A. denaturation and condensation.

B. hydrolysis and oxidation.

C. hydrolysis and condensation.

D. condensation and oxidation.

Question 23

The molecular formula of the widely used organic compound benzene is C_6H_6.

The degrees of unsaturation of benzene is

A. 2

B. 3

C. 4

D. 6

Question 24

Which pair of amino acids can form hydrogen bonds between the R groups?

A. aspartic acid and serine

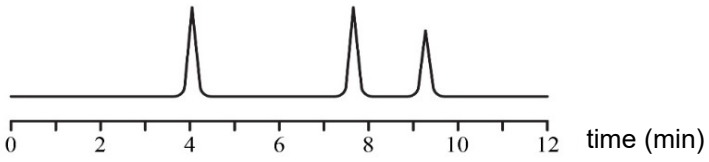
B. aspartic acid and lysine

C. cysteine and leucine

D. serine and leucine

Question 25

The chromatogram below was obtained when a mixture of alcohols was injected into a high-performance liquid chromatography (HPLC) machine.



To determine the concentration of ethanol in the sample, a chemist would need to

A. separate each liquid in the sample and test the purified samples individually.

B. react the mixture with acidified $Cr_2O_7^{2-}$ solution, then retest the sample.

C. change the stationary phase used to ensure ethanol has the shortest retention time.

D. test a series of standard ethanol solutions in the HPLC to compare with the chromatogram above.

Question 26

An enzyme, known as cytochrome c oxidase, catalyses the production of ATP in cellular respiration. It helps body cells produce energy from glucose. When a human is exposed to cyanide ions, the cyanide ions occupy the active site of cytochrome c oxidase and cellular respiration can no longer occur. It is this action of cyanide ions that makes them a dangerous poison to humans.

In the human body, cyanide ions

A. change the shape of the active site of the enzyme.

B. block the enzyme active site from performing its role in respiration.

C. cause the enzyme to denature before it can perform its expected role.

D. catalyse an undesirable reaction in the human body.

Question 27

A university team studies a plant to investigate its suspected medicinal properties. The first step of the team is to blend the leaves and soak them in ethanol to obtain a green extract from the leaves. The extract is then passed into a high-performance liquid chromatography (HPLC) column. The likely use of HPLC in this investigation is to

A. obtain pure samples of the many possible active ingredients in the plant.

B. determine the boiling point of each active ingredient in the plant.

C. determine the concentration of the active ingredient in the plant.

D. identify the active ingredient in the plant.

Question 28

Select the statement that best describes how data should be presented on a scientific poster.

A. Only data that support the author's hypothesis should be shown.

B. Reference should be made to follow relevant health, safety and ethical guidelines.

C. Sources of error and uncertainty should be covered elsewhere.

D. The reader should be able to see the data without any tabulation or organisation.

Question 29

A student conducts a redox titration to determine the vitamin C concentration of a sample of orange juice. The student adds 20 mL aliquots of the same orange juice sample to three different conical flasks. The burette is filled with iodine solution. Starch solution is used as an indicator, turning the orange juice aliquot blue when all the vitamin C has reacted. The titres obtained by the student are shown in the table below.

Run	1	2	3
Titre (mL)	12.6	22.4	18.8

A valid conclusion that can be made from the titres obtained is

A. the repeatability of this experiment is low.

B. the vitamin C concentration varies in different parts of the same solution.

C. the reproducibility of this experiment is low.

D. the titres obtained are not precise, but they might still be accurate.

Question 30

Use the diagram below to answer this question.

Which one of the following is the correct determination of the resolution of the burette and the accepted reading?

