JURONG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CHEMISTRY

8872/01

Paper 1 Multiple Choice

14 September 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 fluid.

Write your name, class and shade your exam index number on the Answer Sheet in the spaces provided.

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.

A *Data Booklet* is provided. Do not write anything on the *Data Booklet*.

SECTION A

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

1 Three half-equations are given below.

$$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$$
$$2CO_2 + 2e^- \rightleftharpoons C_2O_4^{2-}$$
$$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$$

Acidified MnO_4^- ions can oxidise both ions in iron(II) ethandioate, FeC_2O_4.

What is the mole ratio of MnO_4^-: FeC_2O_4 in a complete oxidation?

	MnO_4^-	FeC_2O_4
A	2	5
B	3	5
C	5	2
D	5	3

2 A compound is made up of two elements, **Y** and **Z**.
Each atom of **Y** and of **Z** has exactly 2 unpaired electrons in its outermost p orbitals.

What could the compound be?

A CO_2 **B** CF_4 **C** NF_3 **D** NO_2

3 What is the electronic configuration of vanadium atom, proton number 23?

A $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^4\,4s^1$
B $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,4p^3$
C $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^5$
D $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^3\,4s^2$

4 Nitrogen and phosphorus are both in Group 15 of the Periodic Table. Phosphorus forms a chloride with the formula PCl_5 but nitrogen does not form NCl_5.

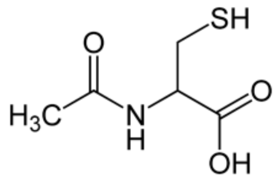
Which statement helps to explain this?

A Nitrogen is less electronegative than phosphorus.
B Nitrogen cannot have an oxidation state of +5.
C Nitrogen's outer shell cannot contain more than eight electrons.
D Nitrogen only has three unpaired electrons in the valence shell.

5 Which compound has more than one type of chemical bond?

A	Ammonium nitrate	**B**	Calcium chloride
C	Silicon(IV) oxide	**D**	Diamond

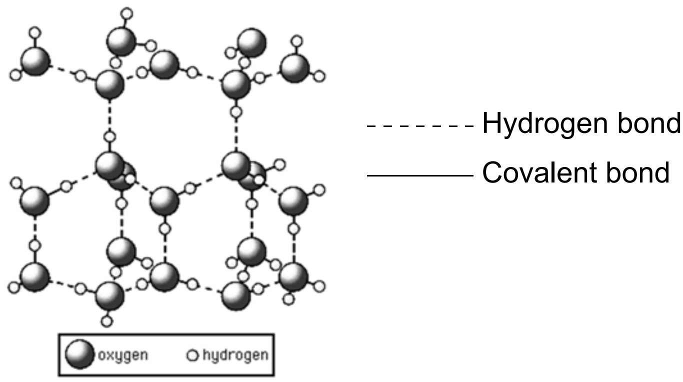
6 Fluimucil is a medicine used to loosen thick mucus in individuals with chronic obstructive pulmonary disease. Its structure is shown below.



How many lone pair of electrons are present in one molecule of fluimucil?

A 5 **B** 6 **C** 8 **D** 9

7 Ice is the crystalline form of water. The diagram below shows part of the structure of ice.



Which of the following statements is **not** true about ice?

A Ice has a lower density than water at 0 °C due to its open structure.

B The bond angle about oxygen in ice is 109.5°.

C Ice does not conduct electricity.

D The hydrogen bonds are stronger than the O-H covalent bond.

8 Which set of bond angles are present in the molecule shown below?

A	90°, 109° and 120° only	**B**	105° and 120° only
C	107° and 180° only	**D**	109°, 120° and 180° only

9 The standard enthalpy change of formation of nitrogen(II) oxide, NO, is +90 kJ mol^{-1}.
What is the enthalpy change of the reaction shown below?

$$2NO(g) \rightarrow N_2(g) + O_2(g)$$

A –180 kJ mol^{-1} **B** –90 kJ mol^{-1} **C** +90 kJ mol^{-1} **D** +180 kJ mol^{-1}

10 In an experiment to measure the enthalpy change for the reaction between hydrochloric acid and calcium carbonate, 20 cm^3 of solution containing 0.04 mol of HC*l* is placed in a plastic cup of negligible heat capacity. When 2.0 g (0.02 mol) of calcium carbonate was added, the temperature rises by 15 K.

Given that the heat capacity per volume of the final solution is 4.2 J K^{-1} cm^{-3}, what is the magnitude of the enthalpy change for the reaction given below?

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

A $\dfrac{(20 + 2) \times 4.2 \times 15}{0.02}$ J mol^{-1}

B $\dfrac{(20 + 2) \times 4.2 \times 15}{0.04}$ J mol^{-1}

C $\dfrac{20 \times 4.2 \times 15}{0.04}$ J mol^{-1}

D $\dfrac{20 \times 4.2 \times 15}{0.02}$ J mol^{-1}

11 Given the following information:

ΔH_c of C(s) = –394 kJ mol^{-1}
ΔH_f of $H_2O(l)$ = –286 kJ mol^{-1}
ΔH_f of $CH_3OH(l)$ = –239 kJ mol^{-1}

Which one of the following is the correct enthalpy change of combustion of liquid methanol, CH_3OH, in kJ mol^{-1}?

