



**TSTX MASTER CLASSES**  
**UNIT 4 CHEMISTRY**  
**WRITTEN EXAMINATION 2020**

**Reading Time:** 15 minutes  
**Writing Time:** 2 hours 30 minutes

**QUESTION AND ANSWER BOOK**

**Student Name:** \_\_\_\_\_

**Structure of Book**

<i>Section</i>	<i>Number of questions</i>	<i>Number of questions to be answered</i>	<i>Number of marks</i>
A	30	30	30
B	10	10	90
			<b>Total 120</b>

- 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 37 pages.
- Data book
- Answer sheet for multiple choice questions.

**Instructions**

- Write your **student number** in the space provided above on this page.
- 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.

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

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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.

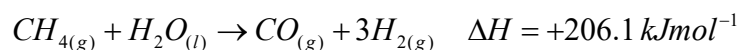
Marks will **not** be deducted for incorrect answers.

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

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

### QUESTION 1

Carbon monoxide is a by-product of the production of hydrogen gas through the reaction of steam and methane. The equation representing the reaction is



The volume of carbon monoxide that could be potentially released to the environment when 1.00 *tonne* of methane is reformed at 850 °C and 2760 *kPa* pressure is

- A  $2.11 \times 10^2 \text{ L}$
- B  $2.11 \times 10^5 \text{ L}$
- C  $1.60 \times 10^4 \text{ L}$
- D  $1.60 \times 10^5 \text{ L}$

### QUESTION 2

Which one of the following substances is most likely to be involved in the production of a natural protein?

- A  $CH_3(CH_2)_{14}COOH$
- B  $NH_2CH_2CH_2COOH$
- C  $HOCH_2CH(OH)CH_2OH$
- D  $H_2NCH(CH_3)COOH$

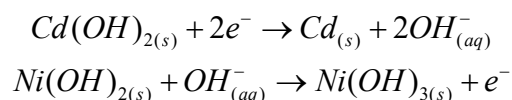
### QUESTION 3

Which of the following statements regarding biofuels is incorrect?

- A Biofuels produce more energy per unit mass than fossil fuels.
- B The reaction that produces some biofuels is similar to the formation of triglycerides in the body in that ester linkages are created during the reaction.
- C Heat, acids and bases can be used to accelerate the rate of formation of biofuels.
- D The type of alkyl ester that is formed during the production of biofuel is determined by the type of alcohol used as a reactant.

### QUESTION 4

The reactions taking place when a nickel cadmium battery is recharged is described by the equations



When the battery discharges

- A  $Cd(OH)_2$  is precipitated.
- B  $Ni(OH)_3$  is precipitated.
- C  $OH^-$  ions are consumed.
- D the  $Cd$  acts as the positive electrode.

### QUESTION 5

An equilibrium exists between copper ions and ammonia as shown below.



A sample was tested at various times and the concentration fraction (CF) was determined. The results obtained were as follows:

T = 1 minute	CF = 0.58
T = 2 minutes	CF = 0.42
T = 3 minutes	CF = 0.33

These results indicate that

- A The position of equilibrium lies to the left.
- B The position of equilibrium lies to the right.
- C The system is in equilibrium at 15 minutes.
- D The rates of the forward and reverse reactions are equal.

**QUESTION 6**

A polysaccharide chain consists of 121 molecules of glucose,  $C_6H_{12}O_6$ . This polysaccharide chain can be described as

- A A condensation polymer with a molecular weight of  $19,620 \text{ g mol}^{-1}$ .
- B A condensation polymer with a molecular weight of  $21,780 \text{ g mol}^{-1}$ .
- C An addition polymer with a molecular weight of  $19,620 \text{ g mol}^{-1}$ .
- D An addition polymer with a molecular weight of  $21,780 \text{ g mol}^{-1}$ .

**QUESTION 7**

A sample of 1-chlorobutane undergoes a substitution reaction with  $NaOH$  to form product  $X$ . Identify the number of different hydrogen environments in this product.

- A 2
- B 3
- C 4
- D 5

**QUESTION 8**

Which one of the following does not reduce the **performance** of a battery?

- A Formation of materials which increase resistance to current flow.
- B Active materials detaching from the electrodes.
- C Warmer temperatures.
- D Moisture and humidity.

**QUESTION 9**

Which of the following is the correct semistructural formula of the product formed when methylpropan-2-ol is mixed with acidified  $MnO_4^-$ .

- A  $CH_3COCH_2CH_3$
- B  $(CH_3)_3COH$
- C  $CH_3CH_2CH_2OH$
- D  $CH_3CHCOCH_3$

### QUESTION 10

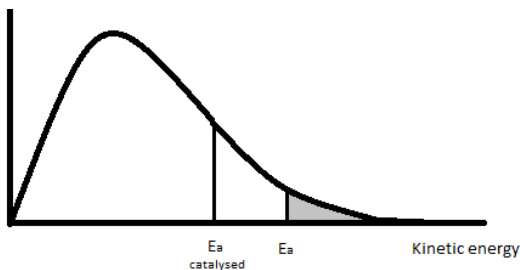
A polyunsaturated fat is hydrolysed to produce glycerol and fatty acids.  
Which one of the following is a possible formula for the acid?

- A  $C_{18}H_{37}COOH$
- B  $C_{18}H_{35}COOH$
- C  $C_{18}H_{31}COOH$
- D  $C_{18}H_{32}COOH$

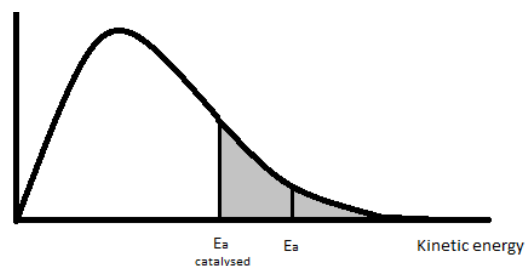
### QUESTION 11

Ethane is formed from the reaction between ethene and hydrogen using nickel catalyst.  
In which of the following diagrams does the shaded area correctly show the number of particles with enough energy to overcome the activation energy requirement for this reaction?

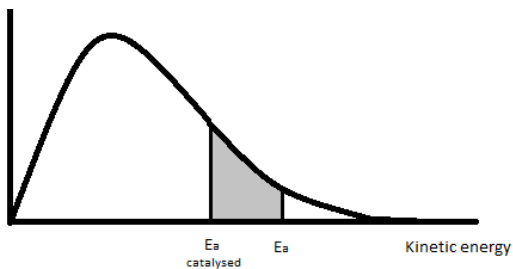
A No. of molecules with a particular kinetic energy



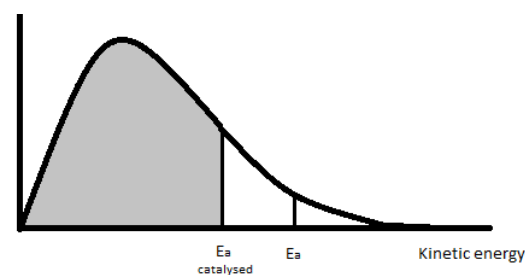
B No. of molecules with a particular kinetic energy



C No. of molecules with a particular kinetic energy

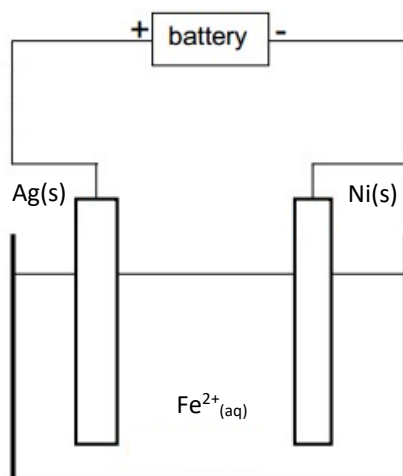


D No. of molecules with a particular kinetic energy



**QUESTION 12**

Consider the following electrolytic cell.

