ANGLO-CHINESE JUNIOR COLLEGE
DEPARTMENT OF CHEMISTRY
Preliminary Examination

CHEMISTRY **8872/01**
Higher 1

Paper 1 Multiple Choice

24 August 2017

50 minutes

Additional Materials: Multiple Choice Answer Sheet
                        Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluids.
Write your name, index number and tutorial class on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **16** printed pages.

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ANGLO-CHINESE JUNIOR COLLEGE
Department of Chemistry

[Turn over

Section A

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 Ether has the formula, CH_3OCH_3.

In a sample of ether, 8.7 % contains the ^{18}O isotope, with the rest contains the ^{16}O isotope.

What is the relative molecular mass of ether in this sample?

A 46.2

B 46.8

C 47.2

D 47.8

2 Copper reacts with dilute nitric acid to produce nitrogen dioxide gas. The balanced ionic equation is given.

$$Cu + 2H^+ + 2HNO_3 \rightarrow Cu^{2+} + 2NO_2 + 2H_2O$$
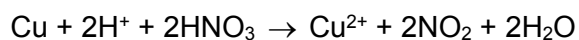
Which of the following is correct?

	Oxidation state of N in		Role of copper
	HNO_3	NO_2	
A	+5	-3	Reducing agent
B	+5	+4	Reducing agent
C	-5	-3	Oxidising agent
D	-5	+4	Oxidising agent

3   10 cm³ of propane was completely burnt in x cm³ of excess oxygen. After cooling to room temperature, the volume of the residual gas was 60 cm³. The residual gas was passed through aqueous sodium hydroxide was passed through and the volume reduced to y cm³.

Which of the following is correct?

	x	y
A	50	30
B	60	20
C	70	20
D	80	30

4   An organic compound with the formula $C_xH_yO_2$ has undergone incomplete combustion, producing carbon dioxide and carbon monoxide in the ratio of 99 : 1.

The equation may be represented as follows:

$$C_xH_yO_2 + \underline{\quad a \quad} O_2 \rightarrow \underline{\quad b \quad} CO + \underline{\quad c \quad} CO_2 + 0.5y\ H_2O$$

a, b and c can be expressed in terms of x and y.

Which of the following is correct?

	a	b	c
A	99x + 0.5x + 0.25y - 1	x	99x
B	99x + 0.5x + 0.25y	x	99x
C	0.99x + 0.005x + 0.25y- 1	0.01x	0.99x
D	0.99x + 0.005x + 0.25y	0.01x	0.99x

5 *Use of the Data Booklet is relevant to this question.*

The components of a 100 g sample of fertilizer is as shown in the table below:

Element	Mass / g
N	15
P	30
K	15
Other Elements	40

The recommended usage of fertilizer is 14 g of fertilizer per 5 dm^3 of water.

What is the concentration of nitrogen atoms in this recommended solution?

A   0.03 mol dm^{-3}

B   0.15 mol dm^{-3}

C   0.42 mol dm^{-3}

D   0.75 mol dm^{-3}

6   The elements **X** and **Y** are in Group 16 and 17 respectively in the same period.

Which of the following statements regarding **X** and **Y** is most likely to be true?

A   **Y** has more unpaired electrons than **X**.

B   **Y** atom is bigger than **X** atom.

C   **X** is more electronegative than **Y**.

D   The first ionisation energy of **X** will likely be less endothermic than that of **Y**.

7   The table gives the successive ionisation energies for an element *X*.

	1st	2nd	3rd	4th	5th	6th
Ionisation energy/ kJ mol^{-1}	950	1800	2700	4800	6000	12300

What could be the formula of the fluoride of *X*?

A   *X*F

B   *X*F$_2$

C   *X*F$_3$

D   *X*F$_4$

8   'Dot-and-cross' diagrams for CO are shown below.

Which circle pair of electrons represent a co-ordinate bond?
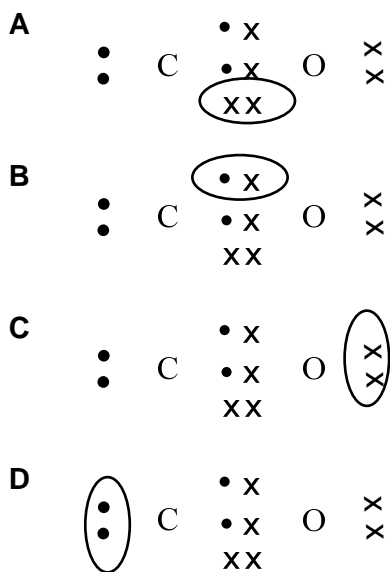
A

B

C

D

9   Which of the following molecules is linear and non-polar?

A   CS$_2$

B   SCN

C   SO$_2$

D   SiO$_2$

10 Consider the following four compounds.

1 $CH_3CH_2CH_2F$

2 $CH_3CH_2CH_2OH$

3 $CH_3CH_2CH_2CH_3$

4 $(CH_3)_3CH$

What is the order of increasing boiling points of the compounds (from lowest to highest)?

A $2 \rightarrow 1 \rightarrow 3 \rightarrow 4$

B $4 \rightarrow 3 \rightarrow 2 \rightarrow 1$

C $3 \rightarrow 1 \rightarrow 2 \rightarrow 4$

D $4 \rightarrow 3 \rightarrow 1 \rightarrow 2$

11 The enthalpy changes for two reactions are given by the equations:

$2Cr(s) + \frac{3}{2}O_2(g) \rightarrow Cr_2O_3(s)$ $\Delta H = -1130$ kJ mol^{-1}

$C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$ $\Delta H = -110$ kJ mol^{-1}

What is the enthalpy change, in kJ mol^{-1}, for the following reaction?

$3C(s) + Cr_2O_3(s) \rightarrow 2Cr(s) + 3CO(g)$
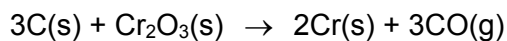
A -800

B +800

C -1460

D +1460

12 Hydrogencarbonate may react with acid according to the equation below.
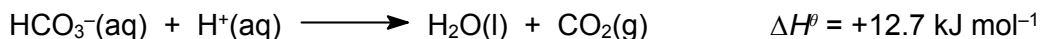
$$HCO_3^-(aq) + H^+(aq) \longrightarrow H_2O(l) + CO_2(g) \qquad \Delta H^\theta = +12.7 \text{ kJ mol}^{-1}$$

Using the following enthalpy changes of formation provided, what is the standard enthalpy change of formation of $H^+(aq)$?

species	ΔH_f^θ / kJ mol^{-1}
$H_2O(l)$	−285.8
$CO_2(g)$	−393.5
$HCO_3^-(aq)$	−692.0

A   −25.4 kJ mol^{-1}

B   0.0 kJ mol^{-1}

C   +25.4 kJ mol^{-1}

D   +1384 kJ mol^{-1}

13 In an experiment, 70 cm^3 of water at 25 ºC was brought to boil by burning butane in excess oxygen. Calculate the volume of butane required if this process is only 85 % efficient.

[ΔH_c (butane) = −2877 kJ mol^{-1}; c = 4.2 J g^{-1} K^{-1}; Molar volume of gas under the given conditions = 24 dm^3]

A 0.0721 dm^3 **B**   0.156 dm^3 **C**   0.184 dm^3 **D**   0.216 dm^3

14 Which statement concerning the equilibrium reaction given below is correct?

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

   yellow   orange

A   It is a redox reaction.

B   The equilibrium constant, K_c, has the units of mol^{-2} dm^6.

C   The colour of the solution change from orange to yellow when pH increases.

D   The addition of a catalyst will result in an increase in the concentration of $Cr_2O_7^{2-}(aq)$.

15   The kinetics of the reaction between iodine and compound **J** is investigated.
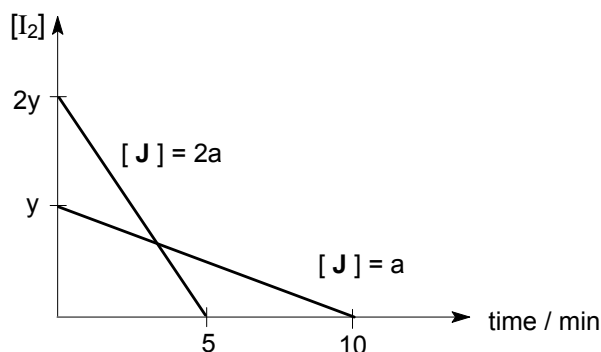
What conclusions can be drawn from the graphs?

A   The reaction is second order with respect to compound **J** because rate of reaction increases by four times when its concentration is increased by two times.

B   Both iodine and compound **J** react in equal mole ratio.

C   The reaction is first order with respect to iodine because half-life is constant.

D   The overall order of the reaction is 1.

16   **X**, **Y** and **Z** are elements in Period 3 of the Periodic Table.

A mixture containing the oxides of **X**, **Y** and **Z** was dissolved in excess dilute sulfuric acid and filtered. The oxide of **Z** was collected as a residue. When excess dilute sodium hydroxide was added to the filtrate, only a white precipitate of the hydroxide of **Y** was formed.

What are the possible identities of **X**, **Y** and **Z**?

	X	**Y**	**Z**
A	Mg	A*l*	P
B	A*l*	Mg	P
C	Mg	A*l*	Si
D	A*l*	Mg	Si

17 The oxide and chloride of an element **X** are separately mixed with water. The two resulting solutions have the same effect on litmus solution.

What is element **X**?

A Sodium

B Magnesium

C Aluminum

D Phosphorus

18 Which property of benzene is reflected as a consequence of the delocalised electrons present in its molecule?

A Benzene is cyclic.

B Benzene is a planar molecule.

C Benzene is a good conductor of electricity.

D Substitution on benzene takes place more easily than addition reactions.

19 2-methylpropylamine, $(CH_3)_2CHCH_2NH_2$ can be produced by the following reaction scheme starting with compound **B**.

$$B \xrightarrow[\text{ethanol}]{\text{KCN in}} C \xrightarrow{\text{reduction}} \text{2-methylpropylamine}$$
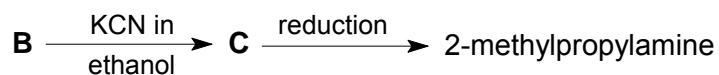
Which one of the following compounds is **B** likely to be?

A $CH_3CH_2CH_2Br$

B $CH_3CHBrCH_3$

C CH_3CH_2CHO

D CH_3COCH_3

20 Which of the following isomers of $C_5H_{11}Br$ gives the greatest number of different alkenes on treatment with hot ethanolic sodium hydroxide?

A $CH_3CH_2CH(CH_3)CH_2Br$

B $CH_3CH_2CH_2CHBrCH_3$

C $CH_3CH_2CHBrCH_2CH_3$

D $CH_3CH_2CH_2CH_2CH_2Br$

21 Four drops of 1-chorobutane, 1-bromobutane and 1-iodobutane were separately added to three test-tubes containing 1.0 cm³ of aqueous silver nitrate at 60 °C. The following reaction occurred.

$$H_2O(l) + R–X(l) + Ag^+(aq) \rightarrow R–OH(aq) + AgX(s) + H^+(aq)$$

[R: C_4H_9–; X: halogen]

Which of the following best explains why the rate of formation of cloudiness (precipitate) in the tubes was in the order RCl < RBr < RI?

A The R–X bond polarity decreases from RCl to RI.

B The bond energy of R–X decreases from RCl to RI.

C The solubility of AgX(s) decreases from $AgCl$ to AgI.
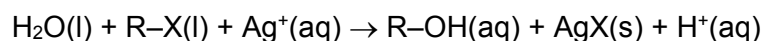
D The ionisation energy of the halogen decreases from Cl to I.

22 Which one of the following compounds:

(i) is unaffected by hot alkaline potassium manganate(VII);

(ii) produces 0.5 mol of hydrogen when 1 mol of compound is treated with excess sodium?

A $(CH_3)_2C(OH)C(OH)(CH_3)CH_2CH_3$

B $(CH_3)_2CHCH_2OH$

C $(CH_3)_3COH$

D $CH_3CH(OH)CH(OH)CH_3$

23 The diagram shows an experimental set-up.
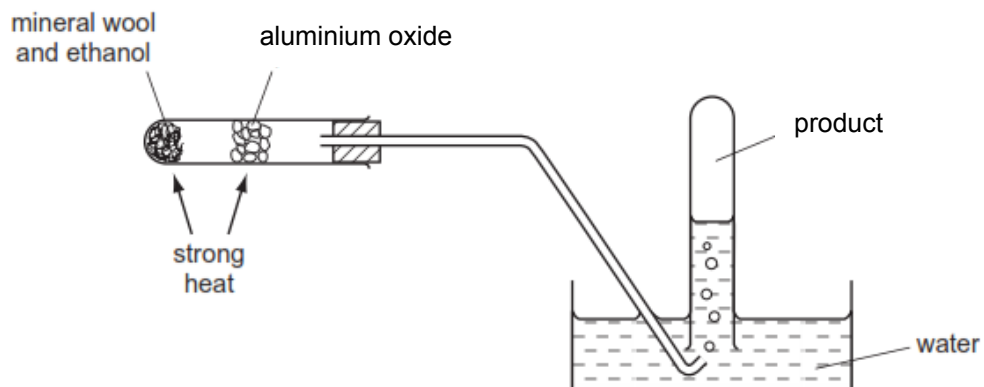
Which compound can be produced by using the above apparatus?