A –441 **B** –727 **C** –919 **D** –1205

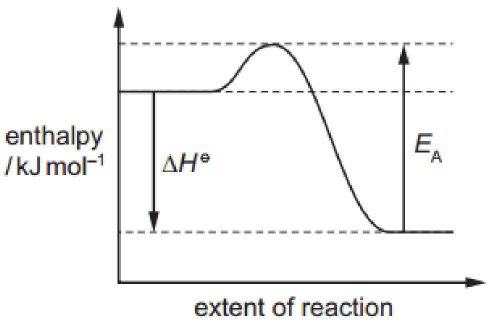
12 Nitric oxide, NO, and bromine vapour react together according to the following equation.

$$2NO(g) + Br_2(g) \rightarrow 2NOBr(g) \qquad \Delta H^{\ominus} = -23 \text{ kJ mol}^{-1}$$

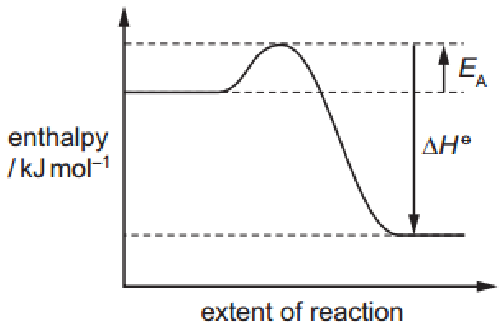
The reaction has an activation energy of +5.4 kJ mol^{-1}.

What is the correct reaction pathway diagram for the above reaction?

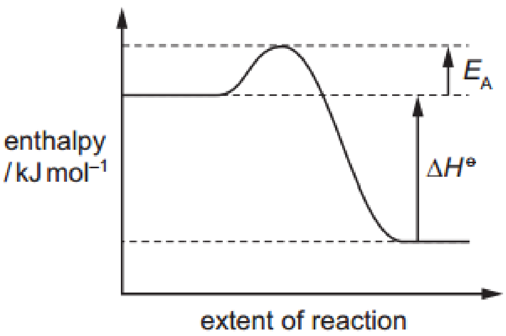
A



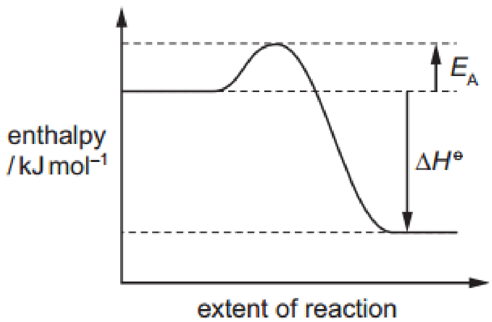
B



C



D



13 A piece of magnesium ribbon was added to 25 cm^3 of dilute hydrochloric acid. The magnesium was completely dissolved and the total volume of hydrogen gas evolved was measured.

In a second experiment, an identical piece of magnesium ribbon of the same mass was used. This was added to another 50 cm^3 of the same dilute hydrochloric acid. The total volume of hydrogen gas evolved was measured.

How will the initial rate of reaction and total volume of hydrogen evolved in the second experiment compare to the first experiment?

	Initial rate of reaction	Total volume of hydrogen evolved
A	Increase	Increase
B	Increase	No change
C	No change	Increase
D	No change	No change

14 The following reaction has a first-order kinetics.

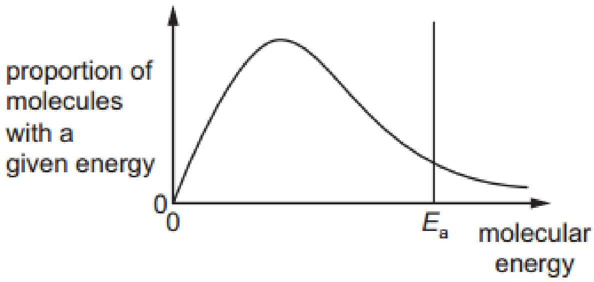
$$XY(g) \rightarrow X(g) + Y(g)$$

It takes 64 seconds for 4 g of XY to decompose till 2 g of XY was left.

How long will it take for 0.25 g of XY to react till 0.125 g?

A 4 s **B** 8 s **C** 64 s **D** 320 s

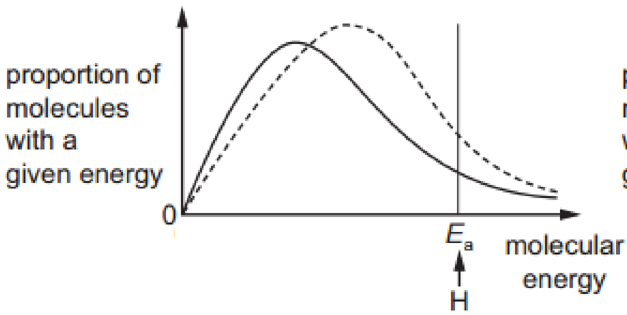
15 The diagram represents, for a given temperature, the Boltzmann distribution of the kinetic energies of the molecules in a mixture of two gases that react together. The activation energy for the reaction, E_a, is marked.



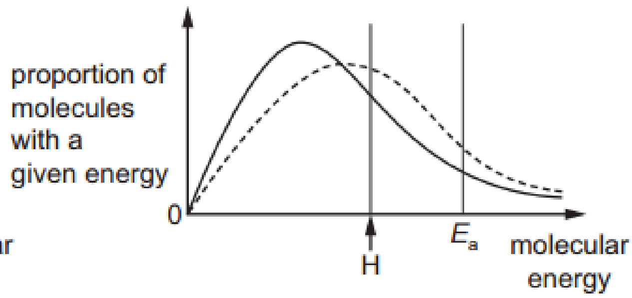
The dotted curves below show the Boltzmann distribution for the same reaction at a higher temperature. On these diagrams, H represents the activation energy at the higher temperature.