	Resolution value (mL)	Accepted reading (mL)
A.	0.05	44.55
B.	0.1	44.60
C.	0.1	44.55
D.	0.1	44.50

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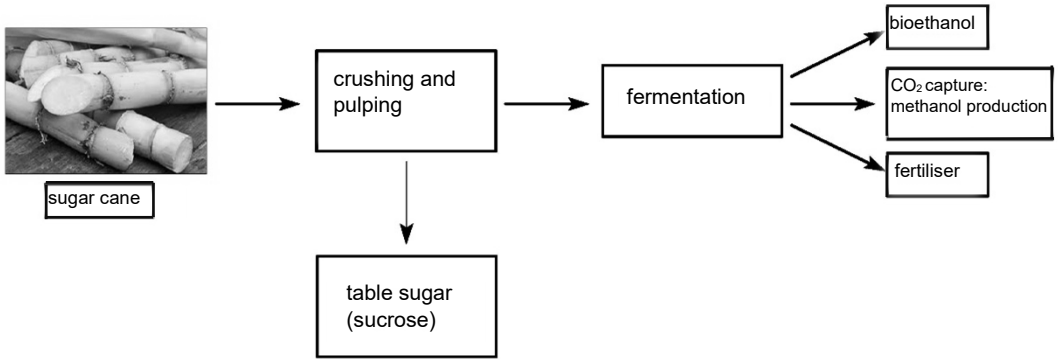
Section B

Instructions

- Answer **all** questions in the spaces provided.
- Write your responses in English.
- 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.

Question 1 (11 marks)

The diagram below is a flowchart for processing sugar cane in a new trial plant that advertises itself as an example of a sustainable industry.

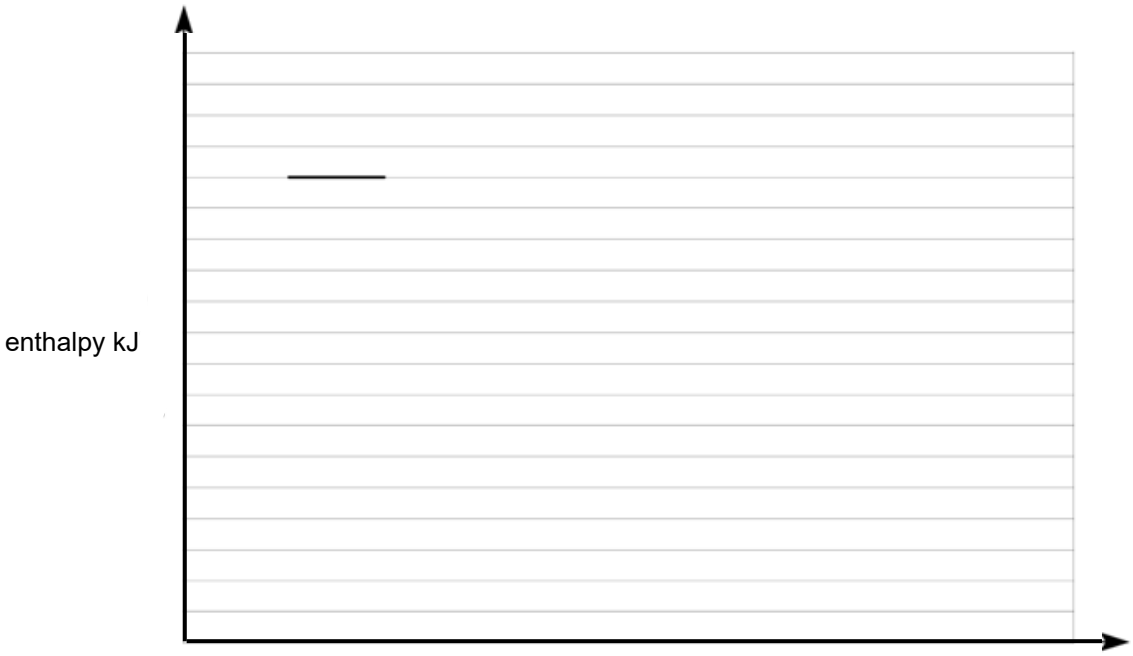


The diagram shows that the sugar cane is crushed and pulped. The juice extracted is high in sucrose and is purified and marketed as table sugar. The pulp waste also has a significant sucrose concentration. It is added to fermentation tanks, where bioethanol is produced and CO_2 is collected and used in the production of methanol. The remaining waste is sold as a fertiliser.

a. Complete the following energy profile diagram for the complete combustion of ethanol. The activation energy for this reaction is 130 kJ.