A   Oxygen

B   Hydrogen

C   Ethene

D   Ethane

24 An alcohol of molecular formula $C_4H_{10}O_2$ contains two -OH groups and has an unbranched carbon chain.

On reaction with an excess of acidified potassium manganate(VII), this alcohol is converted into a compound of molecular formula $C_4H_6O_4$.

To which two carbons in the chain of the alcohol are the two -OH groups attached?

A   1st and 2nd

B   1st and 3rd

C   1st and 4th

D   2nd and 3rd

25   Which of the following reagents and conditions can distinguish between ethyl methanoate and ethyl ethanoate?

    A   Heat with NaOH(aq)

    B   Heat with H_2SO_4(aq)

    C   Heat with NaOH(aq) followed by Na_2CO_3(aq)

    D   Heat with acidified $KMnO_4$(aq)

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26   The pH range and colour changes for two indicators are given below.

Indicator	pH range
X	violet 3.0 – 5.0 red
Y	yellow 5.6 – 7.6 blue

Which of the following solutions will give a red solution when indicator **X** is used and a yellow solution when indicator **Y** is used?

1   0.1 mol dm^{-3} HX (K_a = 2.5 x 10^{-10} mol dm^{-3})

2   0.1 mol dm^{-3} CH$_3$COOH (K_a = 1.8 x 10^{-5} mol dm^{-3})

3   0.1 mol dm^{-3} HCl

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

27 The graph below shows the Boltzmann distribution of molecular energies at a given temperature.
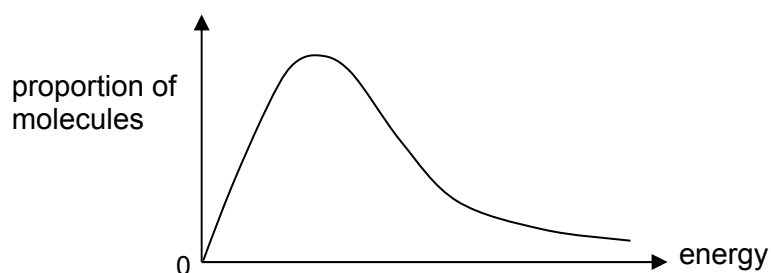

As temperature increases, which statements are correct?

1 The proportion of molecules with any given energy increases.

2 The maximum of the curve is displaced to the right.

3 The proportion of molecules with energies above any given value increases.

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

28 The energy profile for a reversible reaction is shown below.
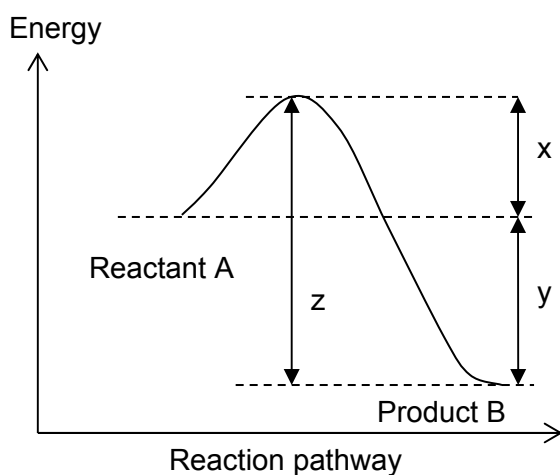
Which of the following statement is/are **correct**?

1 The reaction from **B** to **A** is endothermic.

2 The activation energy of the reaction **A** to **B** is x.

3 The activation energy of the reaction **B** to **A** is $z - y$.

29 Which of the following show an increase in radius?

1 $Al < Mg < Na$

2 $Cl^- < S^{2-} < P^{3-}$

3 $Na^+ < Ca^{2+} < K^+$

The responses **A** to **D** should be selected on the basis of
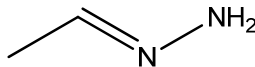
A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

30   The use of *Data Booklet* is relevant to this question.

Carbonyl compounds react with hydrazine, N_2H_4, in the same manner as 2,4-dintrophenylhydrazine.

Which of the following are correct?

1   The product is when ethanal reacts with hydrazine.

2   The enthalpy change of the reaction is negative.

3   It is a condensation reaction.

END OF PAPER

Section A

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1   Ether has the formula, CH_3OCH_3.

In a sample of ether, 8.7 % contains the ^{18}O isotope, with the rest contains the ^{16}O isotope.

What is the relative molecular mass of ether in this sample?

A   46.2

B   46.8

C   47.2

D   47.8

Ar of O = 8.7 x 18 + 91.3 x 16 /100 = 16.174
Relative Molecular Mass = 16.174 + 12 + 3+ 12 + 3 = 46.174 = 46.2

2   Copper reacts with dilute nitric acid to produce nitrogen dioxide gas. The balanced ionic equation is given.

$$Cu + 2H^+ + 2HNO_3 \rightarrow Cu^{2+} + 2NO_2 + 2H_2O$$
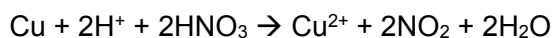
Which of the following is correct?

	Oxidation state of N in		Role of copper
	HNO_3	NO_2	
A	+5	-3	Reducing agent
B	+5	+4	Reducing agent
C	-5	-3	Oxidising agent
D	-5	+4	Oxidising agent

Cu is being oxidised. It is a reducing agent.
HNO_3 = (+1)+ ? + 3(-2) =0
? = +5

NO_2 = ? + 2（-2）= 0
? = +4

3 10 cm³ of propane was completely burnt in x cm³ of excess oxygen. After cooling to room temperature, the volume of the residual gas was 60 cm³. The residual gas was passed through aqueous sodium hydroxide was passed through and the volume reduced to y cm³.

Which of the following is correct?

	x	y
A	50	30
B	60	20
C	70	20
D	80	30

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

10cm³ requires 50cm³ of oxygen for complete combustion and 30cm³ of CO_2 will be produced. Hence x = 50 + (60-30) = 80 cm³. y = volume of excess oxygen = 60-30 cm³

4 An organic compound with the formula $C_xH_yO_2$ has undergone incomplete combustion, producing carbon dioxide and carbon monoxide in the ratio of 99 : 1.

The equation may be represented as follows:

$$C_xH_yO_2 + \underline{\ a\ }\ O_2 \rightarrow \underline{\ b\ }\ CO + \underline{\ c\ }\ CO_2 + 0.5y\ H_2O$$

a, b and c can be expressed in terms of x and y.

Which of the following is correct?

	a	b	c
A	99x + 0.5x + 0.25y - 1	x	99x
B	99x + 0.5x + 0.25y	x	99x
C	0.99x + 0.005x + 0.25y- 1	0.01x	0.99x
D	0.99x + 0.005x + 0.25y	0.01x	0.99x

C = 0.01x + 0.99x = x
Check by balancing O atoms on both sides,
2 + 2(0.99x + 0.005x + 0.25y- 1) = 0.01x + 0.99x(2) + 0.5y
        1.98x+ 0.01x+0.50y = 1.99x + 0.5y

5   *Use of the Data Booklet is relevant to this question.*

The components of a 100 g sample of fertilizer is as shown in the table below:

Element	Mass / g
N	15
P	30
K	15
Other Elements	40

The recommended usage of fertilizer is 14 g of fertilizer per 5 dm^3 of water.

What is the concentration of nitrogen atoms in this recommended solution?

A   0.03 mol dm^{-3}

B   0.15 mol dm^{-3}

C   0.42 mol dm^{-3}

D   0.75 mol dm^{-3}

15/100 x 14grams = 2.1 grams
No of moles of N = 2.1/14 = 0.15mol
Concentration = 0.15/5 = 0.03 mol dm^{-3}

6   The elements **X** and **Y** are in Group 16 and 17 respectively in the same period.

Which of the following statements regarding **X** and **Y** is most likely to be true?

A   **Y** has more unpaired electrons than **X**.

B   **Y** atom is bigger than **X** atom.

C   **X** is more electronegative than **Y**.

D   The first ionisation energy of **X** will likely be less endothermic than that of **Y**.

X: ns^2np^4
Y: ns^2np^5 => less unpaired electrons than X

Y has more protons than X. Thus Y would be smaller than X. The electrons are more strongly attracted to the nucleus in Y than X. Thus Y would be more electronegative than X. More energy is needed to remove 1st electron from its nucleus.
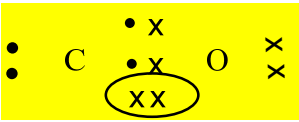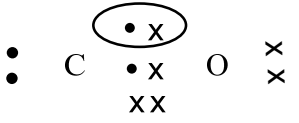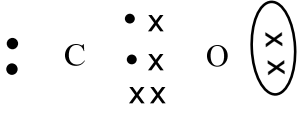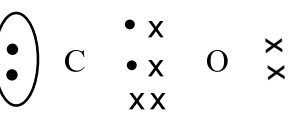
7 The table gives the successive ionisation energies for an element *X*.

	1st	2nd	3rd	4th	5th	6th
ionisation energy/ kJ mol^{-1}	950	1800	2700	4800	6000	12300

What could be the formula of the fluoride of *X*?

A *X*F

B *X*F$_2$

C *X*F$_3$

D *X*F$_4$

The greatest jump in energy is between 3rd and 4th IE. Thus 3 valence electrons are in X which means that the highest oxidation number of X is +3.

8	'Dot-and-cross' diagrams for carbon monoxide are shown below. Which circle pair of electrons represent a co-ordinate bond?
A	
B	
C	
D	

Coordinate bond is a covalent bond in which both electrons come from the same atom.

9 Which of the following molecules is linear and non-polar?

A CS_2

B SCN

C SO_2

D SiO_2

10 Consider the following four compounds.

1 $CH_3CH_2CH_2F$

2 $CH_3CH_2CH_2OH$

3 $CH_3CH_2CH_2CH_3$

4 $(CH_3)_3CH$

What is the order of increasing boiling points of the compounds (from lowest to highest)?

A $2 \rightarrow 1 \rightarrow 3 \rightarrow 4$

B $4 \rightarrow 3 \rightarrow 2 \rightarrow 1$

C $3 \rightarrow 1 \rightarrow 2 \rightarrow 4$

D $4 \rightarrow 3 \rightarrow 1 \rightarrow 2$

Compound 2 has hydrogen bonds between its molecules. Compound 1 is polar and has pd-pd interactions between its molecules.

Compound 3 and 4 are both structural isomers. Compound 3 is linear whereas compound 4 is branched. Thus compound 3 has more id-id interactions due to bigger surface area than compound 4.

11 The enthalpy changes for two reactions are given by the equations:

$$2Cr(s) + \frac{3}{2} O_2(g) \rightarrow Cr_2O_3(s) \qquad \Delta H = -1130 \text{ kJ mol}^{-1}$$

$$C(s) + \frac{1}{2} O_2(g) \rightarrow CO(g) \qquad \Delta H = -110 \text{ kJ mol}^{-1}$$

What is the enthalpy change, in kJ mol^{-1}, for the following reaction?

$$3C(s) + Cr_2O_3(s) \rightarrow 2Cr(s) + 3CO(g)$$

A   -800

B   **+800**

C   -1460

D   +1460

$$Cr_2O_3(s) \rightarrow 2Cr(s) + \frac{3}{2} O_2(g)$$

$$3C(s) + 3/2 \; O_2(g) \rightarrow 3CO(g)$$

$$3C(s) + Cr_2O_3(s) \rightarrow 2Cr(s) + 3CO(g)$$
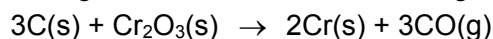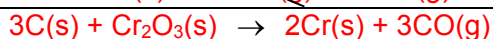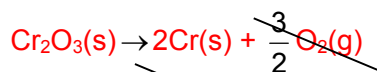
Enthalpy change of reaction = -110(3) + 1130 = + 800 kJ mol^{-1}

12 Hydrogencarbonate may react with acid according to the equation below.

$$HCO_3^-(aq) + H^+(aq) \longrightarrow H_2O(l) + CO_2(g) \qquad \Delta H^\ominus = +12.7 \text{ kJ mol}^{-1}$$

Using the following enthalpy changes of formation provided, what is the standard enthalpy change of formation of H$^+$(aq)?

species	ΔH_f^θ / kJ mol^{-1}
$H_2O(l)$	−285.8
$CO_2(g)$	−393.5
$HCO_3^-(aq)$	−692.0

A   −25.4 kJ mol^{-1}

B   **0.0 kJ mol^{-1}**

C   +25.4 kJ mol^{-1}

D   +1384 kJ mol^{-1}

$\Delta H = \Delta H_f(\text{products}) - \Delta H_f(\text{reactants})$
$+12.7 = -285.8 - 393.5 - (-692.0 + \Delta H_{H^+})$
$\Delta H_{H^+} = 0$

13 In an experiment, 70 cm^3 of water at 25 ºC was brought to boil by burning butane in excess oxygen. Calculate the volume of butane required if this process is only 85 % efficient.

