Neap:

Trial Examination 2013

VCE Chemistry Units 3 & 4

Written Examination

Question and Answer Booklet

Reading time: 15 minutes
Writing time: 2 hours 30 minutes

Student's Name: _____

Teacher's Name: _____

Structure of Booklet

Section	Number of questions	Number of questions to be answered	Marks	Suggested time (minutes)
A Multiple-choice	30	30	30	40
B Short-answer	8	8	95	110
			Total 125	Total 150

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

Materials supplied

Question and answer booklet of 28 pages.
Data booklet of 11 pages.
Answer sheet for multiple-choice questions.

Instructions

Please ensure that you write **your name** and your **teacher's name** in the space provided on this booklet and in the space provided on the answer sheet for multiple-choice questions.
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 booklet and hand them in.

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

Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2013 VCE Chemistry Units 3 & 4 Written Examination.

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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.

Question 1

Which of the following occurs during the analysis of a sample using atomic absorption spectroscopy?

A. a change in molecules as their covalent bonds vibrate and rotate

B. a change in the spin alignment of certain carbon nuclei placed in a strong magnetic field

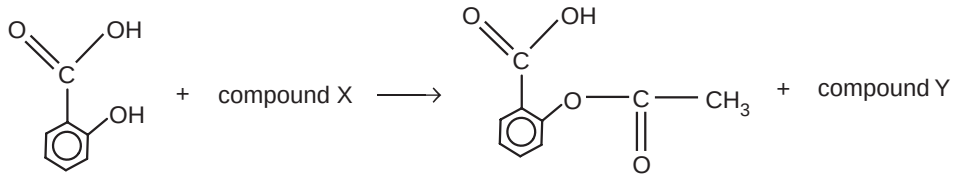
C. deflection of charged particles by a combination of electric and magnetic fields

D. movement of electrons in gaseous atoms to an excited state

Use the following information to answer Questions 2 and 3.

Question 2

The synthesis of aspirin can be represented by the following equation:



The formulas of compound X and compound Y are, respectively,

A. $C_4H_6O_3$ and $C_2H_4O_2$

B. $C_2H_4O_2$ and H_2O_2

C. $C_2H_6O_2$ and H_2O

D. C_3H_6O and CH_4

Question 3

After a synthesis of aspirin in the laboratory, a student wanted to find the percentage conversion to aspirin by sampling the solution in the reaction vessel after the reaction.

Consider the following techniques.

I acid–base titration

II thin-layer chromatography

III UV-visible spectroscopy

Which of the above techniques could be used to determine the amount of aspirin produced?

A. I only

B. III only

C. I and III only

D. I, II and III

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Question 4

The fatty acid, erucic acid, is found in a variety of plants, particularly in members of the *Brassica* family such as broccoli. Molecules of erucic acid contain 22 carbon atoms. It is found that 120 g of bromine gas reacts with 0.75 mole of erucic acid.

Based on the data provided it can be concluded that the formula of erucic acid is

A. $C_{21}H_{43}COOH$

B. $C_{21}H_{41}COOH$

C. $C_{21}H_{39}COOH$

D. $C_{21}H_{37}COOH$

Use the following information to answer Questions 5 and 6.

Sucrose is broken down into simple sugars by the enzyme invertase. Experiments were conducted by mixing sucrose solution and invertase at different pH conditions. All other conditions were identical, with the temperature at 55°C. The results of the experiments are shown in this table below.

Test tube number	pH of solution in test tube	% of sucrose remaining after 30 mins
1	3.0	49
2	4.0	21
3	5.0	10
4	6.0	18
5	7.0	51

Question 5

Which one of the following statements about the experiment is correct?

A. The activity of the enzyme always increases as the hydroxide ion concentration increases.

B. The maximum activity of invertase occurs when $[OH^-] = [H_3O^+] = 10^{-5}$ M.

C. Changing the pH had no effect on the configuration of the active site of this enzyme.

D. The tertiary structure of the enzyme is affected when the pH is altered.

Question 6

If the experiment in test tube 3 was repeated under identical conditions but at 10°C, what percentage of sucrose is likely to remain after 30 minutes?

A. less than 10%

B. 10%

C. more than 10%

D. The result cannot be predicted from the data supplied.

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Question 7

The following information relates to an organic compound X:

- Compound X mixes with $Br_2(aq)$ to produce a colourless solution.
- Compound X undergoes extended oxidation using an acidified dichromate solution to produce an organic product which is not a carboxylic acid.
- Compound X does not react with Na_2CO_3 to evolve a colourless gas.

Which of the following is most likely to be the formula of Compound X?

A. $CH_3CHCHCH_2OH$

B. $CH_3CHCHCOOH$

C. $HOCH_2CH_2CH_2CH_3$

D. $CH_3CH(OH)CHCHCH_2CH_3$

Question 8

Chlorine gas and water react according to the following equation:

$$Cl_2(g) + H_2O(l) \rightarrow HCl(aq) + HOCl(aq)$$

In this reaction, chlorine undergoes

A. oxidation only.

B. reduction only.

C. both oxidation and reduction.

D. neither oxidation nor reduction.

Question 9

Threonine and hydroxproline are amino acids. In a thin-layer chromatography (TLC) analysis of several amino acids, the solvent front moved twice the distance moved by the threonine spot. The hydroxyproline spot moved 2 cm further than the threonine spot.

If the solvent front was 12 cm from the origin, what is the R_f value of hydroxyproline in these conditions?

A. 0.17

B. 0.33

C. 0.67

D. 0.80

Question 10

Which of the following species would be expected to be present in the highest concentration in a solution of methanamine?

A. OH^-

B. H_3O^+

C. $CH_3NH_3^+$

D. CH_3NH_2

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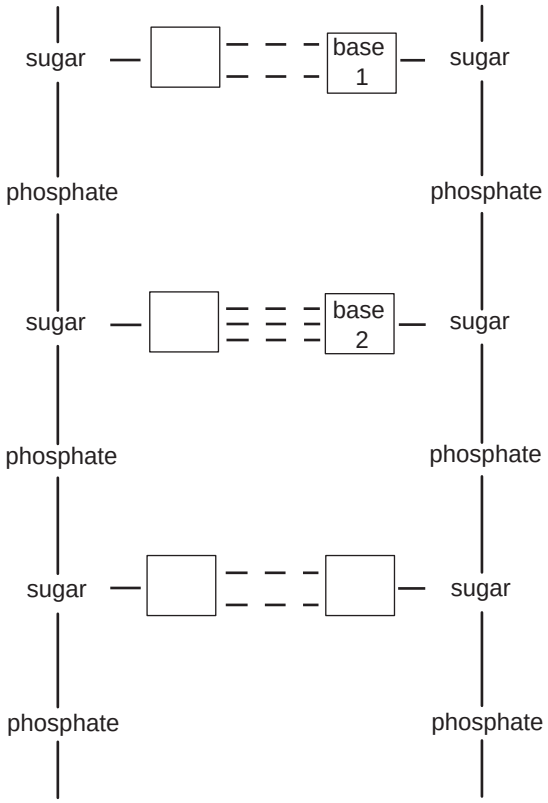
Use the following information to answer Questions 11 and 12.