Include correct scales and full labelling.

2 marks



b. A 3.80 g sample of bioethanol undergoes complete combustion.

i. Calculate the energy released.

1 mark

ii. Calculate the volume of CO_2 produced at SLC.

2 marks

c. The sole function of early bioethanol plants was the fermentation of sugars to ethanol. No other products were considered.

List three ways that this modern plant has improved the sustainability of bioethanol production.

3 marks

d. The initial reaction in the fermentation process is the hydrolysis of sucrose.

i. Name the type of bond broken during the hydrolysis of sucrose.

1 mark

ii. The trial plant includes CO_2 capture technology. Explain why CO_2 is produced in the production of bioethanol. Include an equation to support your answer.

2 marks

Question 2 (10 marks)

a. In the early stages of COVID-19 spreading to Australia, demand for hand sanitiser products soared, leading to shortages of the main active ingredient, alcohol. The two most effective alcohols are ethanol and propan-2-ol.

A high school chemistry class is provided with a sample that is thought to be a mixture of ethanol and propan-2-ol.

i. One student is asked to separate the mixture into its two components. Describe how the student could separate the two liquids and the reason why this separation works.

2 marks

ii. A second student is asked to prove that both liquids are, in fact, alcohols. Explain how the student can use ethanoic acid and other reagents to establish that both liquids contain hydroxyl groups.

2 marks

iii. Having established that the liquids are both alcohols, a third student is asked to conduct laboratory tests to identify which liquid is ethanol and which is propan-2-ol. Explain how the student can test the liquids to identify which alcohol is which. Include in your answer the observations the student is likely to make.

3 marks

Question 2 continues on the next page

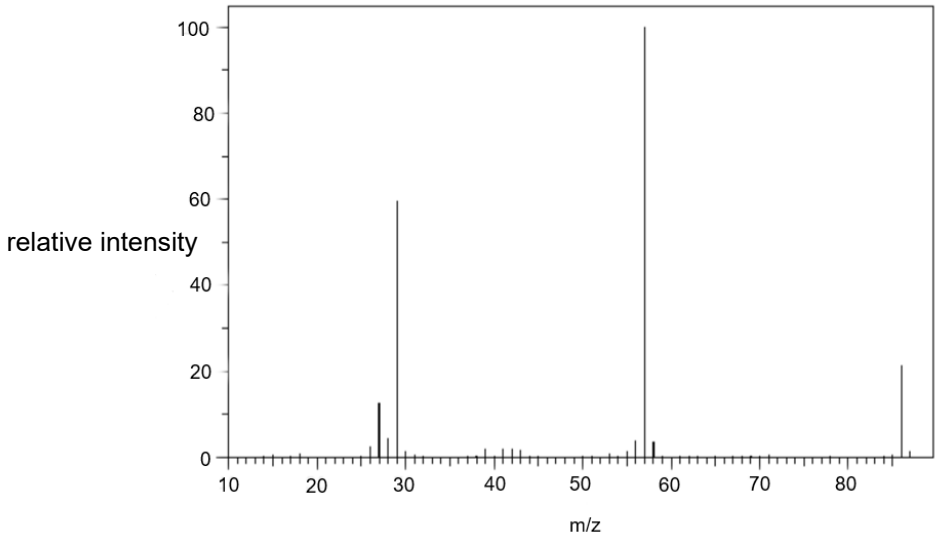
b. A 1.00 g sample of linolenic acid is reacted with 0.20 M iodine solution. Determine the volume of iodine solution required for a complete reaction.
(M(linolenic acid) = 278 g mol^{-1})

3 marks

Question 3 (11 marks)

A chemist uses spectroscopy to identify an unknown organic compound, compound A, that contains carbon, hydrogen and oxygen only.

The mass spectrum of Compound A is shown below.



a. **i.** The mass spectrum shows a parent molecular ion with an m/z ratio of 86. In the table below, suggest a possible molecular formula for Compound A that has 4 carbon atoms and a molecular formula that has 5 carbon atoms.