[ΔH_c (butane) = –2877 kJ mol^{-1}; c = 4.2 J g^{-1} K^{-1}; Molar volume of gas under the given conditions = 24 dm^3]

A 0.0721 dm^3 **B** 0.156 dm^3 **C** 0.184 dm^3 **D** 0.216 dm^3

Heat absorbed = Q = mcΔT = 70 x 4.18 x 75 = 21 945 J

Heat released = 100/85 x 21 945 = 25 817 J
No of moles of butane = 25 817x10^{-3} / 2877 = 0.008973 mol
Volume = 0.008973   x 24 = 0.216 dm^3

14 Which statement concerning the equilibrium reaction given below is correct?
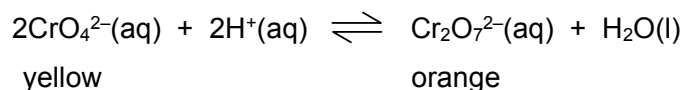
$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$
    yellow   orange

A It is a redox reaction.

B The equilibrium constant, K_c, has the units of mol^{-2} dm^6.

C The colour of the solution change from orange to yellow when pH increases.

D The addition of a catalyst will result in an increase in the concentration of $Cr_2O_7^{2-}(aq)$.

There is no change in oxidation state of Cr (+6 in both species).
$K_c = [Cr_2O_7^{2-}]/[CrO_4^{2-}]^2[H^+]^2$ hence, units is mol^{-3}dm^9
pH increases implies that there is a decrease in H+. By LCP, system shifts to the left as more H+ ions are produced.

15 The kinetics of the reaction between iodine and compound **J** is investigated.
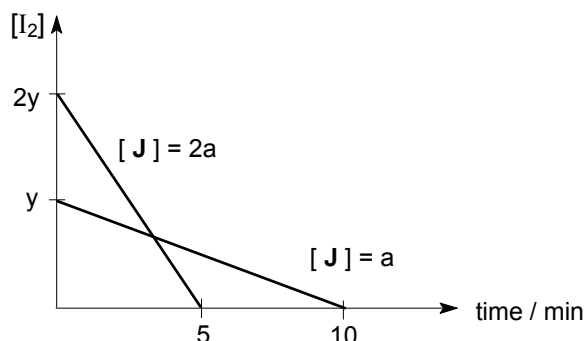
What conclusions can be drawn from the graphs?

A The reaction is second order with respect to compound **J** because rate of reaction increases by four times when its concentration is increased by two times.

B Both iodine and compound **J** react in equal mole ratio.

C The reaction is first order with respect to iodine because half-life is constant.

D The overall order of the reaction is 1.

Gradient represents the rate of reaction. As [J] doubles, gradient of the graph quadruples. This implies that it is a 2nd order reaction.

16 **X**, **Y** and **Z** are elements in Period 3 of the Periodic Table.

A mixture containing the oxides of **X**, **Y** and **Z** was dissolved in excess dilute sulfuric acid and filtered. The oxide of **Z** was collected as a residue. When excess dilute sodium hydroxide was added to the filtrate, only a white precipitate of the hydroxide of **Y** was formed.

What are the possible identities of **X**, **Y** and **Z**?

	X	**Y**	**Z**
A	Mg	Al	P
B	Al	Mg	P
C	Mg	Al	Si
D	Al	Mg	Si

Z has to be an insoluble oxide which is silicon oxide. X oxide is soluble in acid and base. This X oxide is aluminium oxide which is amphoteric in nature.

17 The oxide and chloride of an element **X** are separately mixed with water. The two resulting solutions have the same effect on litmus solution.

What is element **X**?

A Sodium

B Magnesium

C Aluminum

D Phosphorus

Phosphorus oxide dissolves in water to give rise to acidic solution of phosphoric acid. Phosphorus chlorides also give rise to hydrochloric acid and phosphoric acid when it is hydrolysed in water.

18 Which property of benzene is reflected as a consequence of the delocalised electrons present in its molecule?

A Benzene is cyclic.

B Benzene is a planar molecule.

C Benzene is a good conductor of electricity.

D Substitution on benzene takes place more easily than addition reactions.

Substitution would be easier as compared to addition as resonance structure of benzene would keep the stable system intact.
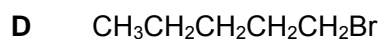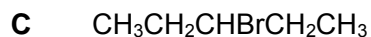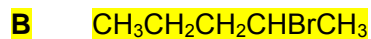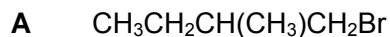
19 2-methylpropylamine, $(CH_3)_2CHCH_2NH_2$ can be produced by the following reaction scheme starting with compound **B**.
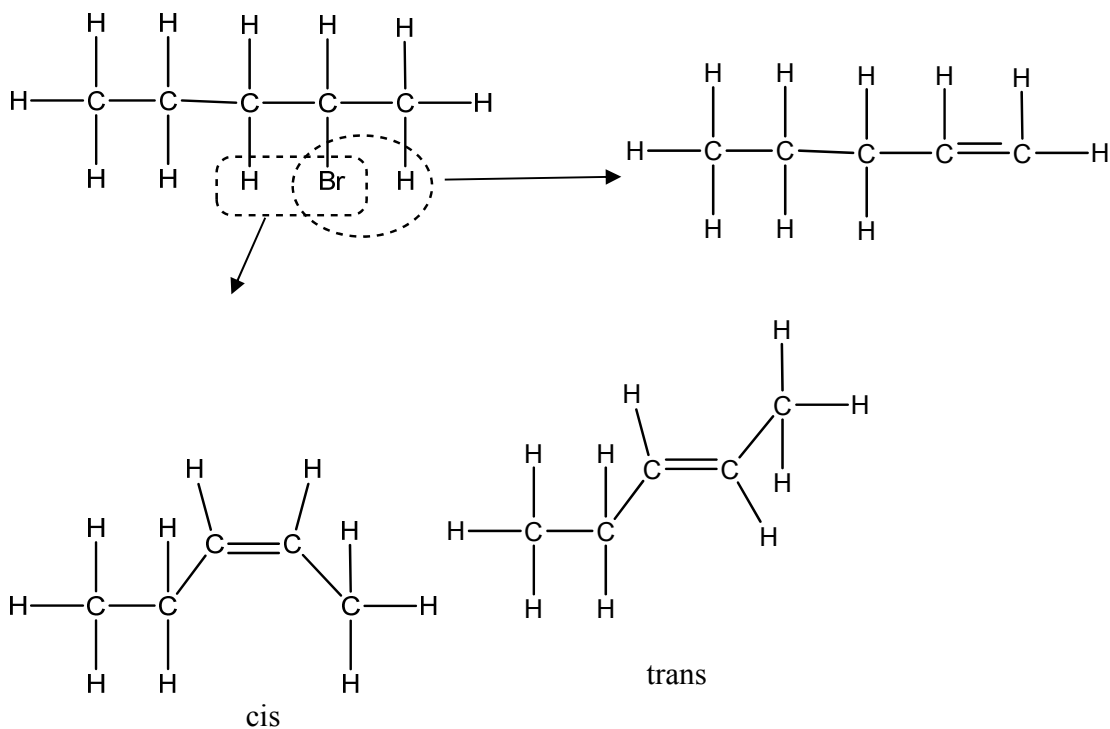
$$B \xrightarrow[\text{ethanol}]{\text{KCN in}} C \xrightarrow{\text{reduction}} \text{2-methylpropylamine}$$

Which one of the following compounds is **B** likely to be?

A $CH_3CH_2CH_2Br$
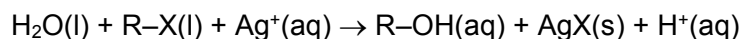
B $CH_3CHBrCH_3$

C CH_3CH_2CHO

D CH_3COCH_3

20 Which of the following isomers of $C_5H_{11}Br$ gives the greatest number of different alkenes on treatment with hot ethanolic sodium hydroxide?

A $CH_3CH_2CH(CH_3)CH_2Br$

B $CH_3CH_2CH_2CHBrCH_3$

C $CH_3CH_2CHBrCH_2CH_3$

D $CH_3CH_2CH_2CH_2CH_2Br$

cis

trans

21 Four drops of 1-chorobutane, 1-bromobutane and 1-iodobutane were separately added to three test-tubes containing 1.0 cm^3 of aqueous silver nitrate at 60 °C. The following reaction occurred.

$$H_2O(l) + R-X(l) + Ag^+(aq) \rightarrow R-OH(aq) + AgX(s) + H^+(aq)$$

[R: C$_4$H$_9$–; X: halogen]

Which of the following best explains why the rate of formation of cloudiness (precipitate) in the tubes was in the order RCl < RBr < RI?

A The R–X bond polarity decreases from RCl to RI.

B The bond energy of R–X decreases from RCl to RI.

C The solubility of AgX(s) decreases from AgCl to AgI.

D The ionisation energy of the halogen decreases from Cl to I.

I is bigger than Cl. Thus the overlapping of orbitals between C-I is less effective as compared C-Cl and the bond strength is weaker.

22 Which one of the following compounds:

(i) is unaffected by hot alkaline potassium manganate(VII);

(ii) produces 0.5 mol of hydrogen when 1 mol of compound is treated with excess sodium?

A $(CH_3)_2C(OH)C(OH)(CH_3)CH_2CH_3$

B $(CH_3)_2CHCH_2OH$

C $(CH_3)_3COH$

D $CH_3CH(OH)CH(OH)CH_3$

A and C are unaffected by oxidation due to tertiary alcohols. C can produce 0.5 mol of hydrogen gas as 1 mol of H^+ is given out from 1 mol of compound.

23 The diagram shows an experimental set-up.
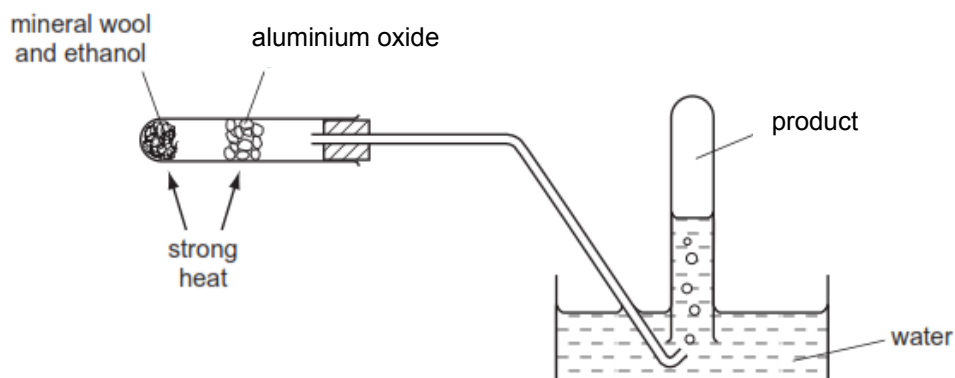
Which compound can be produced by using the above apparatus?

A Oxygen

B Hydrogen

C Ethene

D Ethane

Ethene gas and water are produced as the ethanol is dehydrated.

24   An alcohol of molecular formula $C_4H_{10}O_2$ contains two -OH groups and has an unbranched carbon chain.

On reaction with an excess of acidified potassium manganate(VII), this alcohol is converted into a compound of molecular formula $C_4H_6O_4$.

To which two carbons in the chain of the alcohol are the two -OH groups attached?

A   1st and 2nd

B   1st and 3rd

C   1st and 4th

D   2nd and 3rd

$C_4H_{10}O_2$ → $C_4H_6O_4$.
An Increase by 2 O atoms implies that two primary alcohol functional groups have been converted to 2 carboxylic acid functional groups with 4 oxygen atoms. The two primary alcohol functional groups must be situated at the 1st and 4th carbons.