Which diagram is correct? C

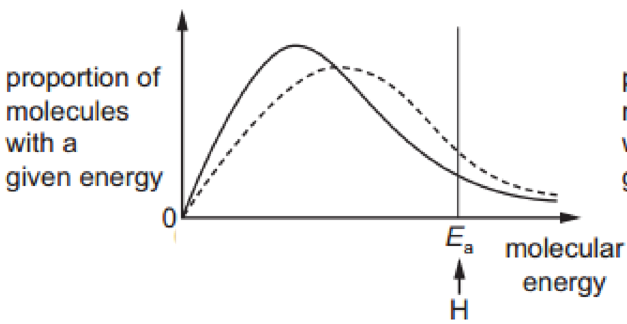
A



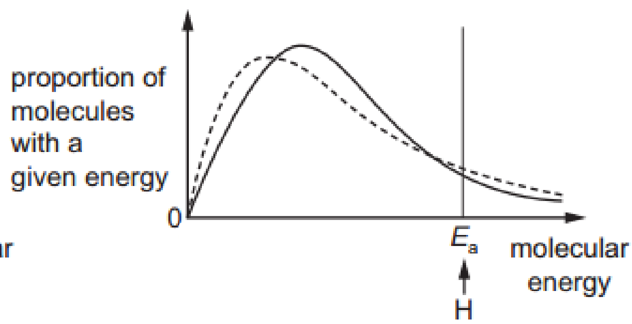
B



C



D



16 Which series is correctly arranged in order of increasing values?

A Atomic radius of P, S, C*l*

B Lattice energy of NaF, MgF_2, AlF_3

C First ionisation energy of Na, Mg, A*l*

D Melting point of P, S, C*l*

17 In the preparation of silicon, silicon dioxide is heated with magnesium.

$$SiO_2 + 2Mg \rightarrow 2MgO + Si$$

The product mixture contains MgO and Si only.

To separate the silicon from the product mixture, students proposed the following two methods.

1. Shake the mixture with aqueous hydrochloric acid and filter.
2. Heat the mixture gently and collect the evaporated silicon.

Which methods would work?

A	1 only	**B**	1 and 2
C	2 only	**D**	Neither 1 or 2

18 What is meant by the term *dynamic equilibrium*?

A an equilibrium that is constantly changing its position

B an equilibrium where the forward and reverse reactions are taking place at different rates

C an equilibrium where the forward and reverse reactions are taking place at the same rates

D an equilibrium which has not yet settled to a constant state

19 Hydrogen and nitrogen react to produce ammonia.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92.4 \text{ kJ mol}^{-1}$$

Which statement is correct?

A Increasing pressure increases the value of the equilibrium constant.

B Increasing the amount of iron catalyst increases the equilibrium yield of ammonia.

C Condensing the gaseous ammonia product shifts the equilibrium position to favour the formation of more ammonia.

D Lowering the volume of the reaction vessel does not affect the rate of reaction and equilibrium yield of ammonia.

20 Which property of benzene results from the stability associated with the ring of delocalised π electrons?

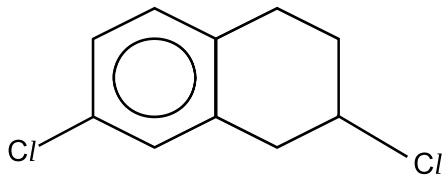
A It does not conduct electricity.

B It is susceptible to attack by electrophiles.

C It undergoes electrophilic substitution instead of electrophilic addition.

D All the carbon-carbon bonds have exactly the same bond length.

21 Which statement about the molecule below is correct?



A It has an empirical formula of C_6H_6Cl.

B It has an molecular formula of $C_{10}H_{10}Cl_2$.

C It has six sp^3 and six sp^2 carbon atoms.

D It is a tertiary alkyl halide.

22 A 0.050 mol dm^{-3} solution of strong acid **R** has a pH of 1.00.

Which acid is **R**?

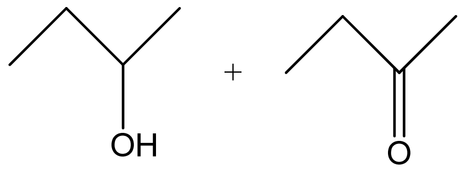
A HCl **B** HNO_3 **C** H_2SO_4 **D** H_3PO_4

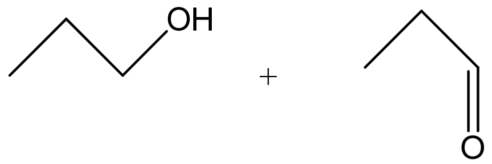
23 10 cm^3 of aqueous silver nitrate was added to two separate samples of bromopropane and chloropropane. The resulting mixtures were allowed to stand.

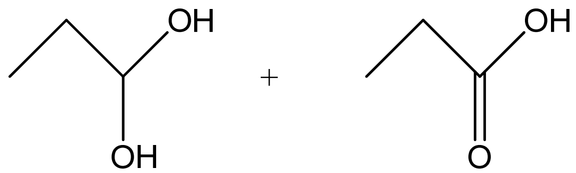
Which of the following shows the correct observation?

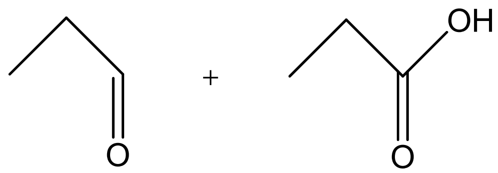
	bromopropane	chloropropane
A	white ppt formed immediately	cream ppt formed immediately
B	cream ppt formed after 2 hours	white ppt formed after 20 minutes
C	cream ppt formed after 20 minutes	white ppt formed after 2 hours
D	white ppt formed after 20 minutes	cream ppt formed after 2 hours

24 Which two compounds can react to produce an ester?

A 

B 

C 

D 

25 Compound **Q** was refluxed with aqueous sodium hydroxide and the resulting mixture was then distilled. The distillate gave a positive tri-iodomethane test. The residue in the distillation flask, after acidification, gave a white precipitate.