The diagram below shows a simplified representation of part of a fragment of double-stranded DNA which has 500 base pairs. Two different bases are numbered.



Question 11

In relation to the diagram above, which one of the following options is correct?

	Level of DNA structure shown	Number of nucleotides shown
A.	primary only	3
B.	primary and secondary	3
C.	primary only	6
D.	primary and secondary	6

Question 12

The ratio of base 1 to base 2 in the 500-base-pair fragment of DNA is 17:8.

How many cytosine bases are in the 500 base pairs?

A. 80
B. 160
C. 320
D. 340

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Question 13

How many mole of butane at SLC will occupy the same volume as 0.238 g of propene at STP?

A. 5.18×10^{-3}

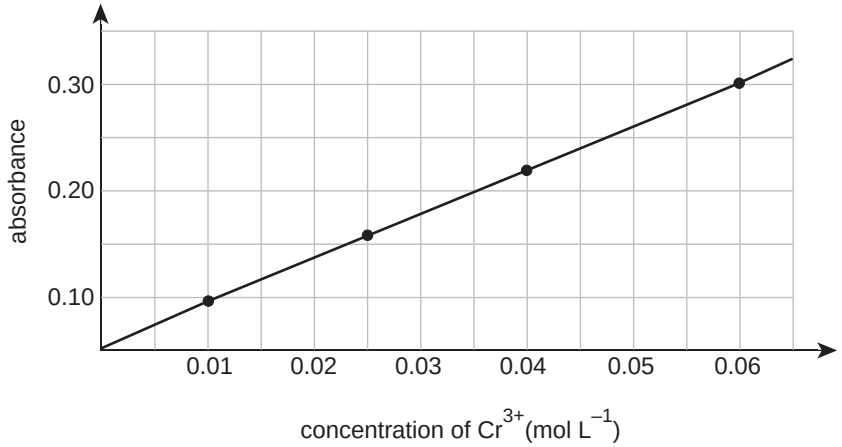
B. 5.41×10^{-3}

C. 5.66×10^{-3}

D. 6.20×10^{-3}

Question 14

The percentage of chromium in a steel sample can be determined quickly and accurately using atomic absorption spectroscopy (AAS). In conducting an analysis of the chromium in a steel sample using AAS, four chromium standards were prepared and the calibration curve (shown below) was obtained at a suitable wavelength.



A solution was prepared by dissolving 15.0 g of steel containing 6.02% Cr by mass in acid, and making the solution up to a total volume of 300.0 mL.

The expected absorbance reading for the dissolved steel solution is closest to

A. 0.1

B. 0.2

C. 0.3

D. a value beyond the range of the calibration curve shown.

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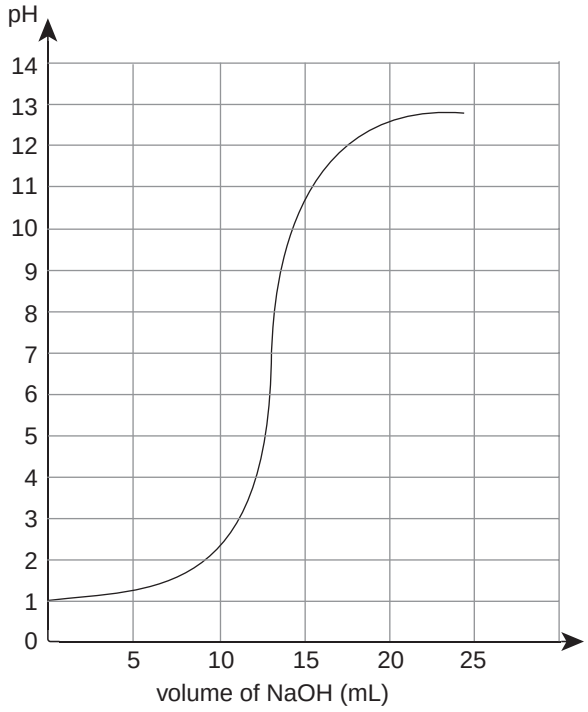
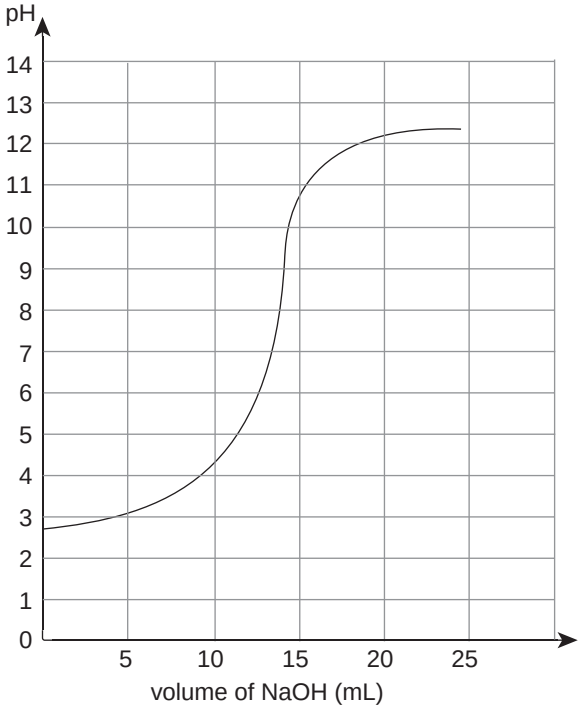
Question 15

Which of the following graphs shows the changes in pH expected when 20.00 mL of an approximately 0.1 M solution of propanoic acid is titrated with a 0.150 M NaOH solution?