25   Which of the following reagents and conditions can distinguish between ethyl methanoate and ethyl ethanoate?

A   Heat with NaOH(aq)

B   Heat with H_2SO_4(aq)

C   Heat with NaOH(aq) followed by Na_2CO_3(aq)

D   Heat with H_2SO_4(aq) followed by $KMnO_4$(aq)

Hydrolysis occurs. Both esters give ethanol, but 1 compound gives ethanoic acid and the other gives methanoic acid which will in turn be oxidised to carbon dioxide and water. Both will decolourise $KMnO_4$ but only ethyl methanoate will give carbon dioxide which will turn limewater chalky.

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26   The pH range and colour changes for two indicators are given below.

Indicator	pH range
X	violet 3.0 – 5.0 red
Y	yellow 5.6 – 7.6 blue

Which of the following solutions will give a red solution when indicator **X** is used and a yellow solution when indicator **Y** is used?

1   0.1 mol dm^{-3} HX (K_a = 2.5 x 10^{-10} mol dm^{-3})

2   0.1 mol dm^{-3} CH$_3$COOH (K_a = 1.8 x 10^{-5} mol dm^{-3})

3   0.1 mol dm^{-3} HCl

Option 1: pH = 5.3
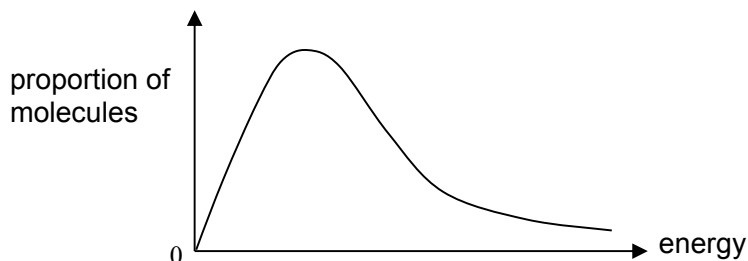   indicator X colour would be red and indicator Y colour would be yellow

Option 2: pH= 2.87
indicator X colour would be violet and indicator Y colour would be yellow

Option 3: pH = 1
indicator X colour would be violet and indicator Y colour would be yellow

**27** The graph below shows the Boltzmann distribution of molecular energies at a given temperature.

As temperature increases, which statements are correct?

1 The proportion of molecules with any given energy increases.

2 The maximum of the curve is displaced to the right.

**3** The proportion of molecules with energies above any given value increases.

It is not true that the proportion of molecules with lower energy would increase.
Maximum of curve displaces to the right as more particles gained higher in energy.
The proportion of molecules with higher kinetic energy increases as T increases and hence would have energies greater than in their original state.

28 The energy profile for a reversible reaction is shown below.
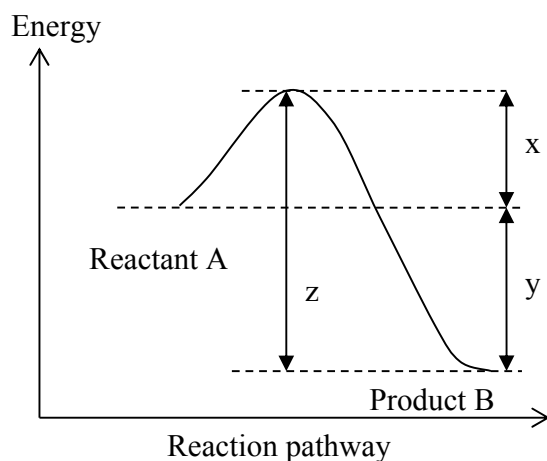
Which of the following statement is/are **correct**?

1 The reaction from **B** to **A** is endothermic.

2 The activation energy of the reaction **A** to **B** is x.

3 The activation energy of the reaction **B** to **A** is $z - y$.
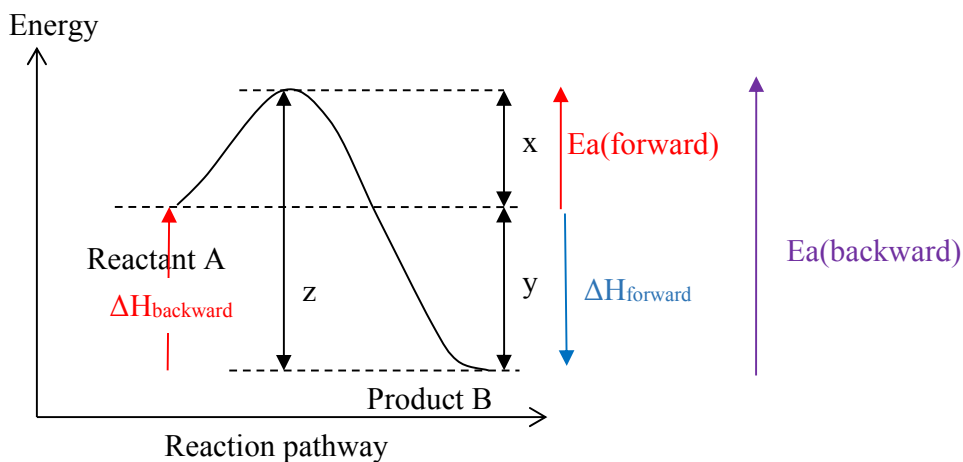
29 Which of the following show an increase in radius?

1 $Al < Mg < Na$

2 $Cl^- < S^{2-} < P^{3-}$

3 $Na^+ < Ca^{2+} < K^+$

Option 1: As proton number decreases, the electrostatic forces of attraction between nucleus and electrons decreases. Hence the atomic radius increases.
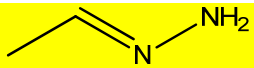Option 2: As proton number decreases, the electrostatic forces of attraction between nucleus and electrons decreases. Thus the ionic radius increases.
Option 3: Sodium ion has one less principal quantum shell than Ca ion and K ion. Thus it would be smaller than the other 2 elements. Ca ion has smaller ionic radius than K ion as it has one more proton than K ion.

30 The use of *Data Booklet* is relevant to this question.

Carbonyl compounds react with hydrazine, N_2H_4, in the same manner as 2,4-dintrophenylhydrazine.

Which of the following are correct?

1 The product is ⟍⟋=N⟍NH₂ when ethanal reacts with hydrazine.

2 The enthalpy change of the reaction is negative.

3 It is a condensation reaction.
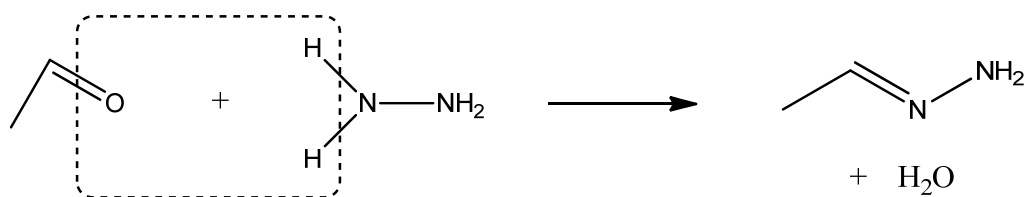
ethanal	hydrazine	Product
		+ H_2O

Bonds Broken	Bonds formed
C=O(740)	C=N(610)
2N-H (390X2)	2H-O(2X460)

Bonds Broken – Bonds Formed = 1520 – 1530 = -10 kJ mol^{-1}
Carbonyl compounds undergo condensation(elimination-addition) with hydrazine.

END OF PAPER

ANGLO-CHINESE JUNIOR COLLEGE
DEPARTMENT OF CHEMISTRY
Preliminary Examination

CHEMISTRY   **8872/02**
Higher 1

Paper 2   15 August 2017

2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Writing Paper
                        Data Booklet
                        Graph Paper

READ THESE INSTRUCTIONS FIRST

Write your index number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** the questions.

Section B
Answer **two** questions on separate answer paper.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
B5	
B6	
B7	
Total	

This document consists of **15** printed pages.

Section A

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

1 Aluminium is the most abundant Group 13 element and constitutes about 8 % of the Earth's crust. The extraction of aluminium is done by processing aluminium ore, bauxite to produce aluminium oxide also known as alumina.

A variety of aluminium compounds, for example aluminium chloride and aluminium hydroxide, are used for different purposes such as food additives, colouring and pharmaceuticals.

Aluminium hydroxide and magnesium hydroxide are antacids. They are used to treat symptoms of increased stomach acid, such as heartburn, upset stomach, sour stomach, or acid indigestion. Once ingested, they react with the hydrochloric acid in the stomach.

One label of a commercial product, Mintox™ is shown below.

Drug Facts

Active ingredients (in each tablet)	Purpose
Aluminum hydroxide (equiv. to dried gel, USP) 200 mg	Antacid
Magnesium hydroxide 200 mg	Antacid
Simethicone 25 mg	Antigas

Uses relieves: ■ acid indigestion ■ heartburn ■ sour stomach ■ upset stomach & gas associated with these symptoms

Warnings

Ask a doctor before use if you have ■ kidney disease ■ a magnesium-restricted diet

Ask a doctor or pharmacist before use if you are ■ presently taking a prescription drug. Antacids may interact with certain prescription drugs.

Do not take more than 16 tablets in a 24-hour period, or use the maximum dosage of this product for more than 2 weeks, except under the advice and supervision of a doctor.

Keep out of reach of children. In case of overdose get medical help or contact a Poison Control Center immediately.

Directions ■ chew 1 to 4 tablets 4 times a day or as directed by a doctor

(a) **(i)** Write down the electronic configuration of Al.

………………………………………………………………………………[1]

(ii) Why is the ionic radius of aluminium far smaller than its atomic radius?

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

………………………………………………………………………………[1]

1 **(a)** **(iii)** Explain why aluminium forms compounds with an oxidation state of +3 but not sodium.

....

....

....[1]

(b) **(i)** Which antacid in the tablet is more effective in reacting with the hydrochloric acid in the stomach? Support your answer with relevant working.

[2]

(ii) Calculate the maximum number of chewable tablets that a person can take in a week.

[1]

(iii) Assuming that a typical adult has a body mass of 70 kg, determine the maximum weekly intake of aluminium hydroxide in grams per kg of body mass.

[2]

1 **(c)** **(i)** Aluminium chloride is an active ingredient used in skin medication to control excessive sweating.

Aluminium chloride is often describe as *electron deficient*. Explain what is meant by *electron deficient*.

……………………………………………………………………………………

……………………………………………………………………………………

………………………………………………………………………………[1]

(ii) In the vapour phase, aluminium chloride forms a gaseous product with a molar mass of 267 g mol^{-1}. With the aid of a clearly labelled diagram, explain how this product is formed from aluminium chloride.

[2]

[Total: 11]

2 In a university laboratory, the percentage purity of a sample of complex iron salt, $K_3Fe(C_2O_4)_3.3H_2O$ can be determined by analyzing the $C_2O_4^{2-}$ content through titrating with acidified $KMnO_4$.

1.20 g of impure $K_3Fe(C_2O_4)_3.3H_2O$ sample was dissolved and made up to 100 cm^3. 10.0 cm^3 of this solution was pipetted into a conical flask and 10.0 cm^3 of 1 mol dm^{-3} sulfuric acid was added. The mixture was heated and titrated with 0.0200 mol dm^{-3} $KMnO_4$. CO_2 is produced during the reaction.

It was determined that 12.30 cm^3 of $KMnO_4$ was required to reach the end-point.

**(a)** **(i)** Suggest why hydrochloric acid is not used to acidify the mixture.

……………………………………………………………………………………

………………………………………………………………………………[2]

(ii) In the acidic medium, $C_2O_4^{2-}$ ions exist as $H_2C_2O_4$.
Write a half equation to show the conversion of $H_2C_2O_4$ to CO_2.

………………………………………………………………………………[1]

(b) **(i)** Calculate the amount of $KMnO_4$ used to react with 10.0 cm^3 of the iron complex salt solution.

[1]

(ii) Using the half-equation below and your answer in **(a)(ii)**, calculate the amount of $C_2O_4^{2-}$ present in 10.0 cm^3 of the iron complex salt solution.
$$MnO_4^- + 8H^+ + 5e \rightarrow Mn^{2+} + 4H_2O$$
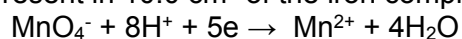
[1]

(iii) Hence, determine the mass of $K_3Fe(C_2O_4)_3.3H_2O$ in 100 cm^3 of iron complex salt solution.
(molar mass of $K_3Fe(C_2O_4)_3.3H_2O$ = 491.1 g mol^{-1})

[2]

(iv) Calculate the percentage purity of the iron complex salt.