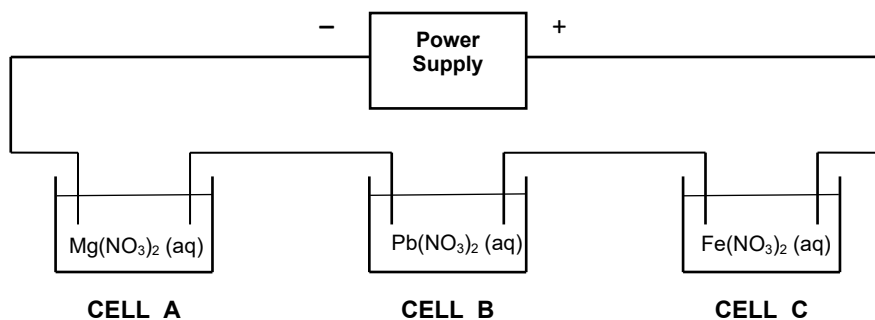


The reaction that occurs at the anode is

- A  $Fe_{(aq)}^{2+} + 2e^{-} \rightarrow Fe_{(s)}$
- B  $Ag_{(aq)}^{+} + e^{-} \rightarrow Ag_{(s)}$
- C  $Ni_{(s)} \rightarrow Ni_{(aq)}^{2+} + 2e^{-}$
- D  $Fe_{(aq)}^{2+} \rightarrow Fe_{(aq)}^{3+} + e^{-}$

**QUESTION 13**

The diagram below shows three cells connected in series. The cells contain 1.00 M solutions of magnesium nitrate, lead nitrate and iron (II) nitrate into which platinum electrodes have been placed. If a current of 3.00 A is passed through the cells for 30.0 minutes, what would be the total mass of metal deposited on the negative electrodes?

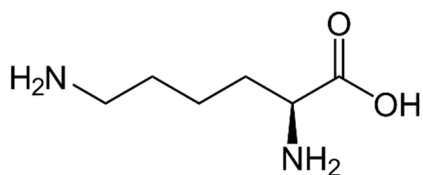


- A 0.12 g
- B 7.36 g
- C 8.62 g
- D 12.4 g

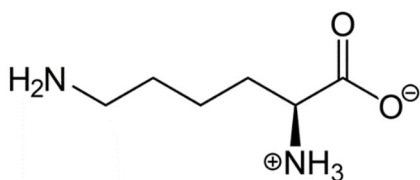
**QUESTION 14**

The skeletal formulae for an amino acid under different conditions is shown below. Which structure shows the amino acid in its zwitterion form?

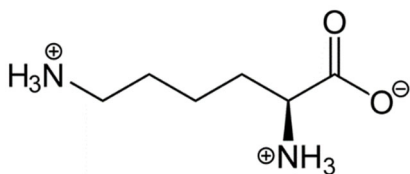
A



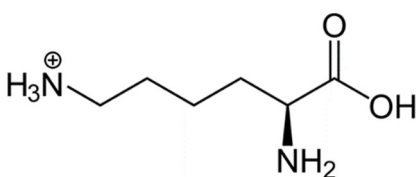
B



C

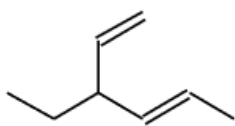


D

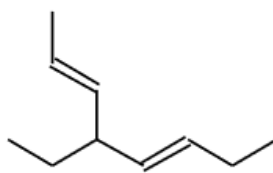
**QUESTION 15**

Which of the following structures is the skeletal formula for 4-ethyloct-2,5-diene?

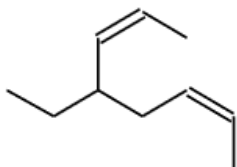
A.



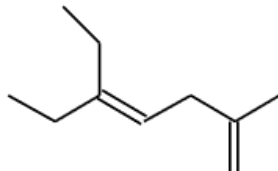
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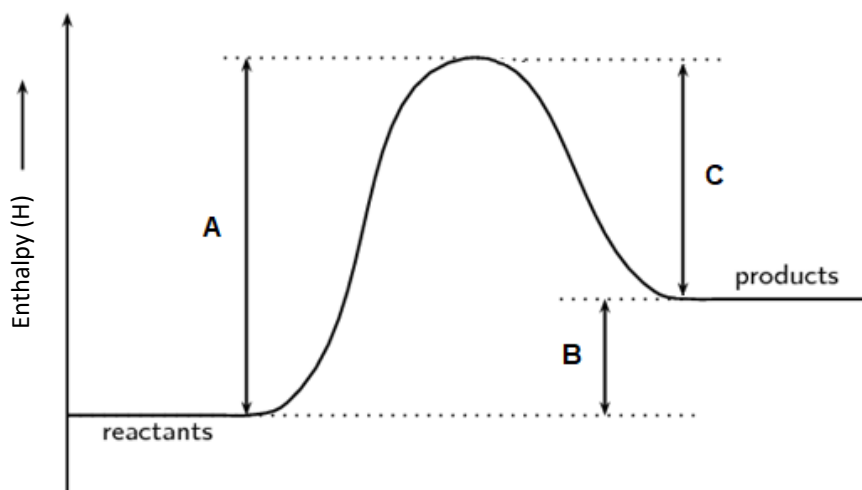
D.





**Questions 16 & 17 refer to the following information.**

The relative enthalpies, on an arbitrary scale, of the reactants and products of a chemical reaction are shown below.



**QUESTION 16**

Which of the following statements is correct?

- A The products are more stable than the reactants and the enthalpy change is positive.
- B The products are more stable than the reactants and the enthalpy change is negative.
- C The reactants are more stable than the products and the enthalpy change is positive.
- D The reactants are more stable than the products and the enthalpy change is negative.

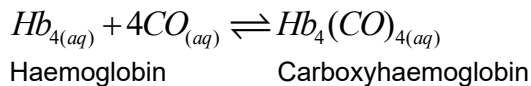
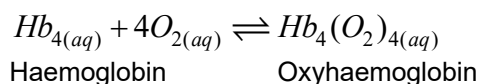
**QUESTION 17**

A catalyst will change the value(s) of

- A A only
- B A and B
- C A and C
- D A, B and C

**QUESTION 18**

Oxygen and carbon monoxide react with haemoglobin as follows.



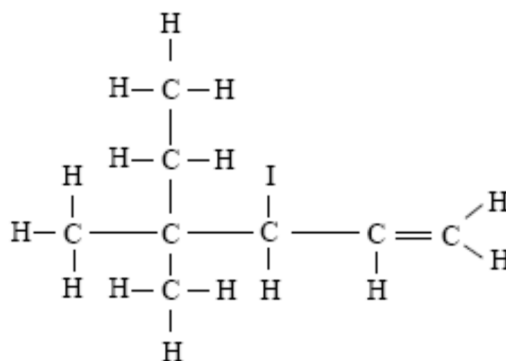
Carbon monoxide poisoning is treated by making the patient breathe pure oxygen to displace the carbon monoxide in their blood.