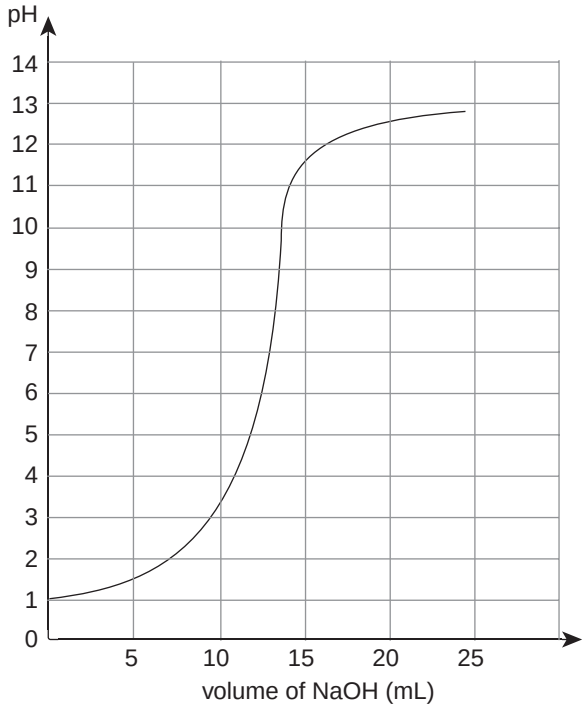
A.



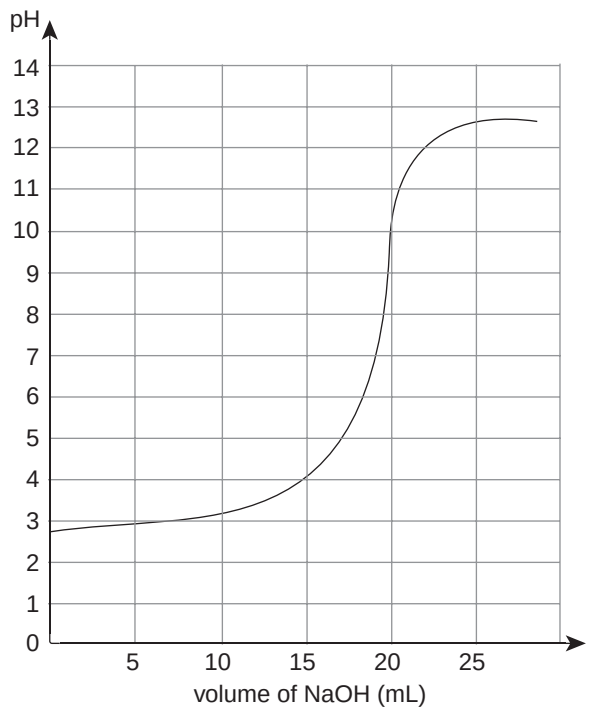
B.



C.



D.



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Question 16

Methane gas may be produced in a number of ways, including:

I the breakdown of plant and animal material over millions of years deep below ground level

II direct conversion of carbon dioxide and water using bacteria in a solar-powered electrolytic cell

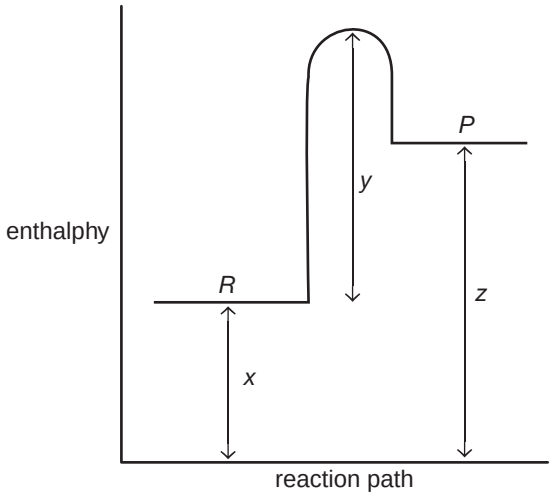
III the decay of organic material in the absence of oxygen in special digesters

Which of the above methods is likely to provide a renewable source of fuel for the future?

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

Question 17

Consider this energy profile for a particular reaction:



Which of the following is a correct conclusion from the data presented?

A. It takes less energy to break the bonds in the reactants than the energy released when the products form.
B. The activation energy of the reverse reaction is $x + y$.
C. Energy equivalent to $x + y - z$ is absorbed during the reaction.
D. The magnitude of the heat of reaction is equal to $z - x$.

Question 18

Which one of the following is a feature of a secondary galvanic cell?

A. When recharging the cell, the connection to the power supply should be positive to negative, and negative to positive.
B. When the cell is discharging, oxidation occurs at the positively charged electrode.
C. The cell can be recharged using an external power source delivering a voltage equal to the secondary cell's voltage.
D. The products of the discharge reaction remain in contact with the electrodes.

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Question 19

11.1 g of calcium chloride was added to 60.0 g of water at 25.0°C. The temperature rose to 57.5°C.
$M(CaCl_2) = 111$ g mol^{-1}.

Based on this experiment, the magnitude of the heat of solution of calcium chloride, in kJ mol^{-1}, is closest to

A. 0.73
B. 56
C. 82
D. 144

Question 20

A chemical reaction occurs between ammonia and oxygen, as shown by the equation:

Reaction I $\quad 4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$

Thermochemical data relevant to the NH_3/O_2 reaction is shown below.

$2NO(g) + 3H_2(g) \rightarrow 2NH_3(g) + O_2(g) \qquad \Delta H = -272$ kJ mol^{-1}

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g) \qquad \Delta H = -484$ kJ mol^{-1}

Given the data above, the value of ΔH, in kJ mol^{-1}, for Reaction I is

A. –908
B. –152
C. +152
D. +908

Question 21

The K_w of pure water at 0°C is 1.14×10^{-15} M^2. The K_w of pure water at 25°C is 1.00×10^{-14} M^2.

Consider the following statements:

I The pH of the water at 0°C is 7.47 and it is basic.

II At 0°C, $[OH^-] = 3.38 \times 10^{-8}$ M, and this is greater than the $[H_3O^+]$.

III The self-ionisation reaction of water is endothermic, and the position of equilibrium greatly favours the reactants.

IV Increasing the temperature of the water would decrease its pH, but it would remain neutral.

Which of the statements above are consistent with the K_w values provided?

A. I and II only
B. II and III only
C. III and IV only
D. II, III and IV only

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Use the following information to answer Questions 22 and 23.

Hydrogen peroxide (H_2O_2) is a strong oxidant as well as being a weak reductant. It can be predicted that solutions of hydrogen peroxide will undergo a decomposition reaction.