[1]

[Total: 8]

3 The emergence of multidrug-resistant bacteria has encouraged vigorous efforts to develop antibacterial agents. N-methylhydroxylamine has been found to show vast potential as an antibacterial agent.

$$H-N \overset{OH}{\underset{CH_3}{\big|}}$$

N-methylhydroxylamine (pK$_b$ = 8.04)

N-methylhydroxylamine has properties similar to ammonia and it dissolves in water as shown below:

$$CH_3NHOH(aq) + H_2O(l) \rightleftharpoons CH_3NH_2OH^+(aq) + OH^-(aq)$$
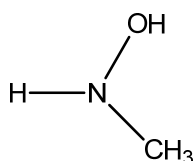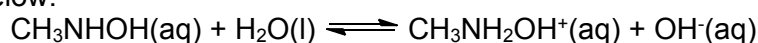
(a) Write the expression for the base dissociation constant of N-methylhydroxylamine in water.

[1]

(b) Calculate the base dissociation constant of the N-methylhydroxylamine solution.

[1]

An aqueous solution of 0.05 mol dm^{-3} hydrochloric acid was gradually added to 50.0 cm^3 of 0.02 mol dm^{-3} aqueous N-methylhydroxylamine.

(c) Determine the initial pH of N-methylhydroxylamine solution.

[2]

3 **(d)** Calculate the volume of hydrochloric acid needed at the equivalence point.

[1]

(e) State the volume of hydrochloric acid required to be added to another identical solution of N-methylhydroxylamine to obtain a solution which best resists pH change.

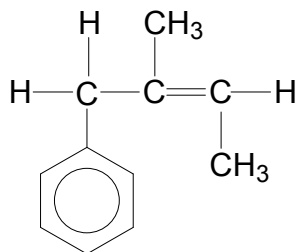……………………………………………………………………………………[1]

(f) Calculate the pH of that solution.

[1]

(g) Write **two** equations to show how the solution in **(e)** resists change in pH when small amounts of acid and alkali are added separately.

[2]

[Total: 9]

4 (a) Draw the structures of the organic product(s) formed when compound **A** below reacts with each of the following reagents.

compound **A**

Reagents and Conditions	Organic Product(s) formed
(i) HBr(g)	
(ii) KMnO₄; dilute H₂SO₄; heat under reflux	
(iii) Cl₂(g); AlCl₃; dark	

[4]

4 (b) State the type of isomerism exhibited by compound **A**, and hence draw the structures of the two isomers formed.

[2]

(c) Ethanal is a flammable liquid with a fruity smell. It occurs naturally in ripe fruit, coffee and fresh bread. A synthetic route involving ethanal is shown below.

(i) Draw the structural formulae of compounds **B**, **C** and **D** in the boxes below.

[3]
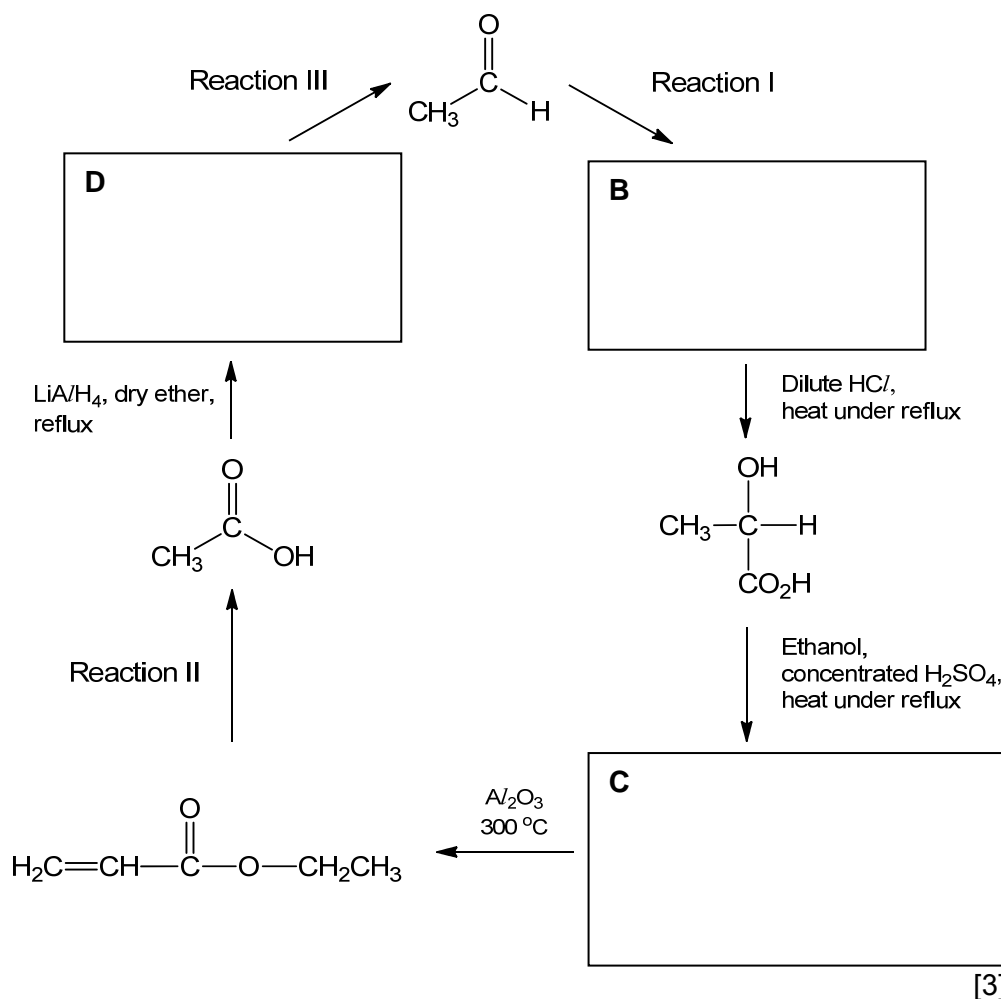
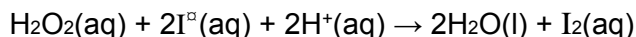**4 (c) (ii)** Suggest reagents and conditions for

Reaction I, ...

Reaction II, ...

Reaction III, ...

[3]

[Total: 12]

Section B

Answer **two** questions from this section on the separate answer papers.

5 **(a)** In an experiment, the effect of reactant concentration on the rate of reaction between hydrogen peroxide and potassium iodide at 298K was investigated.

The rate of formation of iodine in the reaction:
$$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + I_2(aq)$$
is given by:
$$rate = k[H_2O_2]^a[I^-]^b[H^+]^c$$
whereby a, b and c are the orders of reaction.

The iodine liberated in the above reaction was reacted with a fixed amount of sodium thiosulfate until no more sodium thiosulfate was left. The excess iodine caused the solution to become coloured. By adding a few drops of starch, the iodine showed up more clearly as it formed a blue-black complex.

The time taken for the formation of the blue-black complex was measured. The reciprocal of this time ($\frac{1}{t}$) is used as a measure of the initial rate of reaction.

Concentration of KI/ mol dm^{-3}	Time/ s
0.10	5.5
0.075	7.4
0.050	11.3
0.025	22.7

  (i) Plot a graph of initial rate against concentration of iodide ions. [3]

  (ii) Hence, use your graph to determine the order of reaction with respect to iodide ions. [1]

  (iii) In theory, the orders of reaction with respect to hydrogen peroxide and acid are one and zero respectively. [2]

  Using your answer in (**a**)(**ii**) and given that [H_2O_2] = 0.01 mol dm^{-3}, [I^-] = 0.02 mol dm^{-3}, [H^+] = 0.0005 mol dm^{-3} and rate = 2.30 x 10^{-6} mol dm^{-3} s^{-1}, determine the rate constant for this reaction and state its units.

  (iv) Suggest what would happen to the initial rate of reaction if the temperature is changed to 308K. [1]

  (b) **(i)** Describe the reactions, if any when separate samples of sodium and phosphorus are added to water containing universal indicator. [2]

  (ii) Explain the acid-base character of oxides of sodium and phosphorus in water. Suggest the pH of any aqueous solution formed. [2]

5 **(c)** When heated with chlorine under suitable conditions, hydrocarbon **X,** C_6H_{14} forms a total of only 3 mono-chlorinated products.

(i) Draw the three possible chlorinated products of **X**. [3]

(ii) The following table provides the rate of abstraction of a hydrogen on a primary, secondary and tertiary carbon. [2]

Type of C	$-CH_3$	$-CH_2R$	$-CHR_2$
Relative rate	1	4	6

What is the expected ratio of the mono-chlorinated products of **X** formed?

(iii) State one environmental effect of chlorinated products of **X**. [1]

(iv) Describe a simple chemical test to distinguish the chlorinated products of **X** from hydrocarbon **X**. [3]

[Total: 20]

6 **(a)** Carbon forms the backbone of organic compounds and is in Period 2 of the Periodic Table. The second ionisation energy of some consecutive elements in Period 2 are plotted.
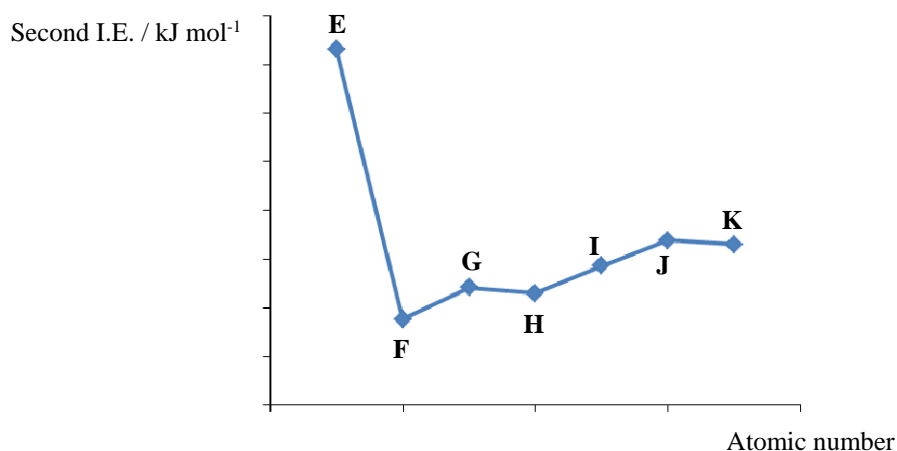
(i) Write an equation to represent second ionisation energy of carbon. [1]

(ii) By considering electronic configurations, explain why the second ionisation energy of carbon is lower than that of boron. [2]

(iii) Which letter represents carbon in the plot? Explain your answer. [2]

(b) Ethanoic acid and ethanol react together in the presence of concentrated sulfuric acid as the catalyst. The following equilibrium is established, in which the ester, ethyl ethanoate, is formed.

$$CH_3COOH(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$$

(i) State Le Chatelier's Principle. [1]

(ii) Use Le Chatelier's Principle to predict and explain how the position of equilibrium of this reaction would be affected when sodium hydroxide is added. [2]

(iii) Equimolar amounts of ethanoic acid and ethanol were mixed and at equilibrium, 1.00 mole of ethyl ethanoate is present. The total volume of the reaction mixture is 0.5 dm³. [3]

Given that the value of K_c for the reaction between ethanoic acid and ethanol is 4.0, determine the initial concentration of ethanoic acid.

(c) Other than ethanoic acid, there are other compounds that have the same molecular formula, $C_2H_4O_2$. [3]

Give the skeletal formulae of **three** other possible isomers, with different functional groups from each other, which have this molecular formula.

6 **(d)** In the laboratory, there are three bottles of chemicals which are unlabelled. [6] The three bottles contain one of the following, but not in the order given.

Ethanoic acid

Propanone

Propanal

Suggest two simple chemical tests that will allow you to distinguish between the three unlabelled bottles. State clearly the observations and write equations for the reactions that occur.

[Total:20]

7 Diethylene glycol (DEG), with the formula (HOCH$_2$CH$_2$)$_2$O, is used in a wide range of industrial products. It is poisonous and has been involved in a number of prominent mass poisonings spanning back to 1937.

(a) Following its ingestion, DEG is rapidly absorbed and distributed within the human body which is made up of up to 60% water.

State and draw the type of bonding between DEG and water. [3]

(b) DEG is produced by the hydrolysis of the cyclic ethylene oxide, (CH$_2$)$_2$O.

$$2 (CH_2)_2O + H_2O \rightarrow HO-CH_2CH_2-O-CH_2CH_2-OH$$
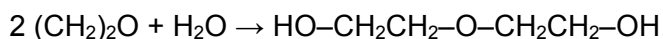
(i) The oxygen atom is bridging the two carbon atoms in the cyclic ethylene oxide. Draw the 'dot-and-cross' diagram of ethylene oxide with all bonding electrons and non-bonding electrons shown clearly. [1]

(ii) State a value for the bond angle around the oxygen atom in ethylene oxide molecule. [1]

(iii) Predict and explain whether ethylene oxide would be more soluble in propanone or hexane. [2]

(iv) Use the *Data Booklet* to calculate the enthalpy change when ethylene oxide is hydrolysed and show clearly which bonds are broken and formed in the above equation. [3]

(c) An organic compound **P**, C$_{10}$H$_{11}$O$_2$Br, does not react with aqueous sodium carbonate. However, it reacts slowly on heating in aqueous sodium hydroxide to form a water-soluble compound **Q**, C$_3$H$_5$O$_3$Na and an insoluble oil **R**, C$_7$H$_8$O. [10]

The acidification of compound **Q** gives compound **S** which reacts with 2 moles of phosphorous pentachloride to give copious fumes. **R** gives benzoic acid upon oxidation.