Which of the following statements is incorrect?

- A The position of equilibrium for both reactions will shift to the left.
- B The position of equilibrium for both reactions will shift to the right.
- C The position of equilibrium for the haemoglobin/carboxyhaemoglobin reaction will shift to the right and the position of equilibrium for the haemoglobin/oxyhaemoglobin will shift to the left.
- D The position of equilibrium for the haemoglobin/carboxyhaemoglobin reaction will shift to the left and the position of equilibrium for the haemoglobin/oxyhaemoglobin will shift to the right.

**QUESTION 19**

The systematic name for the compound, whose structure is given below, is:



- A 2-ethyl-3-iodo-2-methyl-4-pentene
- B 4-ethyl-3-iodo-4-methyl-1-pentene
- C 3-iodo-4,4-dimethyl-1-hexene
- D 4-dimethyl-3-iodo-1-hexene

### QUESTION 20

Excess carbohydrates in the body are converted to palmitic acid and are either stored as fat deposits or used as a precursor to longer fatty acids. Assume that the fat carried by humans is in the form of palmitic acid. What temperature change would occur if the energy released from the complete combustion of 5 kg of human fat was used to heat up 1000 L of water in a small tank?

The oxidation of palmitic acid is represented by the following equation:

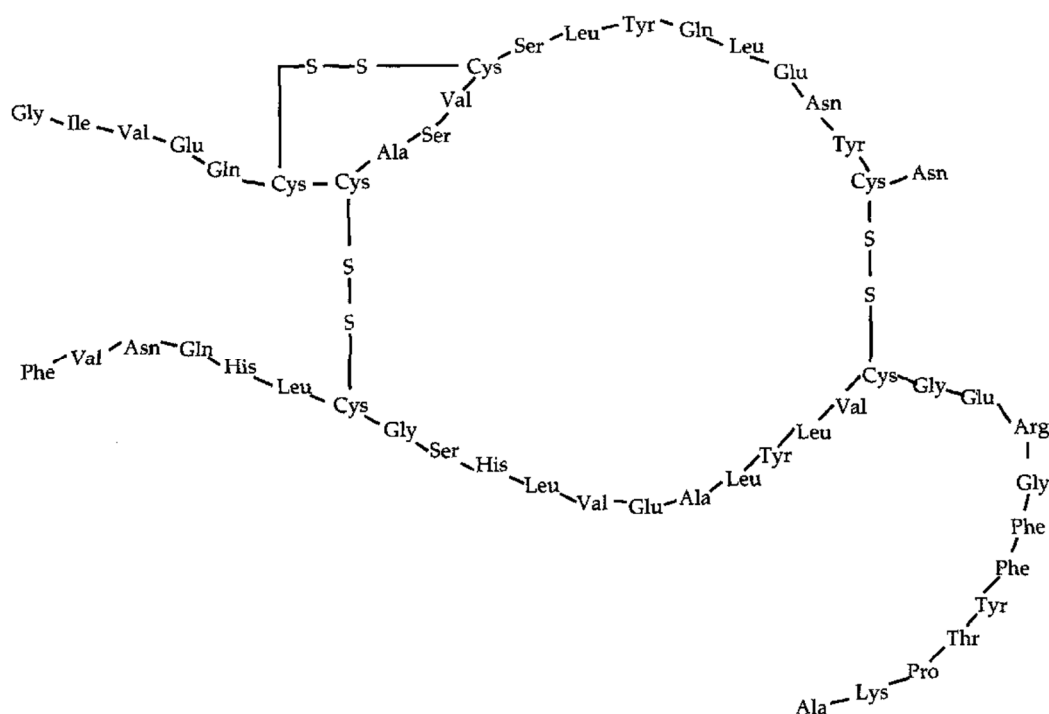


$$M(\text{CH}_3(\text{CH}_2)_{14}\text{COOH}_{(aq)}) = 256 \text{ gmol}^{-1}$$

- A  $4.69 \times 10^{-2} \text{ }^\circ\text{C}$
- B  $4.70 \times 10^{-2} \text{ }^\circ\text{C}$
- C  $46.9 \text{ }^\circ\text{C}$
- D  $47.0 \text{ }^\circ\text{C}$

### QUESTION 21

The diagram below shows the structure of ox insulin.



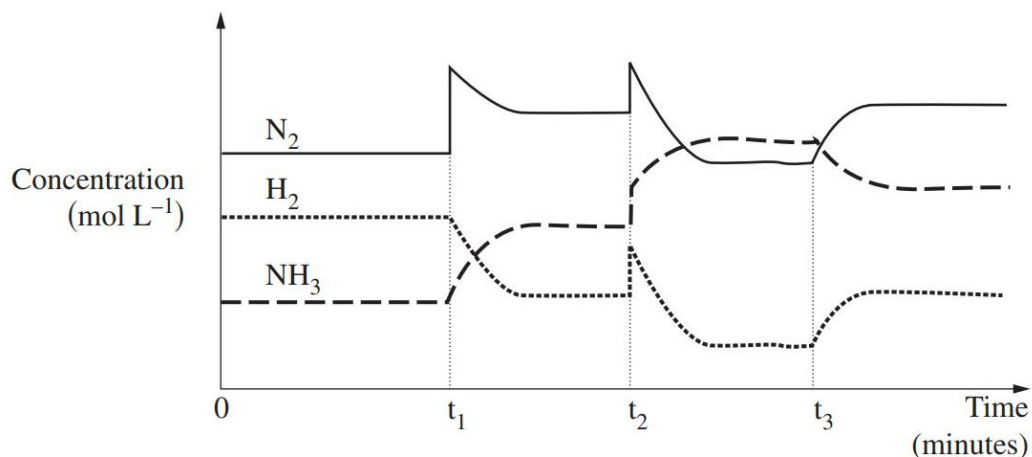
The bond between cysteine residues (Cys) is used to maintain

- A the primary structure of a protein.
- B the secondary structure of a protein.
- C the tertiary structure of a protein.
- D the primary, secondary and tertiary structures of a protein.

### QUESTION 22

The reaction between nitrogen gas and hydrogen gas to produce ammonia is exothermic.

The graph below shows the changes that occur to an equilibrium mixture of hydrogen, nitrogen and ammonia when the system is removed from equilibrium.



Which of the following events occurred at the indicated times?

	$t_1$	$t_2$	$t_3$
A	$N_2$ was added	$N_2$ and $H_2$ were added	Temperature increased
B	$NH_3$ was added	$N_2$ and $H_2$ were added	Temperature decreased
C	$N_2$ was added	Volume was decreased	Temperature increased
D	$N_2$ was added	Volume was decreased	Temperature decreased

### QUESTION 23

The wrapper on a packet of savory crackers gives the following nutritional information.

Serving size	50 g
Protein	5.8 g
Fat – saturated	3.2 g
– unsaturated	0.8 g
Carbohydrates – Sugars and starches	32.6 g
– Cellulose fibres	6.7 g

The maximum energy that would be available to the body per gram of cracker is

- A 15 kJ / g
- B 16 kJ / g
- C 17 kJ / g
- D 18 kJ / g

### QUESTION 24

A number of amino acids are classified as essential amino acids. Which of the following statements regarding essential amino acids is incorrect?