Question 22

Consider the following statements:

I The equilibrium constant for the decomposition reaction is about 10^3 at 25°C.

II The ΔH for the decomposition reaction is –1994 kJ mol^{-1}.

Which of the statements above could be used to explain why 1 M solutions of hydrogen peroxide can be stored at 25°C without decomposition for weeks?

A. I only
B. II only
C. both I and II
D. neither I nor II

Question 23

A galvanic cell could be set up using hydrogen peroxide as the reactant in both half-cells.

Which one of the following is correct with respect to this galvanic cell?

	Electrode at which the oxidation number of oxygen in H_2O_2 decreases	**Maximum voltage of the cell under standard conditions (volts)**
A.	anode	1.09
B.	cathode	1.09
C.	anode	2.45
D.	cathode	2.45

Question 24

Consider the following reaction:

$$2X(g) + O_2(g) \rightleftharpoons 2Z(g) \qquad \Delta H = -220 \text{ kJ mol}^{-1}$$

Which of the procedures listed below is likely to decrease the rate of the reaction?

A. using air instead of pure oxygen
B. adding a Pt catalyst
C. decreasing the volume of the reaction vessel
D. increasing the temperature

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Use the following information to answer Questions 25 and 26.

The molar enthalpy of combustion of the biochemical fuel methyl palmitate, $C_{17}H_{34}O_2$, was determined in a bomb calorimeter which had been previously chemically calibrated using the combustion of benzoic acid. The data from the experiment is shown below.

molar enthalpy of combustion of methyl palmitate	-1.07×10^4 kJ mol^{-1}
molar mass of methyl palmitate	270 g mol^{-1}
mass of methyl palmitate burnt in calorimeter	0.378 g
temperature change due to burning methyl palmitate	4.53°C

Question 25

The calibration factor of the calorimeter, in kJ °C^{-1}, is closest to

A. 2.50
B. 3.00
C. 3.50
D. 4.00

Question 26

Consider the following situations:

I The volume of water surrounding the reaction chamber in the calorimeter was only 90% of the volume specified for the operation of the calorimeter.

II The outer layer of insulation on the calorimeter was removed.

During the calibration of the calorimeter using benzoic acid combustion, which of the above situations would result in a calculated calibration factor which is greater than the actual value?

A. I only
B. II only
C. both I and II
D. neither I nor II

Question 27

The metal platinum will not dissolve in nitric acid or hydrochloric acid under standard conditions. However, platinum will dissolve in a mixture of the two acids. The relevant half-reactions are:

$$PtCl_4^{2-}(aq) + 2e^- \rightarrow Pt(s) + 4Cl^-(aq) \qquad E^0_1$$

$$Pt^{2+}(aq) + 2e^- \rightarrow Pt(s) \qquad E^0_2$$

$$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O(l) \qquad E^0_3$$

Commencing with the lowest value, what is the order of standard reduction potentials which is consistent with the information about dissolving platinum?

A. $E^0_1 < E^0_3 < E^0_2$
B. $E^0_3 < E^0_2 < E^0_1$
C. $E^0_2 < E^0_1 < E^0_3$
D. $E^0_2 < E^0_3 < E^0_1$

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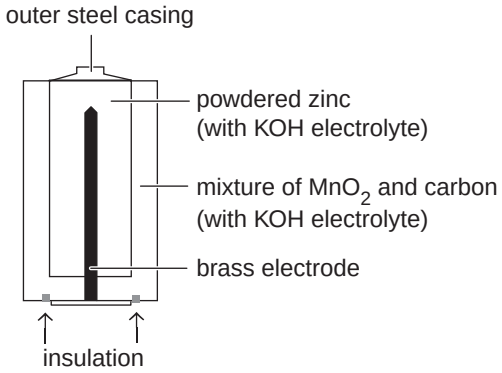
Use the following information to answer Questions 28 to 30.

The alkaline cell is used as a small-scale, portable source of power. It is non-rechargeable. The design of the cell is shown in the diagram below.



Question 28

If the zinc was in pellet form rather than powder, which one of the following would be different?

A. the total amount of electrical energy available from the cell
B. the time it takes to deliver the cell's electrical energy
C. the equilibrium yield of the products of the overall cell reaction
D. the difference between the energy of the reactants and the energy of the products

Question 29

The anode and cathode compartments are divided by a separator.

Which one of the following is likely to be a feature of the separator?

A. porous to allow movement of ions but prevents the mixing of the reactants in the cell
B. made from metal with small holes in it to allow the movement of electrons and ions
C. non-porous and non-reactive material preventing the leakage of the KOH electrolyte
D. does not react with zinc but catalyses the reaction between zinc and MnO_2

Question 30

The electrode half-reactions during production of electricity can be represented by the following equations:

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$$

$$2MnO_2(s) + H_2O(l) + 2e^- \rightarrow Mn_2O_3(s) + 2OH^-(aq)$$

Which one of the following is correct?

A. The pH around the cathode is likely to increase during discharge.
B. MnO_2 is the reductant and it undergoes oxidation at the anode.
C. The mass of zinc will decrease as it undergoes reduction at the cathode.
D. Water is the reductant and MnO_2 is the oxidant at the negative electrode.

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SECTION B: SHORT-ANSWER QUESTIONS

Instructions for Section B

Answer **all** questions in the spaces provided.

To obtain full marks for your responses you should

- give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be given full marks.
- show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.
- make sure chemical equations are balanced and that the formulas for individual substances include an indication of state, for example $H_2(g)$; NaCl(s).

Question 1 (14 marks)

Over thirty million tonnes of the monomer chloroethene (C_2H_3Cl) are produced worldwide annually.