Deduce the structures of compounds **P**, **Q**, **R** and **S**. Explain the chemistry of the reactions described and write equations where appropriate.

[Total:20]

End of Paper

Section A

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

1 Aluminium is the most abundant Group 13 element and constitutes about 8% of the Earth's crust. The extraction of aluminium is done by processing aluminium ore, bauxite to produce aluminium oxide also known as alumina.

A variety of aluminium compounds, for example aluminium chloride and aluminium hydroxide, are used for different purposes such as food additives, colouring and pharmaceuticals.

Aluminium hydroxide and magnesium hydroxide are antacids. They are used to treat symptoms of increased stomach acid, such as heartburn, upset stomach, sour stomach, or acid indigestion. Once ingested, they react with the hydrochloric acid in the stomach.

One label of a commercial product, Mintox™ is shown below.

(a) **(i)** Write down the electronic configuration of Al. [1]

$1s^2 2s^2 2p^6 3s^2 3p^1$

(ii) Why is the ionic radius of aluminium far smaller than its atomic radius?

Al^{3+} ion has a higher proton to electron ratio, hence the remaining electrons experience stronger electrostatic forces of attraction to the nucleus.

In addition, Al^{3+} ion has <u>one less principal quantum shell</u> as compared to the neutral atom, hence the ionic radius is smaller than its atomic radius.

(iii) Explain why aluminium forms compounds with an oxidation state of +3 but not sodium. [1]
As compared to sodium, aluminium would require smaller amount of energy to remove the (2nd and 3rd) electrons which are from the outermost principle quantum shell.

(b) **(i)** Which antacid in the tablet is more effective in reacting with the hydrochloric acid in the stomach? Show relevant working to support your answer. [2]
Relevant working based on masses in the tablet

No of moles of $Mg(OH)_2$ = 200 x 10^{-3} / 58.3 = 3.43 x 10^{-3} mol
No of moles of $Al(OH)_3$ = 200 x 10^{-3} / 78 = 2.56 x 10^{-3} mol
$Al(OH)_3$ will produces more number of moles of hydroxide ions
(7.68 x10^{-3}) than $Mg(OH)_2$(6.86 x10^{-3}) .

Thus aluminium hydroxide is more effective.

(ii) Calculate the maximum number of chewable tablets that a person can take in a week. [1]
4x 4 x 7 = 112

(iii) Assuming that a typical adult has a body mass of 70 kg, determine the maximum weekly intake of aluminium hydroxide in grams per kg of body mass. [2]

Maximum intake of aluminium hydroxide is 200 mg x 112

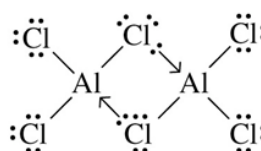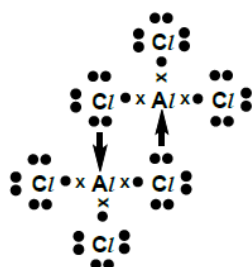Maximum intake per body mass = 0.320 g per kg

(c) **(i)** Aluminium chloride is an active ingredient used in skin medication to control excessive sweating.

Aluminium chloride is often describe as *electron deficient*. Explain what is meant by *electron deficient*. [1]

Electron deficient implies that the central atom, Al has empty orbital in $AlCl_3$

(ii) In the vapour phase, aluminium chloride forms a gaseous product with a molar mass of 267 g mol^{-1}. With an aid of a clearly labelled diagram, explain how this product is formed from aluminium chloride. [2]
Dative Bond

OR

[Total: 11]

2 In a university laboratory, the percentage purity of a sample of complex iron salt, $K_3Fe(C_2O_4)_3.3H_2O$ can be determined by analyzing the $C_2O_4^{2-}$ content through titrating with acidified $KMnO_4$.

1.20 g of impure $K_3Fe(C_2O_4)_3.3H_2O$ sample was dissolved and made up to $100cm^3$. 10.0 cm^3 of this solution was pipetted into a conical flask and $10.0cm^3$ of 1 mol dm^{-3} sulfuric acid was added. The mixture was heated and titrated with 0.0200 mol dm^{-3} $KMnO_4$. CO_2 is produced during the reaction.

It was determined that 12.30 cm^3 of $KMnO_4$ was required to reach the end-point.

(a) **(i)** Suggest why hydrochloric acid is not used to acidify the mixture. [2]

Cl^- ions can possibly be oxidized to Cl_2 and hence will cause an increase in the titration readings.

(ii) In the acidic medium, $C_2O_4^{2-}$ ions exist as $H_2C_2O_4$.

Write a half equation to show the conversion of $H_2C_2O_4$ to CO_2. [1]

$H_2C_2O_4 \rightarrow CO_2 + 2H^+ + 2e$

(b) **(i)** Calculate the amount of $KMnO_4$ used to react with $10.0cm^3$ of the iron complex salt solution. [1]

Amt of $MnO_4^- = 12.3/1000 \times 0.02 = 2.46 \times 10^{-4}$ mol

(ii) Using the half-equation below and that in **(b)(ii)**, calculate the amount of $C_2O_4^{2-}$ present in 10.0 cm^3 of the iron complex salt solution.
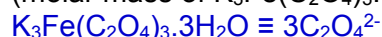$$MnO_4^- + 8H^+ + 5e \rightarrow Mn^{2+} + 4H_2O$$
[1]
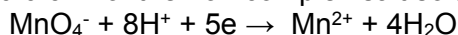
Amount of e involved $= 5 \times 2.46 \times 10^{-4} = 1.23 \times 10^{-3}$
Amount of $H_2C_2O_4$ = amount of $C_2O_4^{2-} = 5/2 \times 2.46 \times 10^{-4} = 6.15 \times 10^{-4}$

(iii) Hence, determine the mass of $K_3Fe(C_2O_4)_3.3H_2O$ in 100 cm^3 of iron complex salt solution.
(molar mass of $K_3Fe(C_2O_4)_3.3H_2O = 491.1$ g mol^{-1}) [2]
$K_3Fe(C_2O_4)_3.3H_2O \equiv 3C_2O_4^{2-}$
amount of $K_3Fe(C_2O_4)_3.3H_2O$ in $100cm^3 = 5/2/3 \times 2.46 \times 10^{-4} \times 10$
Mass of $K_3Fe(C_2O_4)_3.3H_2O$
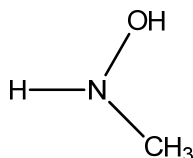$= 5/2/3 \times 2.46 \times 10^{-4} \times 10 \times 491.1 = 1.01g$

(iv) Calculate the percentage purity of the iron complex salt. [1]

$1.01/1.20 \times 100\% = 84.2\%$

[Total: 8]

3 The emergence of multidrug-resistant bacteria has encouraged vigorous efforts to develop antibacterial agents. N-methylhydroxylamine has been found to show vast potential as an antibacterial agent.

N-methylhydroxylamine (pK_b = 8.04)

N-methylhydroxylamine has properties similar to ammonia and it dissolves in water as shown below:
$$CH_3NHOH(aq) + H_2O(l) \rightleftharpoons CH_3NH_2OH^+(aq) + OH^-(aq)$$

(a) Write the expression for the base dissociation constant of N-methylhydroxylamine in water.
[1]

$$K_b = \frac{[CH_3NH_2OH^+][OH^-]}{[CH_3NHOH]}$$

(b) Calculate the base dissociation constant of the N-methylhydroxylamine solution.
[1]
$K_b = 10^{-8.04} = 9.12 \times 10^{-9}$ mol dm^{-3}

An aqueous solution of 0.05 mol dm^{-3} hydrochloric acid was gradually added to 50.0 cm^3 of 0.02 mol dm^{-3} aqueous N-methylhydroxylamine.

(c) Determine the initial pH of N-methylhydroxylamine solution. [2]

$$CH_3NHOH(aq) + H_2O(l) \rightleftharpoons CH_3NH_2OH^+(aq) + OH^-(aq)$$
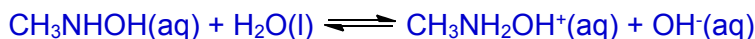
$$K_b = \frac{[CH_3NH_2OH^+][OH^-]}{[CH_3NHOH]}$$

Since [OH$^-$] = [CH$_3$NH$_2$OH$^+$],

$$K_b = \frac{[OH^-]^2}{[CH_3NHOH]}$$

$$9.12 \times 10^{-9} = \frac{[OH^-]^2}{0.02}$$

[OH$^-$] = <u>1.35 $\times$ 10^{-5}</u> mol dm^{-3}

pH = 14 – [-log (1.48 $\times$ 10^{-5})]
    = <u>9.13</u>

(d) Calculate the volume of hydrochloric acid needed at the equivalence point. [1]

$$CH_3NHOH + HCl \longrightarrow CH_3NH_2OH^+Cl^-$$
Volume of HCl needed = (50.0 $\times$ 0.02) $\div$ 0.05
                     = 20.0 cm^3
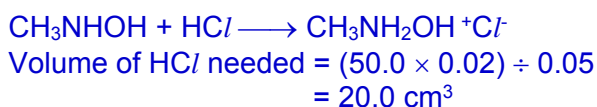
(e) State the volume of hydrochloric acid required to be added to another identical solution of N-methylhydroxylamine to obtain a solution which best resists pH change. [1]
10.0 cm^3

(f) Calculate the pH of that solution. [1]
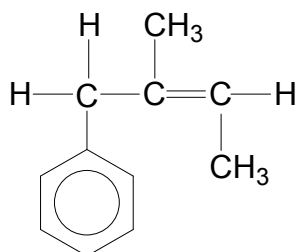$pOH = pK_b = 8.04$
$pH = 14-8.04 = 5.96$

(g) Write **two** equations to show how the solution in **(e)** resists change in pH when small amounts of acid and alkali are added. [2]
$CH_3NHOH + H^+ \longrightarrow CH_3NH_2OH^+$
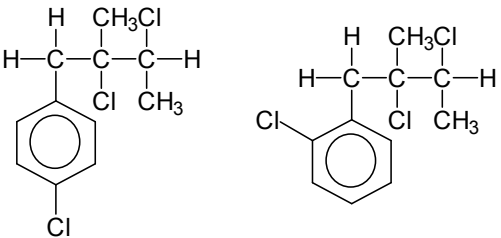$CH_3NH_2OH^+ + OH^- \longrightarrow CH_3NHOH + H_2O$

[Total: 9]

4 (a) Draw the structures of the organic product(s) formed when compound **A** below reacts with each of the following reagents.
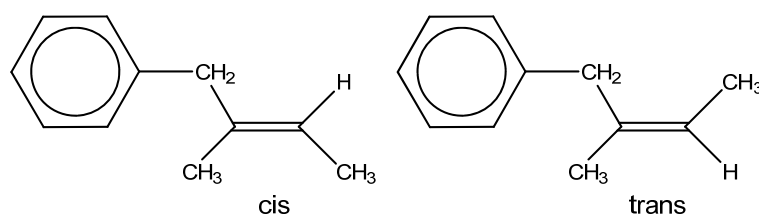

compound **A**

Reagents and Conditions	Organic Product(s) formed
(i) HBr(g)	Students to give either one of the correct structures
(ii) KMnO₄; dilute H₂SO₄; heat under reflux	

(iii) Cl_2(g); AlCl_3 ; dark	Students to give either one of the correct structures

[5]