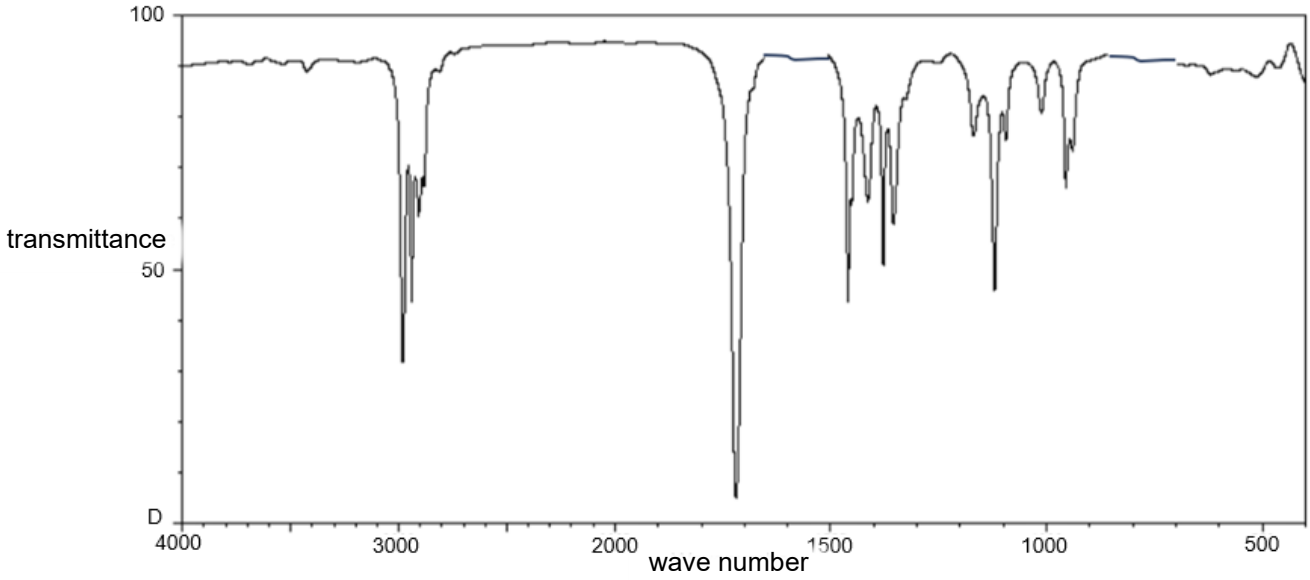
2 marks

Number of carbon atoms	Possible molecular formula
4	
5	

ii. There is a small peak with an m/z ratio of 87. Give a possible explanation for the presence of this peak.

1 mark

The infrared spectrum of Compound A is shown below.



b. State two conclusions you can draw about Compound A from the infrared spectrum.

2 marks

Conclusion 1: _____

_____

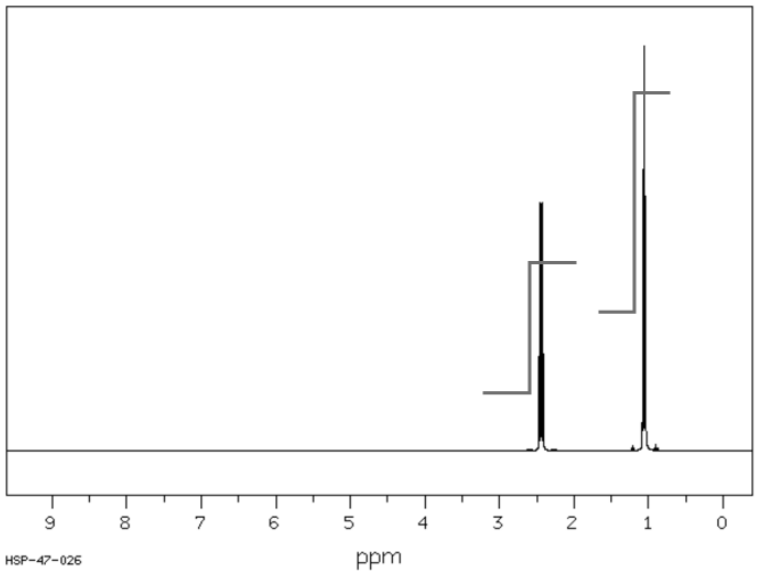
_____

Conclusion 2: _____

_____

_____

The ^{1}HNMR spectrum of Compound A is shown below. The integration curves, showing the area under each peak, are included on the spectrum.



c. **i.** How many hydrogen environments do molecules of Compound A have?