The first reaction in its synthesis occurs using an iron(III) chloride catalyst and is shown by the following equation:

$$\text{Reaction I} \quad C_2H_4(g) + Cl_2(g) \rightarrow C_2H_4Cl_2(g)$$

a. Draw the structural formula of the product of Reaction I, and name this product. 2 marks

_____

b. The gaseous product from the Reaction I is heated in a furnace to 500°C at 30 atm pressure to produce the second reaction:

$$\text{Reaction II} \quad C_2H_4Cl_2(g) \rightleftharpoons C_2H_3Cl(g) + HCl(g) \qquad \Delta H > 0$$

The conversion to products is approximately 60%.

i. Explain one change in conditions of the reaction vessel which would increase the percentage conversion. 2 marks

_____

_____

_____

_____

ii. State one disadvantage for the manufacturer if the new reaction condition listed in part **i.** was used. 1 mark

_____

_____

_____

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iii. The HCl(g) in the products of Reaction II is recycled in a highly exothermic reaction which is shown in the equation below.

$$2C_2H_4(g) + 2HCl(g) + O_2(g) \rightarrow 2C_2H_3Cl(g) + 2H_2O(g)$$

Outline how the waste heat generated in this reaction could be used in the industrial manufacture of chloroethene. 1 mark

_____

_____

_____

c. Another method to produce chloroethene uses the highly exothermic reaction shown below.

$$C_2H_2(g) + HCl(g) \rightarrow C_2H_3Cl(g)$$

This method has many advantages over the use of Reactions I and II, including:

- higher yield
- higher product purity
- lower costs for waste treatment

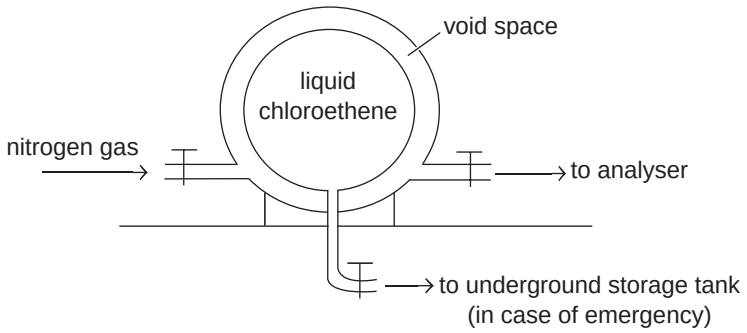
Given these advantages, suggest one reason why chloroethene has been manufactured by predominantly Reactions I and II over the last fifty years. 1 mark

_____

_____

d. As chloroethene is extremely hazardous to human health and is highly flammable, it is stored as a liquid in a high-pressure sphere surrounded by a larger sphere with a void space in between.

The set-up is shown in the simplified diagram below.



Nitrogen gas is flushed through the space and analysed to detect any leaks of chloroethene.

i. Why is nitrogen gas used to flush the void space rather than oxygen gas? 1 mark

_____

_____

_____

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ii. Outline how gas chromatography could be used to identify the chloroethene **and** its concentration when a leak is suspected. 3 marks

_____

_____

_____

_____

_____

_____

_____

e. Chloroethene is the monomer used to produce polyvinyl chloride (PVC).

i. Draw a section of a molecule of PVC. 1 mark

ii. Unwanted products made of PVC are often discarded in landfill waste, leading to the formation of extremely toxic compounds known as dioxins. For example, a dioxin with the formula $C_{12}H_4Cl_4O_2$ is produced during burning of waste at low temperatures.

Explain why dioxins are much less likely to form during high temperature incineration over 900°C. 2 marks

_____

_____

_____

_____

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Question 2 (10 marks)

Permanganate ions (MnO_4^-) and oxalate ions ($C_2O_4^{2-}$) may react according to the following equation:

$$5C_2O_4^{2-}(aq) + 2MnO_4^-(aq) + 16H^+(aq) \rightarrow 10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$$

a. Relevant electrochemical data for the two half-equations involved is shown below.

$$MnO_4^-(aq) \rightarrow Mn^{2+}(aq) \qquad E^0 = +1.51 \text{ V}$$

$$CO_2(g) \rightarrow C_2O_4^{2-}(aq) \qquad E^0 = -0.43 \text{ V}$$

i. Write the balanced half-equation for the oxidation process occurring in the reaction between permanganate and oxalate ions in an acidified solution. 1 mark

_____

ii. Explain why the E^0 values provided indicate that a reaction should occur between permanganate and oxalate ions in an acidified solution. 2 marks

_____

_____

_____

_____

iii. A student mixed the required reactants in a test tube and waited for the purple-coloured MnO_4^- ion to be converted to the pale pink Mn^{2+} ion. No colour change was evident.

Suggest a possible reason for this. 1 mark

_____

_____

b. Under suitable conditions, the reaction was used to standardise a solution of acidified potassium permanganate by titration and the following results were recorded:

Aliquot volume of $C_2O_4^{2-}(aq)$ solution in conical flasks	25.00 mL
Average titre of $MnO_4^-(aq)$ solution to reach endpoint	14.28 mL
The concentration of the $MnO_4^-(aq)$ solution was calculated to be	0.1575 M

i. Calculate the molarity of the $C_2O_4^{2-}(aq)$ solution used in the titration. 3 marks

_____

_____

_____

_____

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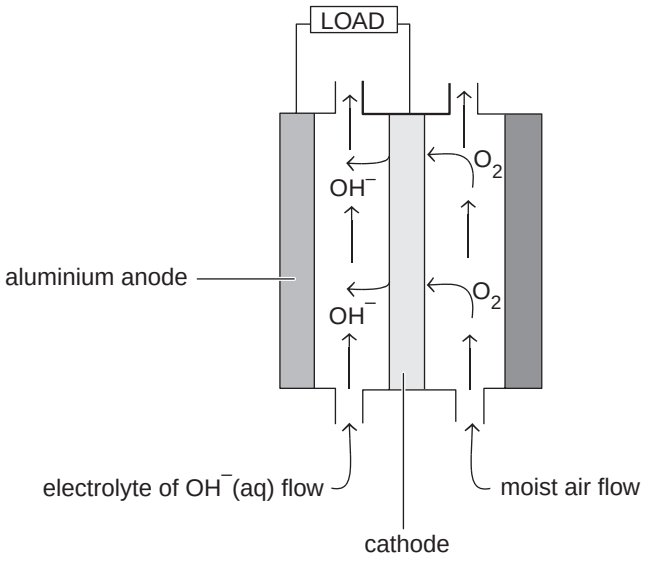
ii. The table below shows possible effects of rinsing the glassware used for the titration.

Indicate the effect on the calculated concentration of the acidified potassium permanganate solution if the piece of glassware used was rinsed with water only, and not dried before use. (*Indicate your choices by placing a tick in the appropriate column of the table for each piece of glassware*.) 3 marks

Piece of glassware left wet with water	**Effect on calculated concentration of acidified MnO_4^-(aq) solution**		
	Higher than actual value	**Same as actual value**	**Lower than actual value**
25.00 mL pipette			
burette			
conical flask			

Question 3 (13 marks)

The aluminium–air cell is a possible future power source for electric vehicles, laptop computers and mobile phones. A simplified diagram of the cell design is shown below. As the cell operates, oxygen from the moist air flow is reduced at the cathode. Aluminium ions formed at the anode react with hydroxide ions to produce aluminium hydroxide precipitate.



a. Write a half-equation for the redox reactions occurring at the

i. cathode 1 mark

_____

ii. anode 1 mark

_____

b. The cathode is electrically conductive, inert and coated in a catalyst.