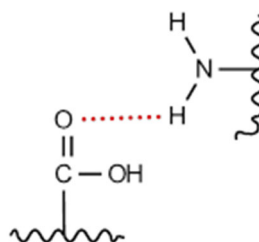
- A Essential amino acids can't be produced by humans.
- B Essential amino acids can't be converted in the body to non-essential amino acids.
- C Essential amino acids can only be primary amines.
- D All essential amino acids are  $\alpha$  amino acids

### QUESTION 25

The diagram below shows an interaction occurring between the 'R' groups in two different protein strands.

This type of interaction could be part of

- i The primary structure of a protein.
- ii The secondary structure of a protein.
- iii The tertiary structure of a protein.
- iv The quaternary structure of a protein.

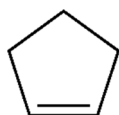


- A ii only
- B ii, iii and iv only
- C iv only
- D i, ii, iii and iv

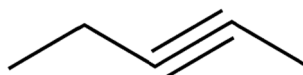
### QUESTION 26

Which of the following is not a structural isomer of pentyne?

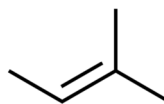
A



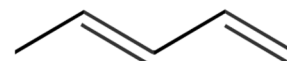
B



C



D



### QUESTION 27

Which of the following statements is **incorrect**?

- A The oxidation number of  $C$  in  $HCHO$  is 0.
- B The oxidation number of  $Fe$  in  $Fe_3O_4$  is  $\frac{8}{3}$ .
- C The oxidation number of  $O$  in  $OF_2$  is  $-2$ .
- D The oxidation number of  $Cl$  in  $Ba(ClO_3)_2$  is  $+5$ .

**QUESTION 28**

Which of the following species would display the highest flash point?

- A Propane
- B Hexane
- C Propanol
- D Hexanol

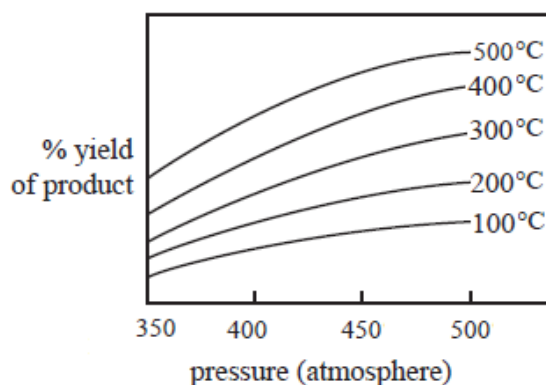
**QUESTION 29**

Which one of the following reactions would occur spontaneously under standard conditions?

- A An acidified solution of  $FeSO_4$  is added to copper metal.
- B Hydrogen gas is bubbled through a mixture containing nickel chloride and zinc chloride.
- C Oxygen gas is bubbled through an acidified solution of iron (II) nitrate.
- D Nickel metal is added to an aluminium nitrate solution.

**QUESTION 30**

The following graph relates to the reaction  $aA_{(g)} + bB_{(g)} \rightleftharpoons cC_{(g)} + dD_{(g)}$ .



Which of the following statements about this reaction is correct?

- A  $a + b > c + d$  and the value of  $K$  increases as the temperature increases.
- B  $a + b < c + d$  and the value of  $K$  increases as the temperature increases.
- C  $a + b > c + d$  and the value of  $K$  decreases as the temperature increases.
- D  $a + b < c + d$  and the value of  $K$  decreases as the temperature increases.

## SECTION B

### Instructions for Section B

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

### QUESTION 1 (9 marks)

With world reserves of petroleum quickly depleting, in recent years, ethanol, particularly bioethanol, has emerged as an important alternative resource for liquid fuel.

- a. List two advantages of using bioethanol, instead of petrol, as a fuel for cars. 2 marks

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Another biochemical fuel which has generated a great deal of research is biodiesel.

- b. i. Which fuel, biodiesel or petrodiesel, has the higher viscosity? Give a reason for your answer. 2 marks

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ii. What implications does a viscous fuel have in terms of suitability as a transport fuel? 1 mark

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iii. With reference to the molecular structure of both petrodiesel and biodiesel, state why incomplete combustion is less of a problem for biodiesel than it is for petrodiesel. 2 marks

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c. Why does the combustion of petrol (and other fossil fuels) add to the amount of carbon dioxide in the atmosphere whilst burning of biofuels such as biodiesel and bioethanol does not necessarily add to the amount of carbon dioxide in the atmosphere over the long term? 2 marks

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**QUESTION 2** (9 marks)

More than ever, Australian's are looking for alternative fuel sources for vehicles, and clean burning hydrogen is being investigated as a potential energy source for fuel cells.

- a. How does a fuel cell differ from a typical galvanic cell? 1 mark

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- b. Although hydrogen is a clean-burning fuel, widespread use of hydrogen as a primary fuel in fuel cells is unlikely in the short term. State two reasons why this is the case. 2 marks

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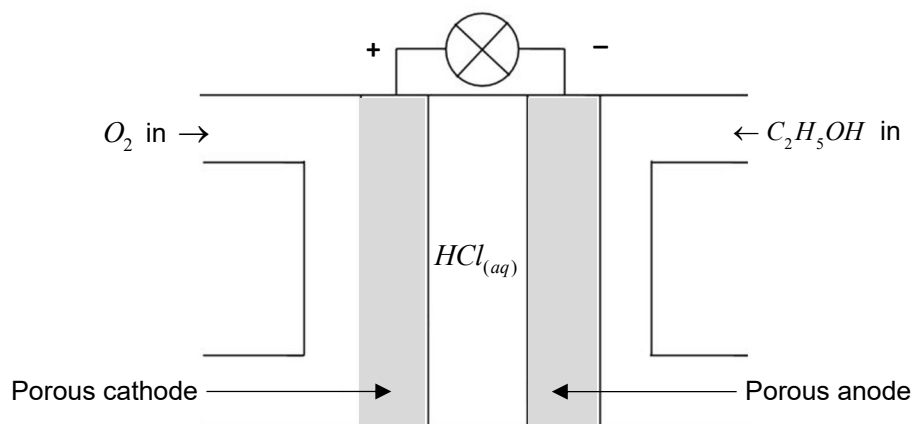
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The diagram below shows a fuel cell designed to use ethanol as a fuel. The half cells contain  $HCl$ , an acidic electrolyte.



The cell reaction is  $C_2H_5OH_{(aq)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$ .

The anode reaction for the cell is  $C_2H_5OH_{(aq)} + 3H_2O_{(l)} \rightarrow 2CO_{2(g)} + 12H^+_{(aq)} + 12e^-$ .

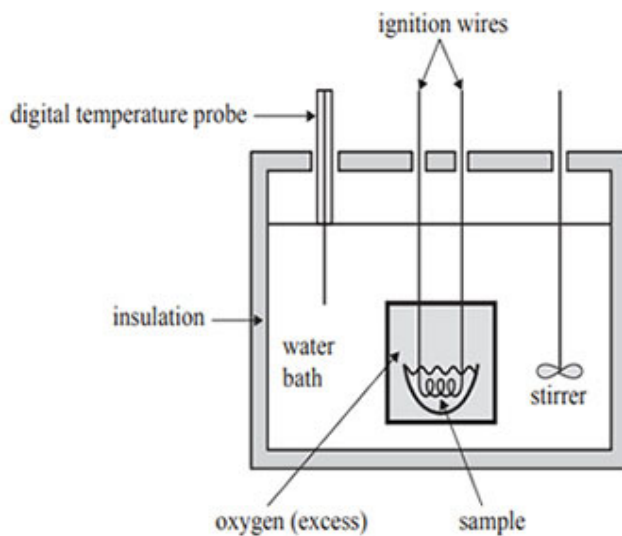
- c. i. State the reaction that occurs at the cathode. 1 mark

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**QUESTION 3** (9 marks)

The heat of combustion of diesel fuel was determined using a bomb calorimeter. The calorimeter was first calibrated by combusting 0.7663 g of pure ethanol. During this process, the temperature increased from 20.62 to 24.64°C.