Which of these could be **Q**?

A $CH_3CH_2OCOC_6H_5$

B $CH_3CH_2OCOCH_3$

C $CH_3CH_2COOCH_2CH_3$

D $C_6H_5COOCH_3$

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.

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 Which molecules have an overall dipole moment?

1 carbon monoxide, CO

2 dichloromethane, CH_2Cl_2

3 phosphine, PH_3

27 Boron is a non-metallic element which is found above aluminium in Group 13 of the Periodic Table. It forms a compound with nitrogen known as boron nitride which has a graphite structure.

Which conclusions can be drawn from this information?

1 The empirical formula of boron nitride is BN.

2 Boron nitride has a layer structure with instantaneous dipole-induced dipole interactions between the layers.

3 The boron and nitrogen atoms in a layer are likely to be arranged alternately in a hexagonal pattern.

28 The diagram illustrates the enthalpy changes of a set of reactions.

$$\begin{tikzcd}
\mathbf{R} \arrow[r, "\Delta H = -134 \text{ kJ mol}^{-1}"] \arrow[d] & \mathbf{S} \arrow[d, "\Delta H = +92 \text{ kJ mol}^{-1}"] \\
\mathbf{T} \arrow[r, "\Delta H = -75 \text{ kJ mol}^{-1}"] & \mathbf{U}
\end{tikzcd}$$

Which statements are correct?

1 The enthalpy change for the transformation **U** $\rightarrow$ **R** is +42 kJ mol^{-1}.

2 The enthalpy change for the transformation **T** $\rightarrow$ **S** is endothermic.

3 The enthalpy change for the transformation **R** $\rightarrow$ **T** is –33 kJ mol^{-1}.

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.

29 Which of the following gives the compounds in order of decreasing K_a?

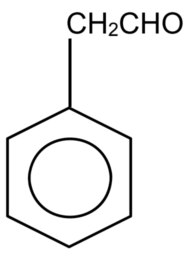
	highest K_a		lowest K_a
1	FCH_2CO_2H	$ClCH_2CO_2H$	$BrCH_2CO_2H$
2	$CH_3CF_2CO_2H$	FCH_2CHFCO_2H	$F_2CHCH_2CO_2H$
3	$CH_3CH(OH)CO_2H$	$CH_3CH_2CO_2H$	$CH_3CH(CH_3)CO_2H$

30 Compound **Z** was subjected to the following tests and the results are recorded below.

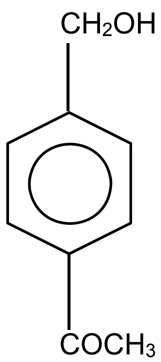
Reagents & Conditions	**Observations**
Acidified $K_2Cr_2O_7$, heat	Orange $K_2Cr_2O_7$ turns green.
Acidified $KMnO_4$, heat	Purple $KMnO_4$ decolourise. A colourless gas formed.
Fehling's reagent, heat	Red brown precipitate formed.

What could be the identity of **Z**?

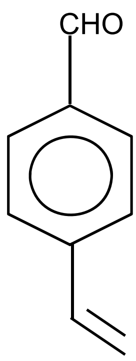
1



2



3



Answers for 2017 JJC Prelim Paper 1 (8872/01)

1	**B**	6	**D**	11	**B**	16	**B**	21	**B**	26	**B**
2	**A**	7	**D**	12	**D**	17	**A**	22	**C**	27	**A**
3	**D**	8	**D**	13	**D**	18	**C**	23	**C**	28	**B**
4	**C**	9	**A**	14	**C**	19	**C**	24	**C**	29	**A**
5	**A**	10	**D**	15	**C**	20	**C**	25	**A**	30	**D**

JURONG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME			
CLASS		EXAM INDEX NUMBER	

CHEMISTRY **8872/02**

Paper 2 Structured Questions **29 August 2017**

2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Answer Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

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

Section A
Answer **all** questions.

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

A *Data Booklet* is provided. Do not write anything on the *Data Booklet*.

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		**Section B**	
1		**7**	
2		**8**	
3		**9**	
4			
5			
6			
Total			

This document consists of **14** printed pages.

Section A

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

1. **(a)** Complete the table to show the composition and identity of some ions.

name of element	Nucleon number	Atomic number	Number of protons	Number of neutrons	Number of electrons	Overall charge
beryllium	9	4				2+
helium				1	1	

[3]

(b) When passed through an electric field, a beam of protons is deflected by 2°.

The beam of beryllium ions in the table in **1(a)** is made to pass through the same electric field. Calculate the angle of deflection for the beam of beryllium ions.

[1]

(c) Radiochemical reactions such as radioactive decay of isotopes, can be represented by equations in which the nucleon numbers and atomic numbers must be balanced.

In the first stage of the radioactive decay of ${}^{232}_{92}\text{Th}$, the products are an isotope of element **E** and two alpha particles ${}^{4}_{2}\text{He}$.

$$ {}^{232}_{92}\text{Th} \rightarrow {}^{y}_{x}\mathbf{E} + 2\ {}^{4}_{2}\text{He} $$

What is the nucleon number, y, of **E**? …………………………………

What is the proton number, x, of **E**? ………………………………….. [1]

[Total: 5]

2. The fifth to eighth ionisation energies of an element in the third period of the Periodic Table are given. The symbol used for reference is **not** the actual symbol of the element.