From the information provided, what other property must this electrode have? 1 mark

_____

c. The aluminium–air cell has been described as 'part fuel cell, part primary cell'.

In what way is the aluminium–air cell similar to:

i. a fuel cell? 1 mark

_____

_____

ii. a primary cell? 1 mark

_____

_____

d. An early problem in the development of the cell was the aluminium hydroxide forming a gel-like material on the anode.

How would this affect the operation of the cell? 2 marks

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e. The aluminium hydroxide in modern cells forms a powdery precipitate due to a special additive in the electrolyte. If the aluminium–air cell is to be a sustainable energy source for the future, the aluminium hydroxide will need to be recycled to produce aluminium metal for use as the anode. A chemistry student proposed that the aluminium hydroxide collected from the cell could be dissolved in acid to produce aluminium ions, as shown in the equation below:

$$Al(OH)_3(s) + 3H^+(aq) \rightarrow Al^{3+}(aq) + 3H_2O(l)$$

The aluminium ions could then be used in an electrolytic cell to produce aluminium metal.

Analyse the viability of this proposal. 2 marks

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f. Aluminium metal is manufactured industrially by electrolysis in the Hall cell, with the overall equation for the cell's chemical reaction being:

$$2Al_2O_3(l) + 3C(s) \rightarrow 4Al(s) + 3CO_2(g)$$

Calculate the volume of carbon dioxide gas at 20°C and 100 000 Pa produced in a Hall cell which operates at 6.5 V for 10.0 hours using a current of 120 000 A. 4 marks

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Question 4 (11 marks)

The compounds in the table below have the same relative molecular mass of 74, but have different boiling points.

Compound	propanoic acid	1-butanol	diethyl ether
Boiling point (°C)	141	117	34

a. In terms of structure and bonding, explain why diethyl ether ($C_2H_5OC_2H_5$) has such a low boiling point compared to the other two compounds. 2 marks

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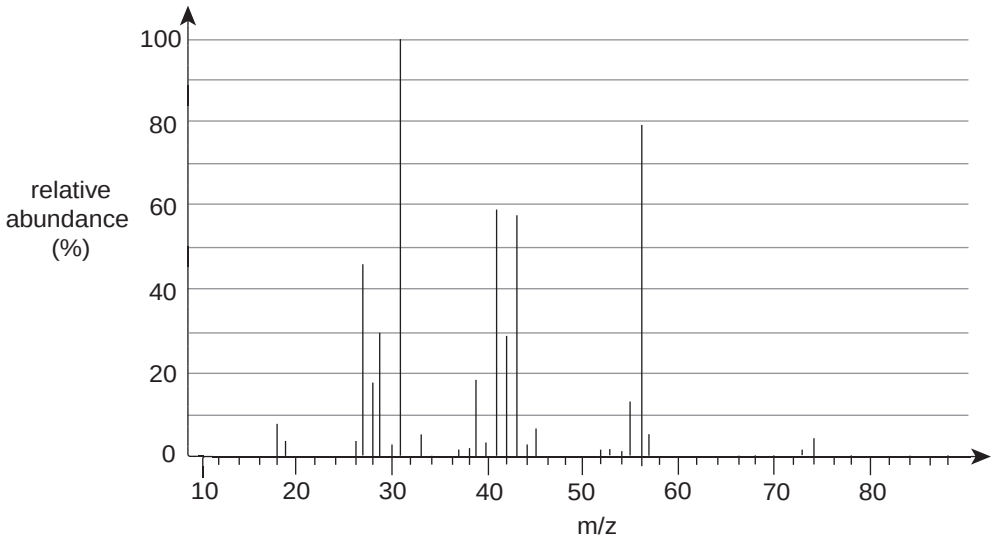
b. The mass spectrum of 1-butanol is shown below:



In mass spectrometry, alkanols produce two characteristic fragments from the molecular ion by different pathways:

- Alpha cleavage: The C–C bond nearest the hydroxyl group is broken, producing an oxygen-containing fragment.
- Dehydration: A water molecule is eliminated, leaving an alkene-like fragment.

i. Give the molecular formula of the oxygen-containing fragment produced by alpha cleavage of a 1-butanol molecule. 1 mark

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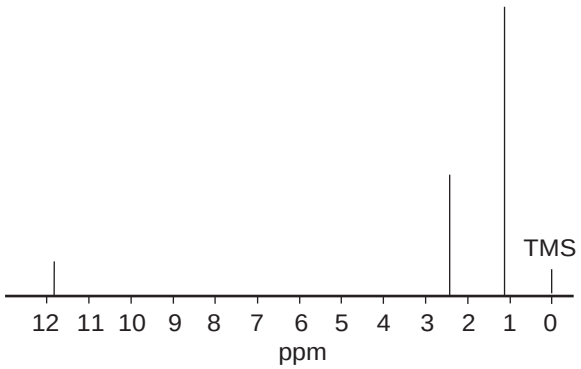
ii. On the mass spectrum of 1-butanol above, identify the peak of the fragment formed by dehydration and mark it clearly with the letter A. 1 mark

c. The low resolution proton nuclear magnetic resonance spectrum (^{1}H NMR) of propanoic acid is shown below.



Complete the table below to show the relative area of each peak and the number of peaks evident when each low resolution peak is split to form the high resolution spectrum. 3 marks