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- a. i. Calculate the Calibration Factor for the calorimeter in  $\text{kJ}^\circ\text{C}^{-1}$ . 2 marks

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- ii. If the bomb had been emptied of water and replaced with the same volume of a solution with specific heat capacity  $1.2 J / g / ^\circ C$ , what effect would this have on the calibration factor? Give a reason for your answer. 2 marks

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After calibrating the calorimeter, a  $1.0 \text{ mL}$  sample of diesel was combusted in the bomb and a temperature rise of  $6.44^\circ C$  was recorded.

- b. i. Determine the heat of combustion of diesel in  $MJL^{-1}$ . 2 marks

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- ii. Calculate the efficiency of the bomb if the energy density of diesel is  $44.8 \text{ kJg}^{-1}$  3 marks and its density is  $0.85 \text{ kgL}^{-1}$ .

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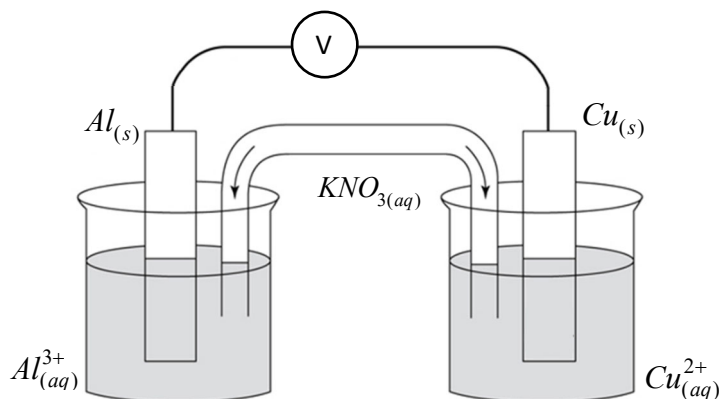
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**QUESTION 4 (7 marks)**

An electrochemical cell is set up as shown in the diagram below.



- a. On the given diagram, label the anode and the direction of electron flow. 2 marks
- b. Why must galvanic cell reactions be conducted using two half-cells rather than one? 2 marks  
Include a reference to energy transformations in your answer.

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- c. Circle the response(s) that best describe the effect on the voltmeter reading after some time if

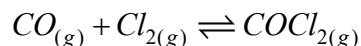
A represents an increase in the voltmeter reading.  
B represents a decrease in the voltmeter reading.  
C represents no change in the voltmeter reading.  
D represents a zero voltmeter reading.

One or more answers apply.

- i. The salt bridge is removed. 1 mark  
A      B      C      D
- ii. The copper electrode is replaced with tin. 1 mark  
A      B      C      D
- iii. The aluminium electrode is replaced with zinc. 1 mark  
A      B      C      D

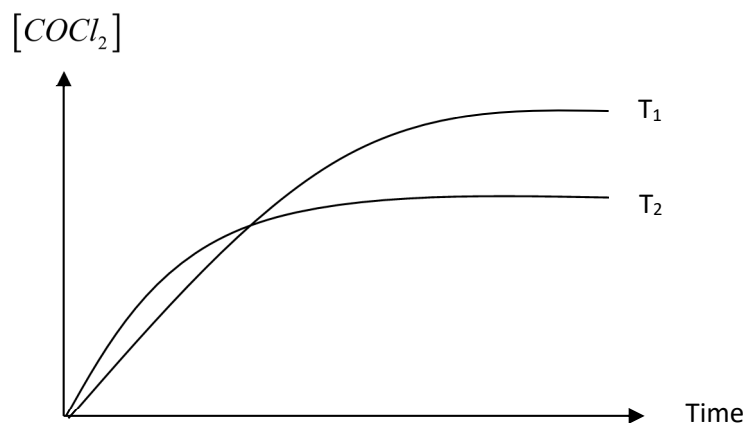
**QUESTION 5** (7 marks)

Carbon monoxide reacts with chlorine to form phosgene,  $COCl_2$ .



1.0 mol of  $Cl_2$  was mixed with 1.0 mol of  $CO$  in two separate 1.0 L containers at two different temperatures –  $T_1$  and  $T_2$ , and the concentration of  $COCl_2$  was measured.

The results of this experiment are given below.



- a. i. Which one of the temperatures,  $T_1$  and  $T_2$  is higher? Give a reason for your answer. 2 marks

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- ii. Is the formation of  $COCl_2$  an exothermic or endothermic process? Give a reason for your answer. 2 marks

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- b. 5.0 mol of CO and 4.0 mol of Cl<sub>2</sub> were added to a 2.0 L vessel and allowed to reach equilibrium. When equilibrium was attained, 3.0 mol of COCl<sub>2</sub> were present. Calculate the equilibrium constant for this reaction system. 3 marks

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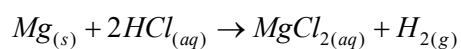
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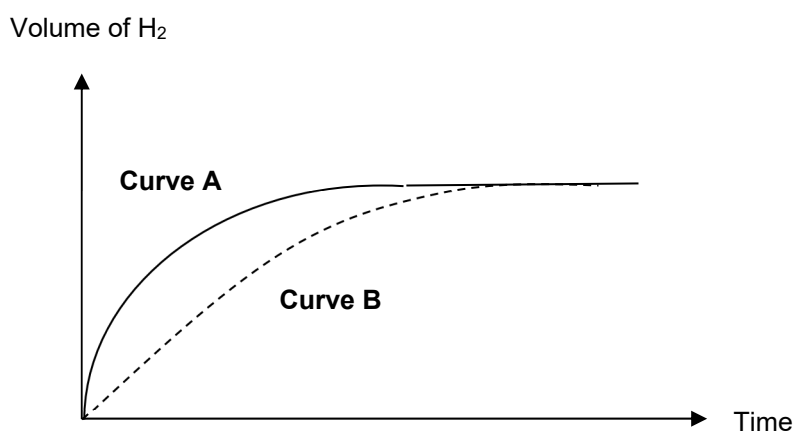
**QUESTION 6** (6 marks)

5 cm of magnesium ribbon was added to 20.00 mL of 1.00 M hydrochloric acid in a closed system and the volume of hydrogen gas evolved at 10 second intervals was recorded.



The experiment was then repeated using a fresh 5 cm of magnesium ribbon, using 20.00 mL of 2.00 M hydrochloric acid.

The following graphs were obtained.