1 mark

_____

ii. Use the integration curves shown to determine the ratio of hydrogen atoms represented by each set of peaks.

1 mark

_____

iii. What is the correct molecular formula for Compound A?

1 mark

_____

d. **i.** Draw a structure of Compound A that is consistent with the data provided.

2 marks

ii. Give the IUPAC name for the molecule you have drawn.

1 mark

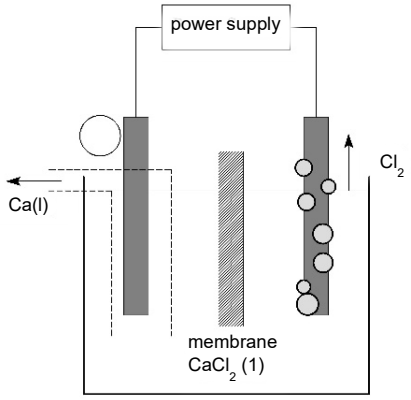
_____

Question 4 (8 marks)

Calcium is the fifth most abundant element in the Earth's crust. However, it is only present in compounds such as calcium carbonate and calcium chloride, never as an element itself.

One of the ways of producing elemental calcium is by electrolysis of molten calcium chloride, $CaCl_2$. A small amount of $BaCl_2$ is added to the electrolyte, lowering the melting point of the $CaCl_2$ from 770 °C to 660 °C.

A sketch of the electrolytic cell used is shown below.



a. **i.** Write an overall equation for the reaction occurring in this cell.

1 mark

_____

ii. In the circle in the diagram above, indicate the polarity of the calcium electrode.

1 mark

iii. What is the likely minimum voltage required for this cell?

1 mark

_____

iv. Explain how the addition of a small amount of $BaCl_2$ to the electrolyte improves the sustainability of this process.

1 mark

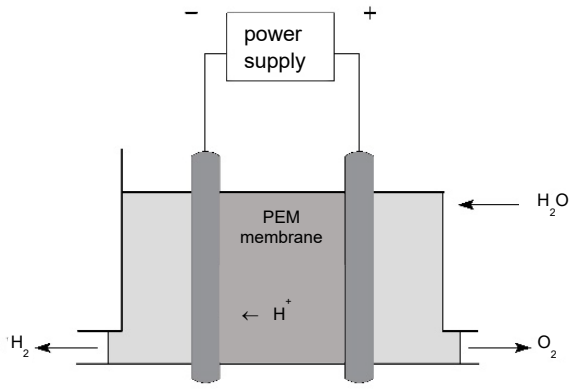
_____

_____

_____

Question 4 continues on the next page

b. A polymer electrolyte membrane (PEM) electrolyser is used to produce hydrogen gas from water. A sketch of the cell is shown below.



i. In the space below, write half-equations for the reactions at each electrode.

2 marks

anode: _____

cathode: _____

ii. State two reasons why the transport of hydrogen gas limits the use of hydrogen gas as a commercial energy source.

2 marks

_____

_____

_____

Question 5 (6 marks)

Modern petrol-driven cars are fitted with a catalytic converter. Toxic exhaust gases pass over the catalytic converter and react to form less harmful products. One section of the converter uses a catalyst that reduces some gases, while another section uses a catalyst that oxidises other gases.

Two of the typical reactions occurring are

$2NO(g) \rightleftharpoons N_2(g) + O_2(g)$ $\Delta H > 0$ N: _____

$CO(g) + O_2(g) \rightleftharpoons CO_2(g)$ $\Delta H < 0$ C: _____

a. On the blank lines beside the equations above, write whether the element listed is oxidised or reduced in its reaction.