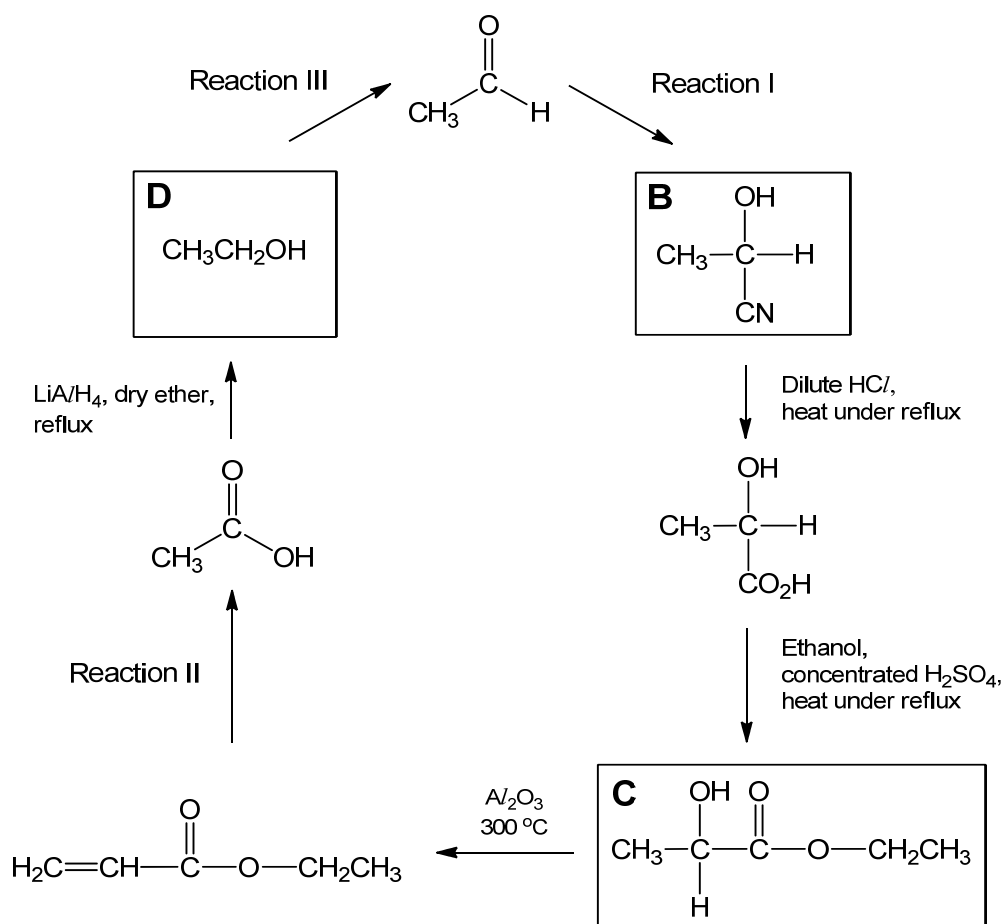**(b)** State the type of isomerism exhibited by compound **A**, and hence draw the structures of the two isomers formed. **[2]**

Cis-trans isomerism

(c) Ethanal is a flammable liquid with a fruity smell. It occurs naturally in ripe fruit, coffee and fresh bread. A synthetic route involving ethanal is shown below.

  (i) Draw the structural formulae of compounds **B**, **C** and **D** in the boxes below. **[3]**

Reaction III

Reaction I

D

CH$_3$CH$_2$OH

B OH

CH$_3$—C—H

CN

LiA/H$_4$, dry ether, reflux

Dilute HCl, heat under reflux

OH

CH$_3$—C—H

CO$_2$H

Reaction II

Ethanol, concentrated H$_2$SO$_4$, heat under reflux

Al_2O$_3$
300 °C

C OH O

CH$_3$—C—C—O—CH$_2$CH$_3$

H

H$_2$C=CH—C—O—CH$_2$CH$_3$

(ii) Suggest reagents and conditions for Reaction

I, ...

Reaction

II, ...

Reaction

III, ...

[3]
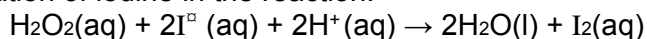
[Total: 14]

- reaction I, HCN, trace amount of NaOH(aq), 10 to 20°C
              or HCN, trace amount of KCN, 10 to 20°C
- reaction II, KMnO$_4$, H$_2$SO$_4$(aq), heat under reflux
- reaction III, K$_2$Cr$_2$O$_7$, H$_2$SO$_4$(aq), heat and distill

Section B (40 marks)

Answer **two** questions from this section on the separate answer papers.

1 **(a)** In an experiment, the effect of reactant concentration on the rate of reaction between hydrogen peroxide and potassium iodide at 298K was investigated.

The rate of formation of iodine in the reaction:
$$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + I_2(aq)$$
is given by:
$$rate = k[H_2O_2]^a[I^-]^b[H^+]^c$$
whereby a, b and c are the orders of reaction

The iodine liberated in the above reaction reacts with a fixed amount of sodium thiosulfate until no more sodium thiosulfate is left. The excess iodine causes the solution becomes coloured. By adding a few drops of starch, the iodine is shown up more clearly as it forms a blue-black complex.

The time taken for the formation of blue-black complex is measured. The reciprocal of this time ($\frac{1}{t}$) is used as a measure of the initial rate of reaction.

Concentration of KI/ mol dm^{-3}	Time/ s
0.10	5.5
0.075	7.4
0.050	11.3
0.025	22.7

(i) Plot a graph of initial rate against concentration of iodide ions. [3]

Concentration of iodide ions/ mol dm^{-3}
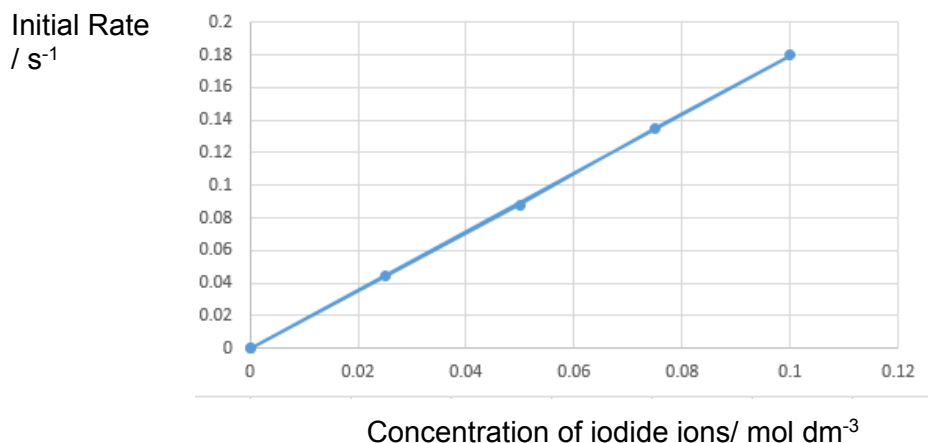
(ii) Hence use your graph to determine the order of reaction with respect to iodide ions. [1]

Clearly initial rate is directly proportional to the concentration. Thus it is first order.

(iii) In theory, the orders of reaction with respect to hydrogen peroxide and acid are one and zero respectively. [2]

Using your answer in **a(ii)** and given that $[H_2O_2]$ = 0.01 mol dm^{-3}, $[I^-]$ = 0.02 mol dm^{-3}, $[H^+]$ = 0.0005 mol dm^{-3} and rate = 2.30 x 10^{-6} mol dm^{-3} s^{-1}, determine the rate constant for this reaction and state its units.

$$rate = k[H_2O_2][I^-]$$
$$2.30 \times 10^{-6} = k(0.01)(0.02)$$
$$k = 0.0115 \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1}$$

(iv) Suggest what would happen to the initial rate of reaction if the temperature is changed to 308K. [1]

The rate would be doubled.

(b) **(i)** Describe the reactions, if any when separate samples of sodium and phosphorus are added to water containing universal indicator. [2]
Sodium dissolves in water to form an alkaline blue/violet solution and effervescence is seen.

Phosphorus does not react with water. Hence it forms a green solution in presence of universal indicator.

(ii) Explain the acid-base character of oxides of sodium and phosphorus in water. Suggest the pH of any aqueous solution formed. [2]
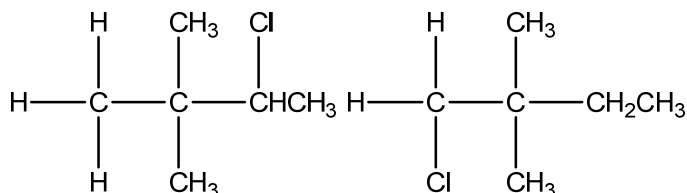Sodium oxide is soluble in water to form an alkaline solution of aq NaOH.
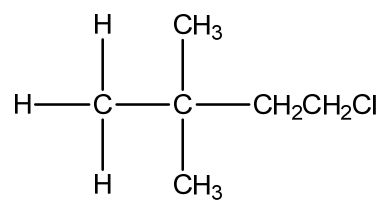$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$ pH =13

Phosphorus oxide is soluble in water to form an acidic solution of phosphoric acid.
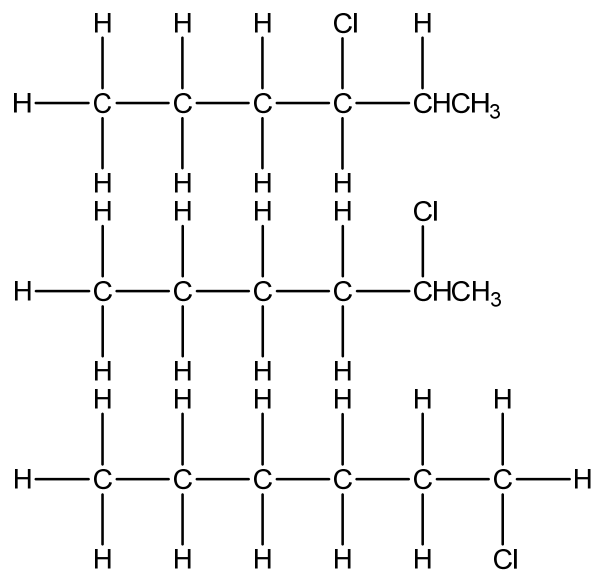$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$ pH =2

(c) When heated with chlorine under suitable conditions, hydrocarbon **X**, C_6H_{14} forms a total of only 3 mono-chlorinated products.

(i) Draw the three possible chlorinated products of **X**. [3]
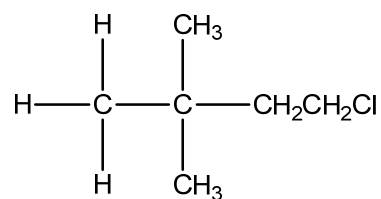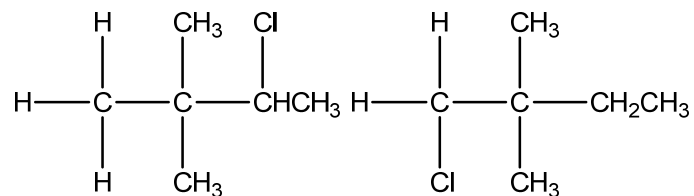
```
        H    CH3
        |    |
   H — C — C — CH2CH2Cl
        |    |
        H    CH3
```

OR

```
        H    H    H    Cl   H
        |    |    |    |    |
   H — C — C — C — C — CHCH3
        |    |    |    |
        H    H    H    H
        H    H    H    H    Cl
        |    |    |    |    |
   H — C — C — C — C — CHCH3
        |    |    |    |
        H    H    H    H
        H    H    H    H    H    H
        |    |    |    |    |    |
   H — C — C — C — C — C — C — H
        |    |    |    |    |    |
        H    H    H    H    H    Cl
```

(ii) The following table provides the rate of abstraction of a hydrogen on a   [1]
primary, secondary and tertiary carbon.

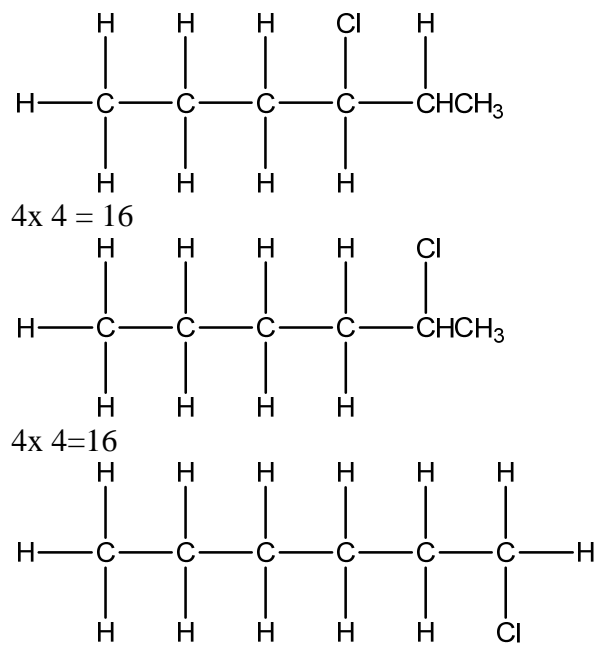| Type of C	-CH$_3$	-CH$_2$R	-CHR$_2$
Relative rate	1	4	6

What is the expected ratio of the mono-chlorinated products of **X** formed?[2]

```
        H    CH3  Cl                 H    CH3
        |    |    |                  |    |
   H — C — C — CHCH3   H — C — C — CH2CH3
        |    |                       |    |
        H    CH3                     Cl   CH3
```

```
        H    CH3
        |    |
   H — C — C — CH2CH2Cl
        |    |
        H    CH3
```

2X4 : 1x 9 : 3x1
8: 9: 3

OR

H   H   H   Cl H
| | | | |
H—C—C—C—C—CHCH$_3$
| | | |
H   H   H   H
4x 4 = 16

H   H   H   H   Cl
| | | | |
H—C—C—C—C—CHCH$_3$
| | | |
H   H   H   H
4x 4=16

H   H   H   H   H   H
| | | | | |
H—C—C—C—C—C—C—H
| | | | | |
H   H   H   H   H   Cl

6x 1=6
8: 8: 3

(iii) State one environmental effect of chlorinated products of **X**. [1]

Depletion of ozone layer

(iv) Describe a simple chemical test to distinguish the chlorinated products [3]
of **X** from hydrocarbon **X**.