- a. i. Which curve, A or B, best describes the reaction occurring in 2.00 M hydrochloric acid? 1 mark

\_\_\_\_\_

- ii. Give one reason why the two reactions produce the same volume of hydrogen. 1 mark

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

- b. 10 cm of magnesium ribbon was added separately to 20.00 mL of 1.00 M and 2.00 M hydrochloric acid in a closed system. It was observed that in both cases, the initial rate of  $H_2$  evolution was higher when compared to when just 5 cm of magnesium ribbon was used. Use the collision theory to explain why the larger magnesium ribbon increased the reaction rate. 2 marks

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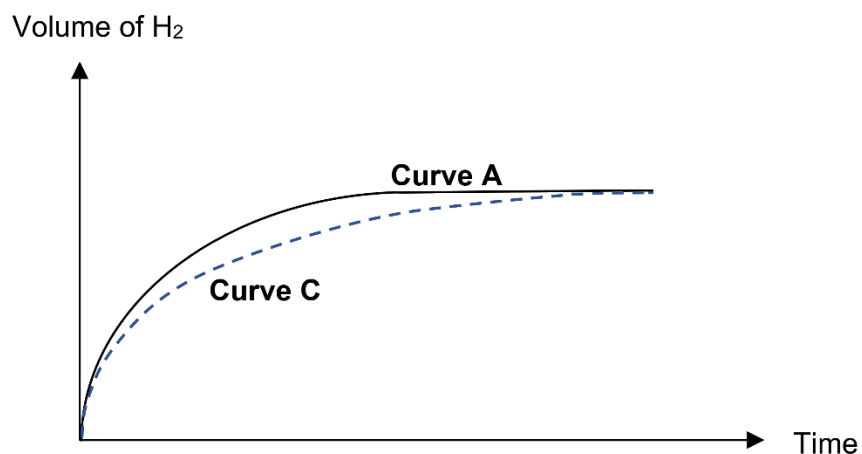
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- c. 5 cm of magnesium ribbon was added separately to 20.00 mL and 40.00 mL of 1.00 M hydrochloric acid at constant temperature in a closed vessel. The following graphs were obtained. 2 marks



Which curve, A or C, best describes the reaction occurring in the greater volume of hydrochloric acid? Give a reason for your answer.

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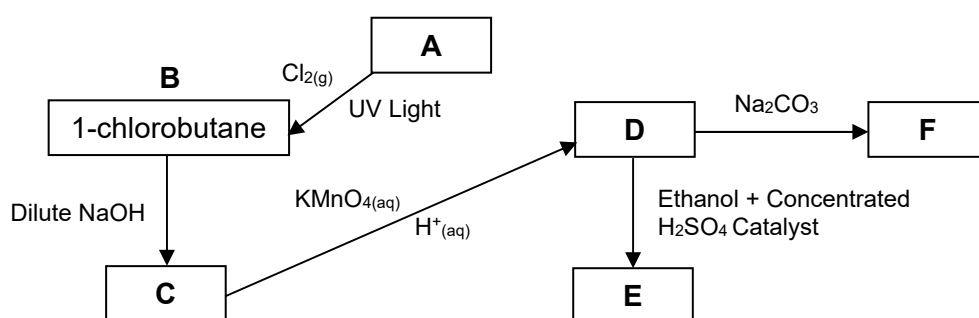
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**QUESTION 7** (9 marks)

Compound A is a hydrocarbon with molar mass  $58 \text{ g mol}^{-1}$ . It reacts with chlorine gas in the presence of UV light to produce a number of products, one which is 1-chlorobutane.

1-chlorobutane was isolated and reacted with a dilute solution of sodium hydroxide to form Compound C, which oxidises with acidified potassium permanganate to form Compound D.

Compound D reacts with sodium carbonate to produce a salt (Compound F) and carbon dioxide. Compound D may also react with ethanol and concentrated sulfuric acid to produce a fruity smelling substance – Compound E.



a. Identify compounds:

- A: \_\_\_\_\_ 1 mark
- C: \_\_\_\_\_ 1 mark
- E: \_\_\_\_\_ 1 mark

b. Write semi-structural equations for the formation of the following compounds.

i. Compound C 1 mark

\_\_\_\_\_

\_\_\_\_\_

ii. Compound F 1 mark

\_\_\_\_\_

\_\_\_\_\_

**c. i.** Write a structural equation to describe the production of compound D from compound E. Show all bonds. 2 marks

**ii.** Below are some terms that are used to describe reactions. Circle the term(s) that describe(s) the production of compound D from compound E. 1 mark

Condensation    Dehydration    Hydration    Hydrolysis    Oxidation    Reduction

**d.** Give a chemical reason why alcohols such as ethanol can mix with both water and petrol. 1 mark

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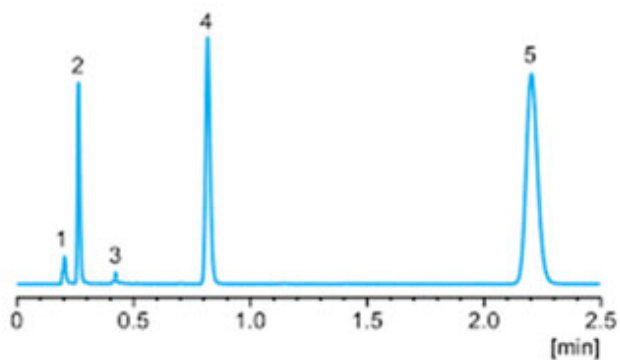
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**QUESTION 8** (11 marks)

A mixture of organic compounds was analysed using high pressure liquid chromatography (HPLC). When a polar stationary phase was used, the following chromatogram was obtained.



- a. i. If the mixture consists of pentanol, pentane, pentanoic acid, chloropentane and methylbutanoate, which would represent peak 5? Give a reason for your answer. 2 marks

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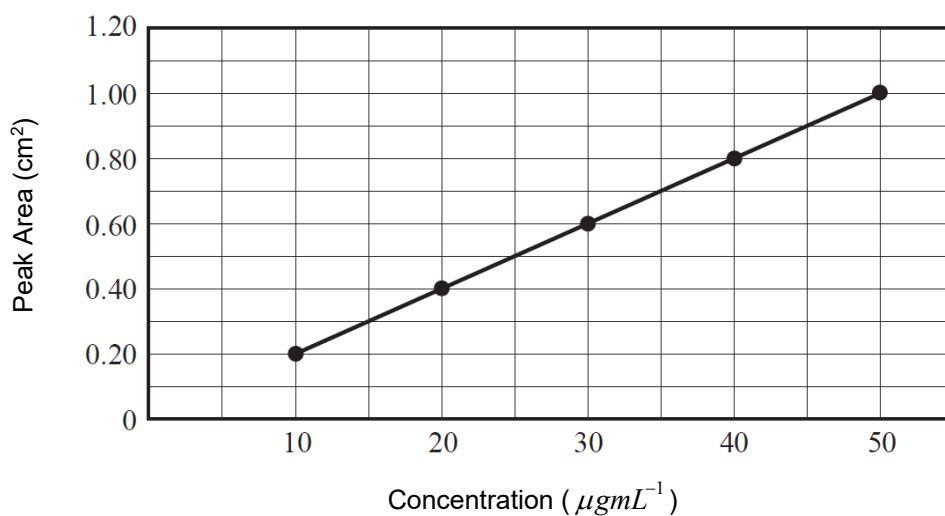
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- ii. Which compound, 1, 2, 3, 4 or 5 is present in the lowest concentration? 1 mark

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The concentration of the compound that produces Peak 1 was determined by running a series of standards of known concentration under the same conditions as the sample. The following calibration curve was obtained.