2 marks

b. Catalytic converters have long thin tubes in them that are coated with catalysts. The exhaust gas must pass through these tubes before they emerge from the car.

Suggest a reason why catalytic converters are designed this way.

1 mark

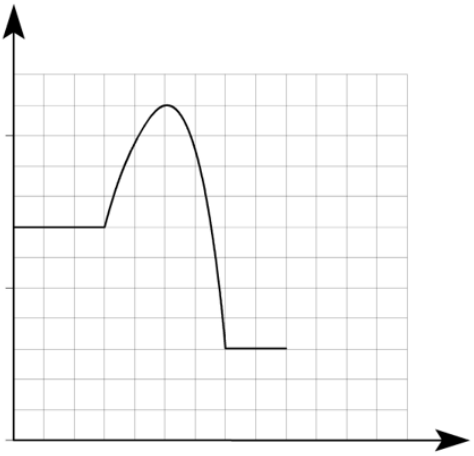
_____

_____

c. The energy profile diagram below is for the uncatalysed reaction between carbon monoxide and oxygen gases to form carbon dioxide.

Draw on this graph the impact of the addition of a catalyst to the reaction.

1 mark



Question 5 continues on the next page

d. When a car first starts, the catalytic converter will be at the same temperature as the outside temperature. Once the car has been running for over 5 minutes, the temperature will have climbed to around 250 °C.

Give two reasons why the composition of the exhaust gas at 250 °C will differ from its effectiveness when the engine is first switched on.

2 marks

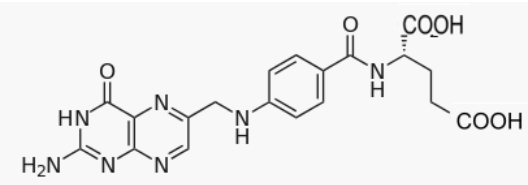
Reason 1:

Reason 2:

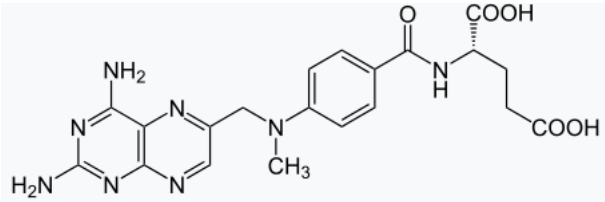
Question 6 (9 marks)

D-methotrexate is used in the treatment of various forms of cancer. It is an example of a competitive enzyme inhibitor. Folic acid normally has a positive function in the body but, for people with cancer, enzymes convert folic acid to chemicals that increase the rate of growth of cancer cells. The use of D-methotrexate inhibits the functioning of enzymes on folic acid, limiting the spread of the cancer.

The structures of both folic acid and D-methotrexate are shown below.



folic acid



D-methotrexate

a. Refer to the structure of D-methotrexate provided to explain what an optical isomer is.

2 marks

b. **i.** Enzymes in the body can convert folic acid to chemicals that increase the rate of cancer cell formation.

Refer to the structures provided on the previous page to explain the mechanism by which D-methotrexate limits this harmful reaction.

3 marks

ii. Researchers have found that L-methotrexate has no impact on any reactions in the human body. Explain why this finding is not unexpected.

2 marks

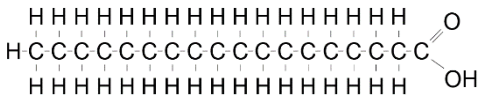
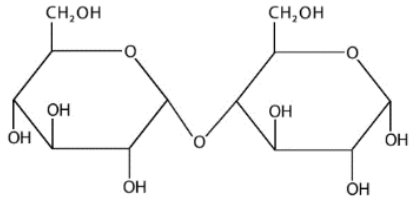
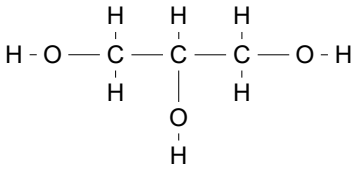
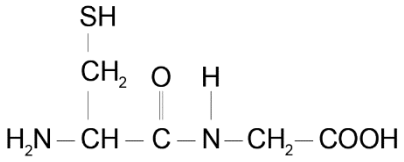
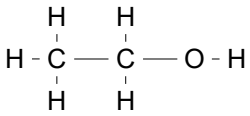
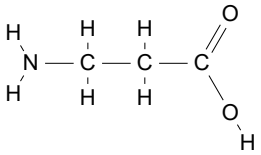
c. A researcher suspects that her sample of folic acid has been contaminated with methotrexate. The melting points of folic acid and methotrexate are, respectively, 250 °C and 195 °C.