	Ionisation energies, kJ mol^{-1}			
	fifth	sixth	seventh	eighth
G	6274	21269	25398	29855

(a) State and explain the group number of element **G**.

Group number …………………………….

Explanation…………………………………………..…………………………

……………………………………………………………….…………………. [2]

(b) Explain why the seventh IE of **G** is higher than its sixth IE.

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………… [1]

(c) How would the first ionisation energy of **G** compare with that of the element on its right in the Periodic Table? Explain your answer.

…………………………………………………………………………………………

…………………………………………………………………………………………

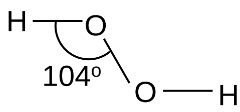
…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………… [2]

[Total: 5]

3. Hydrogen peroxide, H_2O_2, is a colourless liquid with the structure shown below.



(a) Determine the oxidation number of O in hydrogen peroxide.

………………………………………………………………………………………….. [1]

(b) By considering the number of electron pairs around the O atom in H_2O_2, explain why the H-O-O bond angle in H_2O_2 molecule is 104°.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

………………………………………………………………………………………….. [2]

(c) Volume strength is a term used to indicate the concentration of hydrogen peroxide solution.

It may be defined as the volume of O_2 produced, in cm^3 at s.t.p, when 1 cm^3 of the H_2O_2 solution decomposes according to the following equation.

$$H_2O_2\,(aq) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$

Calculate the volume strength of a 0.250 mol dm^{-3} aqueous solution of H_2O_2. [2]

(d) Excess KI(aq) is added to another aqueous solution containing 0.008 mol H_2O_2 and brown iodine solution is produced.

$$2I^- + 2H_2O_2 + 2H^+ \rightarrow I_2 + 2H_2O$$

The resulting iodine solution is then titrated with 0.400 mol dm^{-3} $Na_2S_2O_3$.

(i) Write an equation for the reaction between I_2 and $Na_2S_2O_3$.

…………………………………………………………………………………

[1]

(ii) Calculate the volume of $Na_2S_2O_3$ solution required for the titration.

[1]

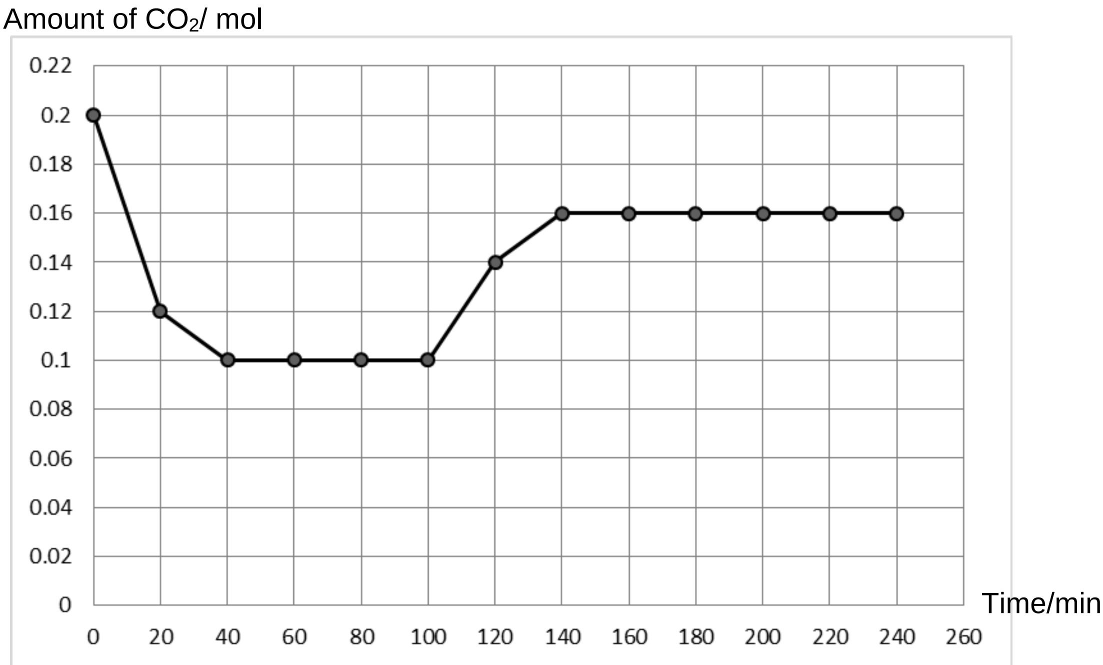
[Total: 7]

4. Growing concerns about global climate change have increased researchers' attention on the various approaches to reduce CO_2 emissions. A widely studied approach is the Sabatier reaction.

$$CO_2(g) + 4H_2(g) \rightleftharpoons CH_4(g) + 2H_2O(g)$$

(a) One researcher did some experiments to investigate the optimum temperature for the Sabatier reaction.

First, he mixed 0.2 mol of CO_2(g) and 0.8 mol of H_2(g) in a 3 dm^3 vessel at 350 ^oC. At every 20 minutes interval, he monitored the amount of CO_2 present in the mixture using a gas chromatography. At 100th min, he raised the temperature to 500 ^oC and continued to monitor the amount of CO_2. The results are shown graphically below.



(i) Determine the amount of CO_2, H_2, CH_4 and H_2O in the mixture at the 80th minute.

[1]

(ii) Hence, calculate the value of the equilibrium constant, K_C for the Sabatier reaction at 350 ^oC, stating its units.

[2]

4. **(a)** **(iii)** Use the graph to determine whether the CO_2 content in the equilibrium mixture increases or decreases when temperature is raised to 500 ^{o}C.