- b. The concentration of the compound that produced Peak 1 was found to be  $2.77 \times 10^{-4} \text{ molL}^{-1}$ . If the molar mass of the compound is  $72 \text{ gmol}^{-1}$ , calculate the peak area produced (in  $\text{cm}^2$ ) by this compound. 3 marks

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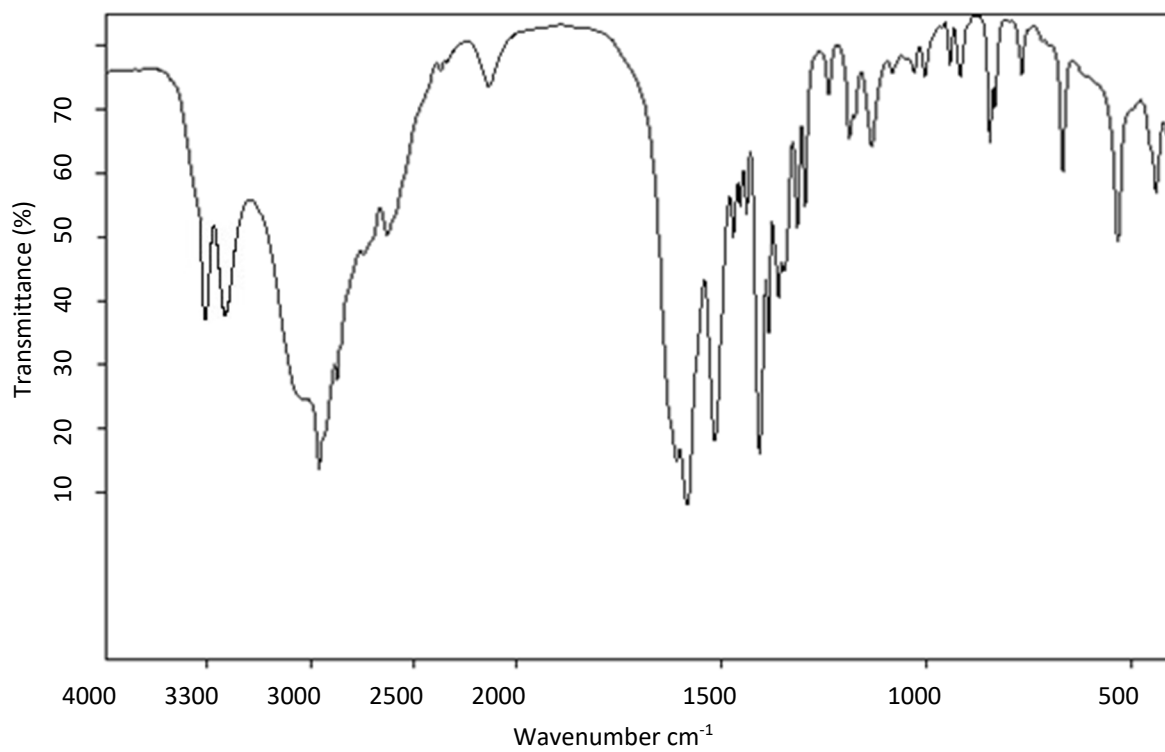
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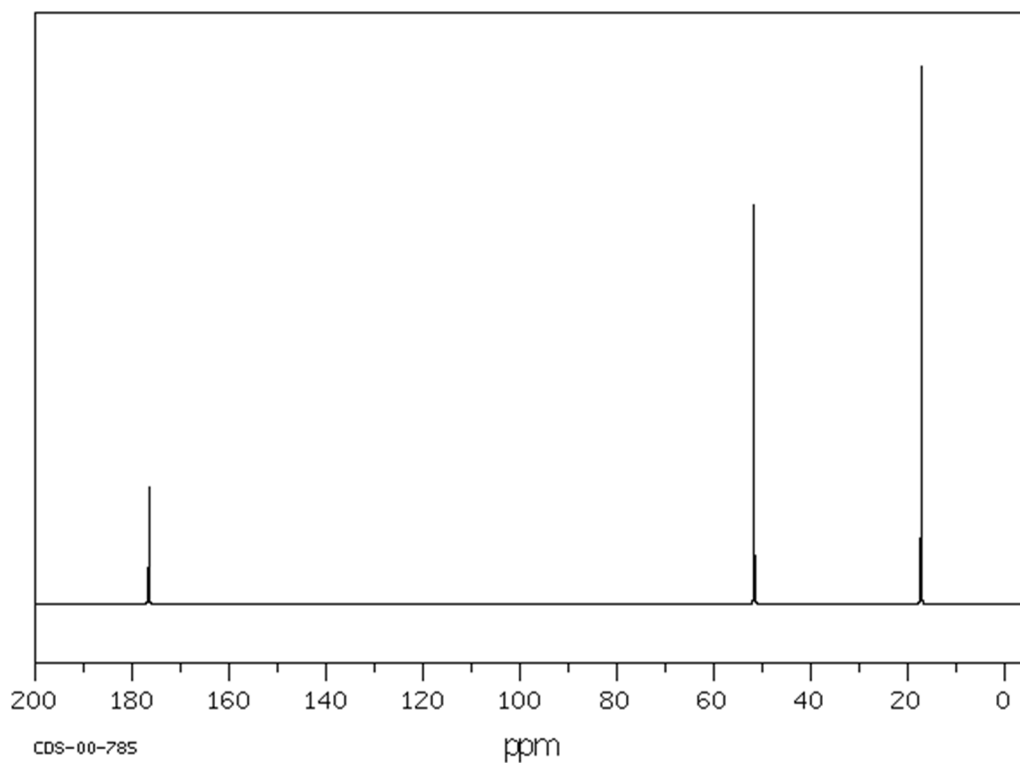
The infrared spectrum, C-NMR and proton-NMR spectra for an organic compound with a molecular weight of  $89.0 \text{ gmol}^{-1}$  have been provided below and overleaf.