Chemical shift (ppm)	Relative peak area	Peak splitting
1.1		3
2.4		
11.8	1	1

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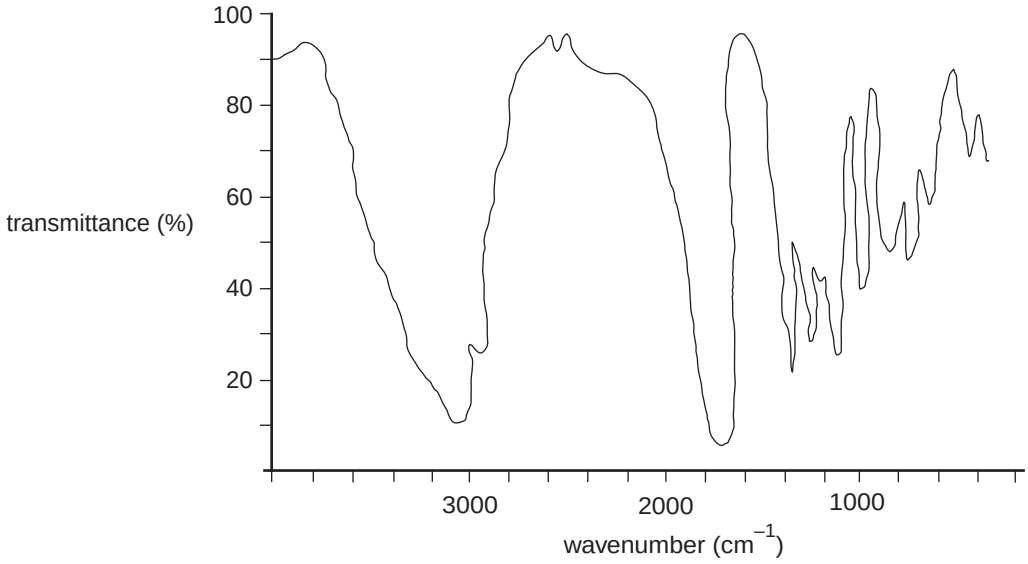
d. Examine the infrared spectrum shown below.



Explain whether the spectrum shown is that of propanoic acid or 1-butanol. 2 marks

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e. An ester with the same molecular formula as propanoic acid produces the ^{1}H NMR data shown in the table below.

Chemical shift (ppm)	Relative peak area	Peak splitting
1.3	3	3
4.2	2	4
8.0	1	1

i. Draw the structural formula of this ester. 1 mark

ii. Name the organic compound used to produce this ester in a chemical reaction with an alkanol in the presence of concentrated sulfuric acid. 1 mark

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Question 5 (13 marks)

a. Aluminium ions in aqueous solution will precipitate when treated with a solution of 8-hydroxyquinoline (C_9H_7NO) as shown by the equation:

$$Al^{3+}(aq) + 3C_9H_7NO(aq) \rightarrow Al(C_9H_6NO)_3(s) + 3H^+(aq)$$

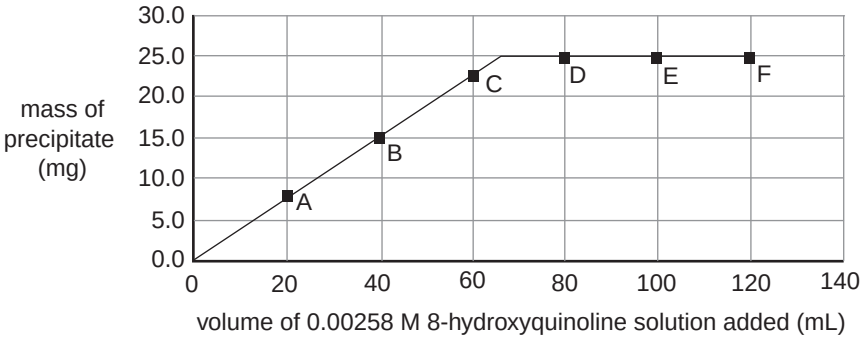
To determine the volume of 8-hydroxyquinoline solution needed to remove all of the aluminium ions from 500 L of contaminated water, the following steps were taken:

I 100.0 mL samples of the contaminated water were placed in six flasks labelled with the letters A to F.

II Different volumes of 0.00258 M 8-hydroxyquinoline solution were added to each flask.

III Each precipitate was isolated, washed, dried and weighed.

The results of the experiment are displayed in the graph below. $M(Al(C_9H_6NO)_3) = 459$ g mol^{-1}



i. In which flasks (A to F) was the 8-hydroxyquinoline solution in excess in the reaction mixture? 1 mark

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ii. Calculate the maximum amount of (in mol) of $Al(C_9H_6NO)_3$ precipitate formed in the 100.0 mL sample of contaminated water. 1 mark

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iii. Calculate the volume of 0.10 M 8-hydroxyquinoline solution which would be needed to remove all of the aluminium ions from 500 L of contaminated water. 3 marks

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iv. Complete the table below by explaining the procedures used in step III of the experiment. Answer these questions in the spaces provided in the table. 2 marks

What is the purpose of washing each precipitate in step III?	
What steps should be taken to ensure that the mass of each precipitate is accurate?	

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v. The original experiment was repeated three times, each time changing one condition.

Tick any of the boxes in the table below to indicate which of the conditions would produce a results graph which plateaus at a higher precipitate mass value. 1 mark

0.00516 M 8-hydroxyquinoline solution was used	
150.0 mL samples of contaminated water were used	
each precipitate was washed several more times than originally	

b. At 25°C, the K_a of the monoprotic compound 8-hydroxyquinoline (C_9H_7NO) is 1.58×10^{-9}.

i. Write an equation showing the ionisation of 8-hydroxyquinoline in water. 1 mark

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ii. Write an equilibrium expression for the acidity constant, K_a, for the reaction in part **i.** 1 mark

iii. Calculate the pH of a 0.30 M solution of 8-hydroxyquinoline at 25°C. 3 marks

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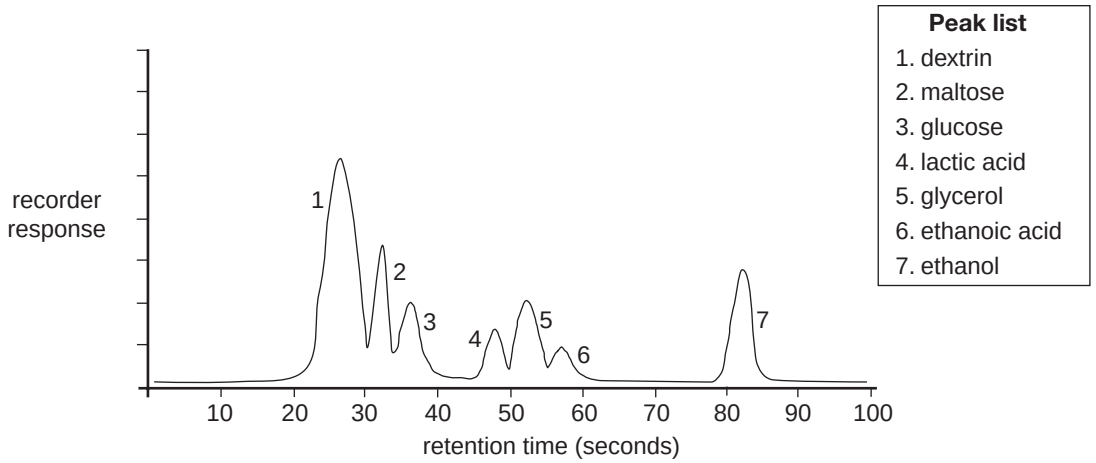
Question 6 (13 marks)