Aq NaOH, heat
Cool and add excess nitric acid
Lastly add silver nitrate solution

X: no white ppt
Chlorinated products: white ppt

[Total: 20 marks]

2 **(a)** Carbon forms the backbone of organic compounds and is in the Period 2 of the Periodic Table. The second ionisation energy of some consecutive elements in Period 2 are plotted.

(i) Write an equation to represent second ionisation energy of carbon. [1]

$C^+(g) \rightarrow C^{2+}(g) + e$
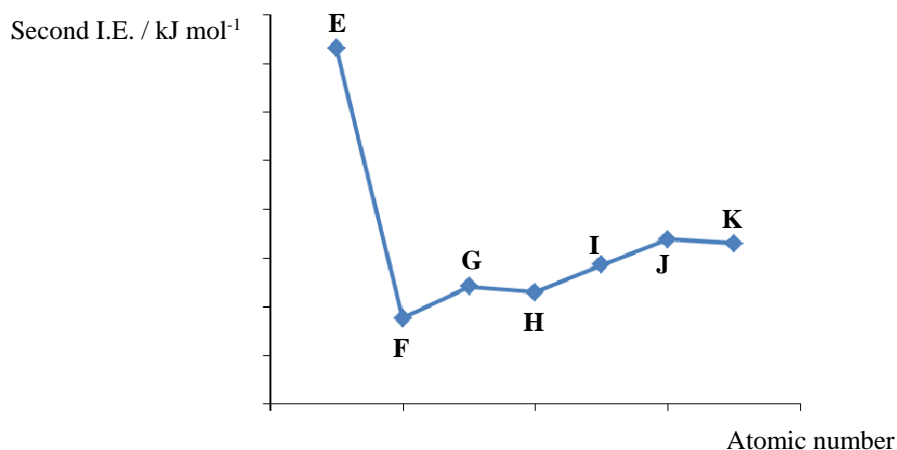
(ii) Considering electronic configurations, explain why the second ionisation energy of carbon is lower than that of boron. [2]

C^+ : $1s^2 2s^2 2p^1$

B^+ : $1s^2 2s^2$

The second IE of carbon involves removing an electron from the 2p subshell, which is further away from the nucleus. Hence, less energy is required.

(iii) Which letter represents carbon in the plot? Explain your answer. [2]

H. There is a large difference between the second IE of E and F. This suggests that E is Li as the electron is removed from the inner principal quantum shell.

(b) Ethanoic acid and ethanol react together in the presence of concentrated sulfuric acid as the catalyst. The following equilibrium is established, in which the ester, ethyl ethanoate, is formed.

$$CH_3COOH\ (l) + CH_3CH_2OH\ (l) \rightleftharpoons CH_3COOCH_2CH_3\ (l) + H_2O\ (l)$$
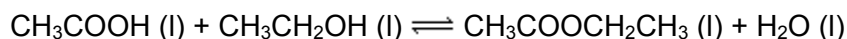
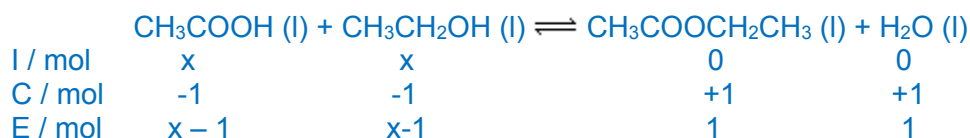**(i)** State Le Chatelier's Principle. [1]

Le Chatelier's Principle states that when a change is introduced into the system, the system will respond in such a way to counteract the change.

(ii) Use Le Chatelier's Principle to predict and explain how adding sodium hydroxide to the system will affect the position of equilibrium of this reaction. [2]

When sodium hydroxide is added, the concentration of ethanoic acid decreases. Hence, POE will shift to the left to counter this change.

(iii) Equimolar amounts of ethanoic acid and ethanol were mixed and at equilibrium, 1.00 mole of ethyl ethanoate is present. The total volume of the reaction mixture is 0.5 dm^3.

Given that the value of K_c for the reaction between ethanoic acid and ethanol is 4.0, determine the initial concentration of ethanoic acid. [3]

$$CH_3COOH \text{ (l)} + CH_3CH_2OH \text{ (l)} \rightleftharpoons CH_3COOCH_2CH_3 \text{ (l)} + H_2O \text{ (l)}$$

I / mol	x	x	0	0
C / mol	-1	-1	+1	+1
E / mol	x – 1	x-1	1	1

K_c = 1 / (x-1)(x-1) = 4
(x-1)(x-1) = ¼
x -1 = ½
x = 1.5 mol

[ethanoic acid] = 1.5/0.5 = 3.00 mol dm^{-3}

(c) Other than ethanoic acid, there are other compounds that have the same molecular formula, $C_2H_4O_2$.

Give the skeletal formulae of **three** other possible isomers, with different functional groups from each other, which have this molecular formula. [3]
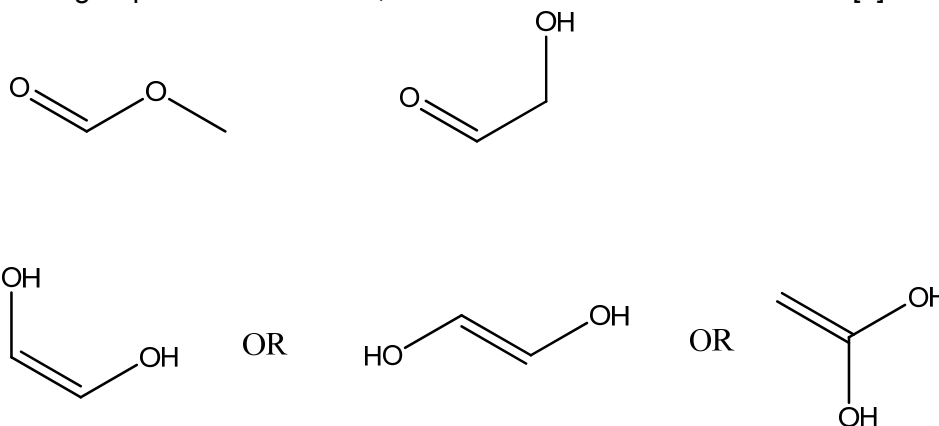
(d) In the laboratory, there are three bottles of chemicals which are unlabelled. The three bottles contain one of the following, but not in the order given.

Ethanoic acid

Propanone

Propanal

Suggest two simple chemical tests that will allow you to distinguish between the three unlabelled bottles. State clearly the observations and write equations for any reaction that occur. [6]

R & C: Na_2CO_3 (aq)

Observations: effervescence for ethanoic acid, no effervescence for propanone and propanal

Eqn: $2 CH_3COOH + Na_2CO_3 \rightarrow 2 CH_3COO^-Na^+ + CO_2 + H_2O$

R & C : $KMnO_4$ (aq), H_2SO_4 (aq), heat

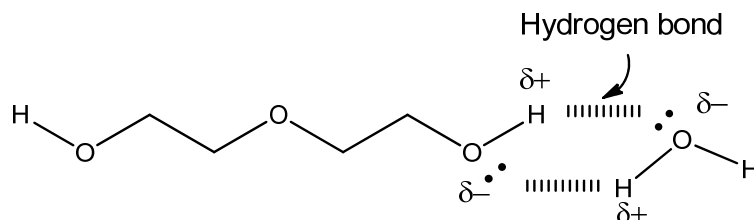Observations: purple $KMnO_4$ decolourised for propanal, purple $KMnO_4$ remains for propanone.

Eqn: $CH_3CH_2CHO + [O] \rightarrow CH_3CH_2COOH$

Accept any logical tests.

[Total:20]

3   Diethylene glycol (DEG), with the formula $(HOCH_2CH_2)_2O$, is used in a wide range of industrial products. It is poisonous and has been involved in a number of prominent mass poisonings spanning back to 1937.
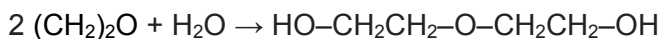
(a)   Following its ingestion, DEG is rapidly absorbed and distributed within the human body which is made up of up to 60% water.

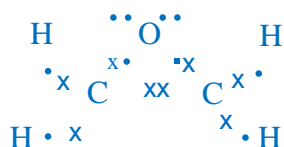State and draw the type of bonding between DEG and water.   [3]

(b)   DEG is produced by the hydrolysis of the cyclic ethylene oxide, $(CH_2)_2O$.

$2 (CH_2)_2O + H_2O \rightarrow HO–CH_2CH_2–O–CH_2CH_2–OH$

(i)   The oxygen atom is bridging the two carbon atoms in the cyclic ethylene [1] oxide. Draw the 'dot-and-cross' diagram of ethylene oxide showing all bonding electrons and non-bonding electrons clearly.

(ii) Give a value for the bond angle around the oxygen atom in ethylene oxide [1]
molecule.
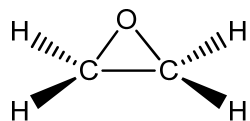
60 °

(iii) Predict and explain whether ethylene oxide would be more soluble in [2]
propanone or hexane.
Propanone

Ethylene oxide is polar and dissolves well in polar solvent such as
propanone through permanent dipole-permanent dipole interaction

(iv) Use the *Data Booklet* to calculate the enthalpy change when ethylene oxide [3]
is hydrolysed showing clearly which bonds are broken and formed in the
above equation.

Bonds broken = 2 (O-H) +2(C-O)
Bonds formed = 2 (O-H) +2(C-O)

ΔH = 0 kJ mol^{-1}

(c) An organic compound **P**, $C_{10}H_{11}O_2Br$, does not react with aqueous sodium
carbonate. However, it reacts slowly on heating in aqueous sodium
hydroxide to form a water-soluble compound **Q**, $C_3H_5O_3Na$ and an insoluble
oil **R**, C_7H_8O.

The acidification of compound **Q** gives compound **S** which reacts with 2
moles of phosphorous pentachloride to give copious fumes. **R** gives benzoic
acid on oxidation.

Deduce the structures of compounds **P**, **Q**, **R** and **S**. Explain the chemistry
of the reactions described, writing equations where appropriate. [10]

Compound **P** does not react with Na_2CO_3(aq). Hence, compound **P** is not a
carboxylic acid.

Compound **P** undergoes alkaline hydrolysis when heated with NaOH(aq). **P**
has alkyl halide functional group. The Br atom in compound **P** is substituted
by –OH.

Compound **Q**, $C_3H_5O_3Na$, and compound **R**, C_7H_8O, were produced upon
alkaline hydrolysis. Ester linkage present in compound **P**.

Q has an alcohol functional group. The acidification of compound **Q** gives
compound **S** which reacts with 2 moles of phosphorous pentachloride to
give copious fumes. Compound **S** is an alcohol and carboxylic acid.

Compound **R** gives benzoic acid on oxidation. Compound **R** contains a
benzene ring with a side chain, (oxidation of side-chain) **R** has an alcohol
group.

$C_6H_5CH_2OCOCH(Br)CH_3 + 2NaOH \longrightarrow CH_3CH(OH)COONa + C_6H_5CH_2OH + NaBr$

$C_6H_5CH_2OH + 2[O] \longrightarrow C_6H_5COOH + H_2O$

$CH_3CH(OH)COONa + H^+ \longrightarrow CH_3CH(OH)COOH + Na^+$

$CH_3CH(OH)COOH + 2PCl_5 \longrightarrow CH_3CH(Cl)COCl + 2HCl + 2POCl_3$

P is $C_6H_5CH_2OCOCH(Br)CH_3$ or $C_6H_5CH_2OCOCH_2CH_2Br$
Q is $CH_3CH(OH)COONa$ or $CH_2(OH)CH_2COONa$
R is $C_6H_5CH_2OH$
S is $CH_3CH(OH)COOH$ or $CH_2(OH)CH_2COOH$

[Total: 20]

End of Paper