### Infrared Spectrum

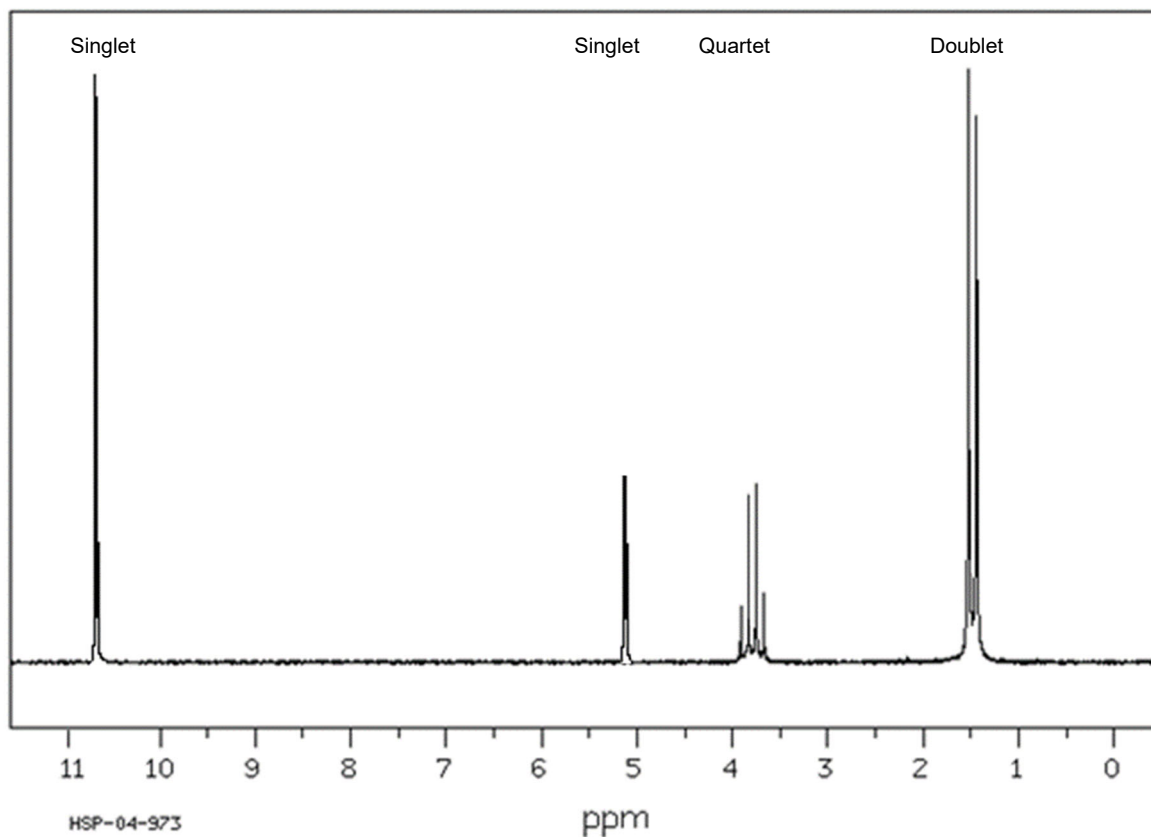


www.intechopen.com

### Carbon NMR Spectrum



### Proton NMR Spectrum



[www.chemicalbook.com](http://www.chemicalbook.com)

- c. i. Draw the structure of the compound that is consistent with the spectral data, clearly showing all bonds. 4 marks

- ii. State the systematic name of the compound. 1 mark

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**QUESTION 9** (9 marks)

Carbohydrates are a large and important group of natural compounds that are present in greater abundance than any other type of organic compound on earth. Examples of important carbohydrates includes glycogen, cellulose and starch.

- a. i. Explain, in terms of bonding, why carbohydrates such as cellulose are insoluble in water. 1 mark

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- ii. Some carbohydrates can be used as an energy source in a process known as cellular respiration. 2 marks

Write a balanced thermochemical equation for the respiration reaction given that  $2803 \text{ kJmol}^{-1}$  of energy is released in the process.

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- iii. Hexokinase is an enzyme that's involved in cellular respiration. Briefly explain why hexokinase is able to increase the respiration reaction rate when glycogen monomers are used as the energy source, but no reaction is observed when cellulose monomers are used. 2 marks

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- b. Demonstrate your understanding of glycogen and its metabolism in the **human body**. In your answer: 4 marks

- show or describe the structure of glycogen and how it is produced.
- describe one other important type of reaction involving glycogen.

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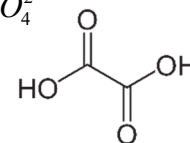
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**QUESTION 10** (13 marks)

A student carried out an experiment to determine whether a sample of anhydrous oxalic acid that had been stored in a school laboratory was pure, as stated by the manufacturer. The experiment involved determining the formula of the salt  $H_2C_2O_4 \cdot xH_2O$  by titrating  $C_2O_4^{2-}$  ions with acidified potassium permanganate.



Part of the report produced by the student is given below.

**Aim:**

To determine the formula of hydrated  $H_2C_2O_4$  crystals ( $H_2C_2O_4 \cdot xH_2O$ ) by titration and hence determine whether the school's supply of anhydrous oxalic acid is pure.

**Background Information:**

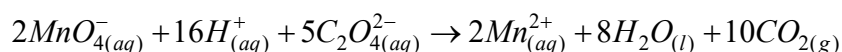
Oxalic acid is a hygroscopic colourless crystal or white powder and can be found in various states of hydration. It typically occurs as the stable dihydrate with the formula  $H_2C_2O_4 \cdot 2H_2O$ . The hydrated solid can be dehydrated with heat, and at high humidity, the anhydrous form readily converts to the hydrated form.

**Hypothesis:**

The school's supply of anhydrous oxalic acid is no longer pure and has absorbed water from the atmosphere.

**Method:**

1. Accurately weigh out 25.0 g of oxalic acid crystals.
2. Dissolve the crystals in deionised water and make up the solution to 500 cm<sup>3</sup> in a volumetric flask.
3. Pipette 25.00 cm<sup>3</sup> of this solution into a conical flask that has been rinsed with deionised water and acidify by adding 25 cm<sup>3</sup> of 1.00 M sulfuric acid.
4. Transfer a 0.15 M potassium permanganate solution ( $KMnO_4$ ) into a 50.00 cm<sup>3</sup> burette that has been rinsed with deionised water.
5. Slowly heat the flask containing the oxalic acid solution to 75°C.
6. Place the flask under the burette and titrate the acidified oxalic acid solution with potassium permanganate until the colourless solution is replaced by a permanent pink tinge. Record the titre.
7. Repeat the titration until 3 concordant titres are obtained.

**Equation for the reaction:****Results:**

Titres: 25.43, 26.67, 27.91

Average Titre Used: 26.67 mL

**Calculations:**

$$n(\text{MnO}_4^-) = cV = 0.15 \times 0.02667 = 0.004000 \text{ mol}$$

$$n(\text{C}_2\text{O}_4^{2-}) = \frac{5}{2} \times 0.004000 = 0.0100 \text{ mol} = n(\text{H}_2\text{C}_2\text{O}_4 \cdot x\text{H}_2\text{O})$$

$$\text{Used } \frac{25}{500} \times 25.0 \text{ crystals in each titration} = 1.25 \text{ g}$$

Molar mass of sample:

$$M = \frac{m}{n} = \frac{1.25}{0.0100} = 125 \text{ g mol}^{-1}$$

Molar mass of anhydrous  $\text{H}_2\text{C}_2\text{O}_4$ :

$$M(\text{H}_2\text{C}_2\text{O}_4) = 90 \text{ g mol}^{-1}$$

Difference in mass due to water:

$$125 - 90 = 35 \text{ g mol}^{-1}$$

Mole of water:

$$x = \frac{35}{18} = 1.9444$$

There are 2 waters of crystallisation present and the formula of oxalic acid is  $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ .

**Conclusion:**

It was determined that the formula of the oxalic acid crystals is  $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ . This means that the school's supply of anhydrous oxalic acid is not pure and should be replaced.

a. Why is the acidified oxalic acid solution heated before the titration?

1 mark

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b. i. Briefly describe the two mistakes that the student made in the experimental procedure and indicate how these mistakes affected the calculated value of  $x$ .

4 marks

Description of Error	Effect on Calculated Value of $x$
Experimental Procedure Error 1	
Experimental Procedure Error 2	

- ii. The true titre for the experiment was  $24.45 \text{ mL}$ . Was the titre used accurate? 2 marks  
Include a calculation to support your answer.

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- c. Classify the following errors as random or systematic and state a step that should have been performed to reduce this error.

- i. Inaccuracy of volumetric glassware 1 mark

Random error or systematic error? \_\_\_\_\_

Step to reduce error: \_\_\_\_\_ 1 mark

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- ii. Inaccuracy of molarity of the standard solution,  $\text{KMnO}_4$ .

Random error or systematic error? \_\_\_\_\_ 1 mark

Step to reduce error: \_\_\_\_\_ 1 mark

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d. One of the products of this reaction acts as a catalyst for the reaction.

i. Which product is this?

1 mark

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ii. How could you demonstrate what substance is acting as the catalyst?

2 marks

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**End of Examination Paper**