…………………………………………………………………………………… [1]

(iv) Using your answer in **(a)(iii)**, predict and explain whether the Sabatier reaction is exothermic or endothermic.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [2]

(b) The Sabatier reaction is also widely studied by NASA because water and methane are regenerated from the carbon dioxide produced by the cabin crew.

Some of the water produced by the reaction is then electrolysed to generate oxygen gas, a life support consumable, and hydrogen gas which is then passed into the Sabatier reactor to further produce more water and methane.

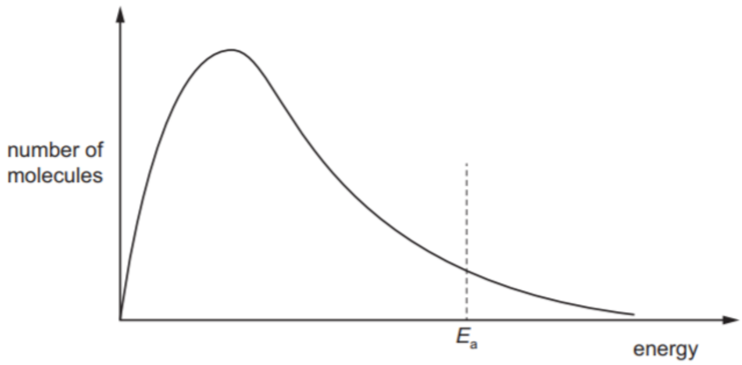
Research by NASA also shows that Ru is the most efficient catalyst for the Sabatier reaction.

(i) Explain the term *catalyst*.

……………………………………………………………………………………

…………………………………………………………………………………… [1]

(ii) The Boltzmann distribution curve shows the distribution of energies in a mixture of CO_2 and H_2 at 350 ^{o}C.



Add a suitable label to the horizontal axis and use it to explain why a catalyst is used in the Sabatier reaction.

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [2]

4. **(c)** Methane produced from the Sabatier reaction can be stored and used as a rocket propellant.

(i) Write an equation for the complete combustion of methane.

……………………………………………………………………………………… [1]

(ii) Using appropriate bond energies from the *Data Booklet*, calculate the amount of energy evolved when 1 mole of methane is completely burnt in oxygen.

[1]

[Total: 11]

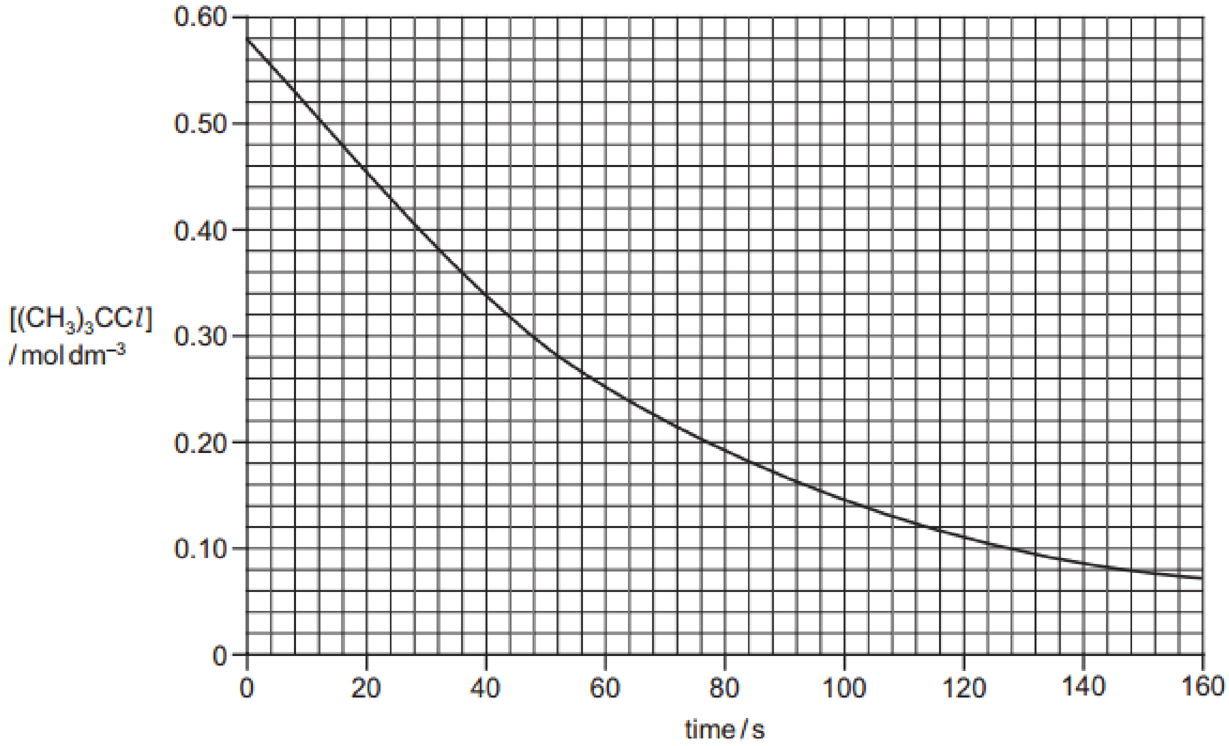
5. In aqueous solution, 2-chloro-2-methylpropane reacts with potassium hydroxide to form 2-methylpropan-2-ol.

(a) Write a balanced equation for the above reaction.

……………………………………………………………………………………………... [1]

The rate of this reaction was investigated using a **large excess** of sodium hydroxide.

(b) The graph below shows the results of the experiment.



The reaction is first order with respect to $[(CH_3)_3CCl]$. This can be confirmed from the graph using half-lives.