Explain how a melting point test of the sample could be used to determine if the folic acid sample has been contaminated.

2 marks

Question 7 (7 marks)

Consider the following six compounds.

 Compound A	 Compound B
 Compound C	 Compound D
 Compound E	 Compound F

a. Which two compounds can be combined to form biodiesel?

1 mark

_____

b. Which two compounds can be combined to form a triglyceride?

1 mark

_____

c. The combustion of 1.0 g of which compound is likely to release the most energy?

1 mark

_____

d. How many peptide bonds are present in the molecules shown?

1 mark

_____

e. Name the product formed from the hydrolysis of compound B.

1 mark

_____

f. Draw the zwitterion of one of the compounds listed on the previous page.

1 mark

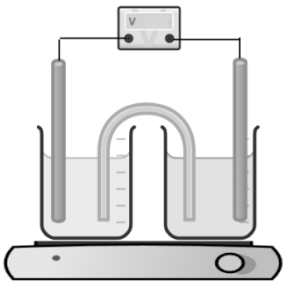
g. Which of the compounds listed above is likely to have the lowest polarity?

1 mark

Question 8 (13 marks)

A student is investigating the effect of temperature on the voltage produced in a galvanic cell.

The set-up of the experiment is shown below, where the galvanic cell is placed on a hot plate. A voltmeter is included in the circuit and a thermometer is placed in each half-cell.



The student's notes and measurements are shown below.

***Aim**: To investigate the impact of temperature on the voltage of a galvanic cell.*

***Hypothesis**: That voltage will increase with temperature because the particles will be moving faster.*

Half-cells used: 0.50 M $NiSO_4$ with nickel electrode

0.10 M $AgNO_3$ with silver electrode

Procedure

1. Add 60 mL of $NiSO_4$ to a beaker. Place a nickel electrode in the beaker.

2. Add 60 mL of $AgNO_3$ to a beaker. Place a silver electrode in the beaker.

3. Connect both beakers with a salt bridge.

4. Create a circuit between the beakers with electrical leads and a voltmeter.

5. Record the temperature and the voltage.

6. Turn the hot plate on and record the voltage and temperature every 4.0 minutes.

Temperature (°C)	***Voltage (V)***
16	*0.91*
24	*0.89*
31	*0.88*
39	*0.86*
46	*0.84*

***Conclusion**: Hypothesis has not been validated. The experiment needs to be repeated with new solutions because the results are not possible.*

a. State the variables in the experiment.

2 marks

Dependent variable:

_____

A controlled variable:

_____

b. **i.** Write a half-equation for the reaction occurring at the positive electrode in this cell.

1 mark

_____

ii. A mass change of 0.0587 g occurs at the nickel electrode. Determine the mass change at the silver electrode.

3 marks

_____

_____

_____

_____

c. **i.** Comment on the student's conclusion.

2 marks

_____

_____

_____

ii. State an alternative conclusion that better reflects the data obtained.

2 marks

_____

_____

_____

Question 8 continues on the next page

d. Does it matter that the student measured the voltage at uneven temperature increments? Explain your answer.

2 marks

e. Suggest one change you would make to improve the experiment.

1 mark

Question 9 (10 marks)

Ethene is the most important organic chemical, by tonnage, that is manufactured. It is the building block for a vast range of chemicals, from plastics to antifreeze solutions and solvents. Annual world production is over 130 million tonnes and accounts for over 1.2% of global energy consumption.