The fermentation process to produce the biochemical fuel ethanol (also known as bioethanol) can be monitored using high performance liquid chromatography (HPLC). A chromatogram of a fermentation mixture twelve hours after fermentation was initiated is shown below.



a. Write an overall equation for the fermentation of glucose to form ethanol. 2 marks

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b. **i.** On the chromatogram above, draw in **one** significant change to any peak which is likely to be evident after 24 hours of fermentation. 1 mark

ii. Identify the **two** correct statements about HPLC by ticking the appropriate boxes in the table below. 2 marks

Increasing the temperature of the HPLC analysis will not change the retention times of the components.	
Doubling the volume of mixture analysed by HPLC will double the retention time of the components.	
Using smaller stationary phase particles will increase the retention times of the components.	
The component most strongly adsorbed to the stationary phase is ethanol.	
Using a mobile phase of a different polarity will have no effect on the retention times.	
Once a component is adsorbed strongly to the column, no desorption will occur.	

iii. Peak 1 on the chromatogram is produced by dextrins. Dextrins are short chains of glucose units formed by condensation reactions between glucose molecules.

Draw and name the linkage between glucose units in dextrins (you are only required to draw the linkage, not the entire structure of the molecule). 2 marks

iv. Peak 2 on the chromatogram is produced by maltose. Maltose is a disaccharide formed by the condensation reaction of two glucose molecules.

Write the molecular formula for maltose. 1 mark

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c. The bioethanol produced by fermentation is seen as a replacement for petrol as a fuel in cars. Petrol contains a high proportion of octane.

i. By calculation, show that the amount (in mol) of carbon dioxide produced for each kilojoule of energy released in the combustion of both bioethanol and octane is almost identical. 3 marks

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ii. 'The carbon dioxide gas released from burning octane is of much greater environmental concern than the carbon dioxide gas released from burning bioethanol.'

Explain this statement. 2 marks

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Question 7 (10 marks)

a. An electrolytic cell was set up using copper electrodes with an aqueous electrolyte containing 0.20 mol each of $Pb^{2+}(aq)$, $Ni^{2+}(aq)$ and $Mg^{2+}(aq)$. A current was passed through the electrolyte until no further metal deposition was evident.

i. Outline the sequence of events occurring at the cathode, including what happens to each of the metal ions during the electrolysis. Include any relevant half equations in your response. 4 marks

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ii. Write a half-equation for the initial reaction occurring at the anode. 1 mark

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b. A student wanted to investigate the factors which affected the amount of copper metal deposited during the electroplating process in an electrolytic cell containing $CuSO_4$ solution.

The following experimental procedure was used:

- Four electrolytic cells were set up using different conditions.
- The electrodes in each cell were made of copper.
- The cathode in each cell was weighed before the electroplating.
- A current of 1.5 amperes was used for each cell for 30 minutes.
- After electroplating, each cathode was washed, dried and weighed so that the mass of metal deposited could be determined accurately.

The conditions used for each cell are shown in the table below.

Conditions	**Cell A**	**Cell B**	**Cell C**	**Cell D**
temperature of electrolyte (°C)	20	30	40	40
concentration of $CuSO_4$ solution (M)	0.15	0.30	0.45	0.60
surface area of cathode (cm^2)	30	30	60	60

i. Critically evaluate the design of the experiment in achieving its purpose to determine which conditions affect the mass of copper deposited during electroplating. 3 marks

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ii. Outline two changes which could be made to improve the design of the experiment. 2 marks

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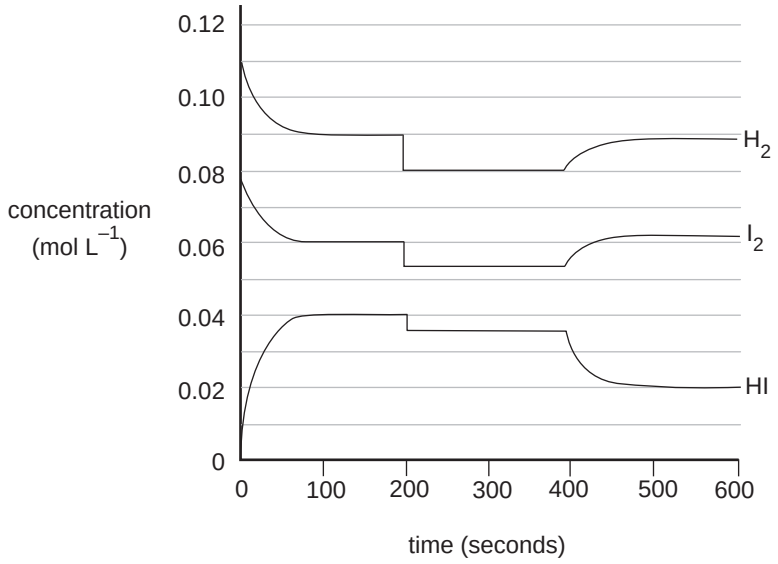
Question 8 (11 marks)

When $H_2(g)$ and $I_2(g)$ are placed in a sealed container, equilibrium will establish according to the following equation:

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

The results of an experiment using this equilibrium system are shown in the graph below.



During the time interval 0 to 200 seconds, the temperature of the system was kept constant by removing heat from the container.

a. Explain how it can be demonstrated that chemical reactions are still occurring during a state of equilibrium by introducing into this system a trace amount of the radioactive isotope of hydrogen known as deuterium. 2 marks

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b. Calculate the equilibrium constant for the equilibrium which occurred in the time interval 0 to 200 seconds. 3 marks

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c. At t = 200 seconds, a change was made to the volume of the reaction vessel.

Outline what change was made, and indicate the magnitude of the change. 2 marks

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d. **i.** Circle one of the following to indicate the value of *K* at 560 seconds compared to the value of *K* at 260 seconds. 1 mark

lower unchanged higher

ii. Without any calculation, explain the reasoning for your choice in part **d. i.** 2 marks

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e. The experiment was repeated under identical conditions except that a suitable catalyst was used.

By drawing a line on the graph on the previous page, show the effect of the catalyst on the concentration of HI in the interval 0 to 200 seconds. 1 mark

END OF QUESTION AND ANSWER BOOKLET

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