(i) Explain what is meant by the *half-life* of a reaction?

……………………………………………………………………………………….

……………………………………………………………………………………….

………………………………………………………………………………………. [1]

(ii) Determine the half-life for this reaction. Show all your working and show clearly any construction lines on the graph.

[1]

5. **(b)** **(iii)** It is known that the reaction is zero order with respect to [KOH].

Using your answer in **(b)(ii)**, calculate the value of the rate constant, *k*, for this reaction and give its units.

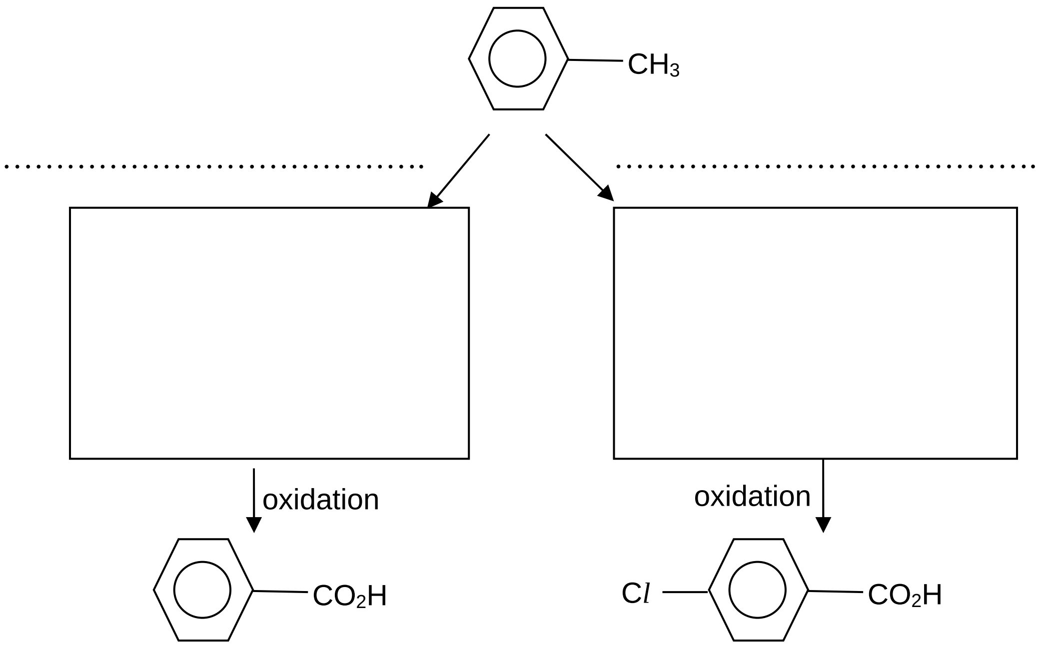
[2]

(iv) What would be the effect on the half-life of this reaction if the initial concentration of 2-chloro-2-methylpropane was doubled.

………………………………………………………………………………………. [1]

[Total: 6]

6. **(a)** Methylbenzene undergoes monochlorination under two different conditions to form two isomers. These two isomers then undergo oxidation to form carboxylic acids.



Benzoic acid

4-chlorobenzoic acid

In the boxes and space provided above, draw the structural formula of the monochlorinated products formed and state the reagent and conditions needed. [4]

(b) Compare and explain the relative acidity of benzoic acid and 4-chlorobenzoic acid formed in **(a)**.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………………….. [2]

[Total: 6]

Section B

Answer **two** questions from this section on separate answer paper.

7. This question is about aluminium and its compounds.

(a) **(i)** State and describe the structure and bonding of solid aluminium. [2]

(ii) A common use of aluminium is to make the electrical cables in long distance overhead power lines.

Suggest **two** properties of aluminium that make it suitable for this use. [2]

(b) Aluminium reacts with chlorine to form a white solid chloride that contains 79.7% chlorine and sublimes at 180 ^{o}C.

(i) Determine the empirical formula of the chloride, showing your working clearly. [2]

(ii) Given that the molar mass of the chloride is 267 g mol^{-1}, determine the molecular formula of the chloride. Draw a labelled diagram to illustrate the bonding in the chloride. [2]

(iii) Explain, in terms of structure and bonding, why this chloride has a low sublimation temperature. [2]

(iv) When water is added to the solid chloride, it dissolves to form an acidic solution. However, when water is added to solid Na*Cl*, a neutral solution is obtained.

Using relevant data from the *Data Booklet*, explain why this solid chloride forms an acidic solution but not Na*Cl*. Write equation to illustrate the reaction that occurred.

You may use the empirical formula determined in **(b)(i)** to write the equation. [3]

(c) $LiAlH_4$ is a reducing agent commonly used in organic synthesis. It reacts vigorously with water to produce H_2, LiOH and an amphoteric hydroxide. Hence $LiAlH_4$ must be stored under dry condition and its reaction must be carried out in anhydrous organic solvents such as diethyl ether, $CH_3CH_2OCH_2CH_3$.

(i) Write a balanced equation for the reaction between $LiAlH_4$ and water. [1]

(ii) The above reaction produced an amphoteric hydroxide.

Write two equations to show that it is amphoteric [2]

(d) From the following compounds, identify the compounds that can be reduced by $LiAlH_4$ to form ethanol.

CH_3CHO CH_3CO_2H CH_2=CHOH [1]

7. **(e)** Reactions involved $LiAlH_4$ are carried out in anhydrous organic solvents such as diethyl ether, $CH_3CH_2OCH_2CH_3$.