Source from: Essential Chemical Industry, <https://www.essentialchemicalindustry.org/chemicals/ethene.html#:~:text=Ethene%20(ethylene)%20is%20the%20most,to%20antifreeze%20solutions%20and%20solvents>

Currently, most ethene is produced from ethane in a reversible reaction that forms a carbon-to-carbon double bond. The equation for the reaction is

$$C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g) \qquad \Delta H > 0$$

The conditions used for this reaction are:

- 850 °C – 950 °C
- pressure of ethane 50 kPa
- addition of steam to the reaction mix
- SiO_2/Ni catalyst.

At temperatures above 1000 °C, side reactions occur to the point where the ethene yield is low. Although this appears to be a simple one-step production process, the energy required to form a C=C double bond is very high

a. The reaction conditions listed on the previous page must be used if a viable yield is to be obtained in this reaction.

i. Explain why a low pressure of 50 kPa is used.

2 marks

ii. Explain why lower temperatures are not used.

2 marks

b. The ethene industry consumes large amounts of energy. One of the first changes made by industries when moving to the production of green ethene is to switch from gas heating to electrical energy. Explain how this change might improve the sustainability of the ethene industry.

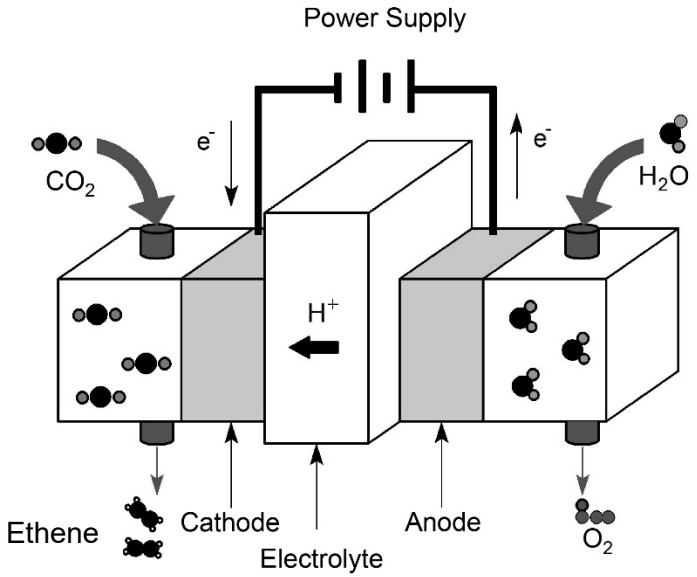
2 marks

Question 9 continues on the next page

c. A bigger change currently under trial is the production of ethene from the electrolysis of carbon dioxide gas. The overall equation for this cell is

$$2CO_2(g) + 2H_2O(l) \rightarrow C_2H_4(g) + 3O_2(g)$$

A sketch of the cell used shown below.



i. Write a balanced half-equation for the reaction of CO_2 to C_2H_4. (States are not required.)

1 mark

_____

ii. What is the oxidation state change of the carbon atoms in this reaction?

1 mark

_____

iii. Outline two green chemistry principles that support this method producing ethene over the more conventional process outlined in **part a.**

2 marks

_____

_____

_____

_____

Question 10 (5 marks)

Sustainability is a key financial and ethical focus of the chemical industry. Manufacturers are aware that an understanding of the principles of green chemistry can be used to improve the efficiency of production and minimise the impact on the environment.

One of the first decisions made in the production of some chemicals is the choice of a pathway. The vinegar industry can be used as an example. The active ingredient in vinegar is ethanoic acid. Pathway 1, described below, is the high-volume commercial way of making ethanoic acid from crude oil. Pathway 2 is to use a microbial process whereby microorganisms catalyse the reactions.

Pathway 1: Ethanoic acid can be made by the petrochemical industry, using ethane as a starting point.

Pathway 2: Ethanoic acid can be made from biomass, such as waste from the wine industry, with the fermentation of grape waste to ethanol as the starting point.

Outline the chemicals and reagents used in both processes and explain how Pathway 2 can offer sustainability improvements.

Pathway 1: ethane to ethanoic acid _____

_____

_____

Pathway 2: grape waste to ethanoic acid _____

_____

_____

Sustainability improvements: _____

_____

_____

_____

_____

_____