Diethyl ether can be prepared from ethanol in two steps as shown.

$$CH_3CH_2OH \xrightarrow[\text{Step 1}]{\text{Na}} \textbf{W} \xrightarrow[\text{Step 2}]{} CH_3CH_2OCH_2CH_3$$

(i) State the type of reaction that occurred in Step 1. [1]

(ii) Draw the displayed formula of **W**. [1]

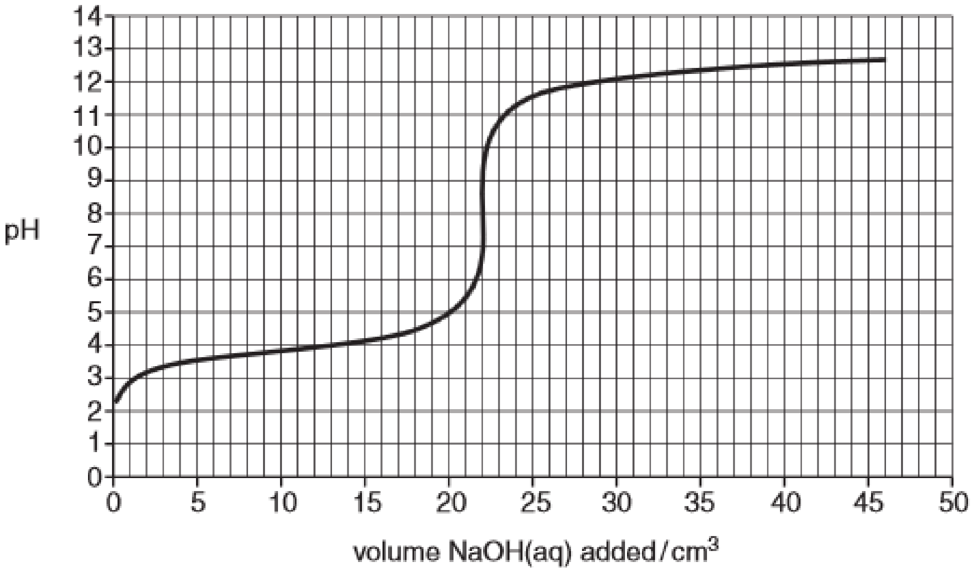
(iii) Given that **W** acts as a nucleophile in Step 2, draw the structural formula of the organic reactant required in Step 2. [1]

[Total: 20]

8. **(a)** Compound **R** is a weak monobasic acid.

A student dissolved 2.29 g of **R** in 250 cm^3 of deionised water and pipetted 25.0 cm^3 of this solution into a conical flask. He added 0.100 mol dm^{-3} NaOH(aq) solution from a burette and monitored the pH of the reaction mixture in the conical flask using a pH meter.

The pH curve obtained by the student is shown below.



(i) Using the data provided below, choose the most suitable indicator for the above titration. State the colour change of the solution at endpoint.

Indicator	pH at which colour changes	Acid colour	Base colour
Tetrabromophenol blue	3 – 5	yellow	blue
Methyl red	5 – 6	yellow	red
phenolphthalein	8 – 10	colourless	red

[2]

(ii) Use the titration curve above to calculate the amount of NaOH required to completely neutralise 25.0 cm^3 of solution **R**. [1]

(iii) Hence, calculate M_r of **R**. [2]

(b) Three weak monobasic acids are shown below.

S	T	U
$CH_3CH{=}CHCO_2H$	$CH_3CH(OH)CH(OH)CO_2H$	$CH_3CH(OH)CH_2CO_2H$

It is possible to convert **S**, **T** or **U** into one another **in a single step.**

State the reagents and conditions that would be used for the following conversions.

(i) **S** into **T** [1]

(ii) **S** into **U** [1]

(iii) **U** into **S** [1]

8. **(c)** State the type of reaction that occur in the following conversion.

(i) **S** into **U** [1]

(ii) **U** into **S** [1]

(d) **(i)** The acid **S** shows cis-trans isomerism. Draw diagrams to illustrate this type of isomerism, labelling each isomer clearly. [2]

(ii) Draw the skeletal formula of the organic product formed when acid **S** reacts with H_2 in the presence of Pt. [1]

(iii) With the aid of an equation, explain why **S** is miscible with water. [2]

(e) **(i)** Acid **T** reacts with dry PCl_5. Draw the structural formula of the organic product formed. [1]

(ii) Explain, with the aid of an equation, why the reaction must be carried out using **dry** PCl_5. [1]

(f) When **U** is heated with ethanoic acid and a small amount of concentrated sulfuric acid, an organic product, $C_6H_{10}O_4$, is obtained.

(i) State the type of reaction that occurred. [1]

(ii) Write a balanced equation for this reaction. Include the structural formula of the organic product in the equation. [2]

[Total: 20]

9. Oxygen-containing compounds, both organic and inorganic, are essential to our life.

(a) One example is the phosphate buffer system that operates in biological cells. The buffer contains dihydrogen phosphate, $H_2PO_4^-$, which acts as a weak acid.

(i) Write an equation to show that $H_2PO_4^-$ is a weak Bronsted acid. [1]

(ii) Explain the term *buffer* solution and write **two** equations to show how a solution containing $H_2PO_4^-$ and HPO_4^{2-} function as a buffer. [3]

(iii) The pH in many living cells is 7.40.

Given that the K_a of $H_2PO_4^-$ is 6.31×10^{-8} mol dm^{-3}, calculate the value of $[HPO_4^{2-}]/[H_2PO_4^-]$ needed to give a pH of 7.40 in the cells. [2]

(b) The α-amino acids $RCH(NH_2)COOH$ are essential building blocks for proteins in our body.

The simplest α-amino acids is glycine, H_2NCH_2COOH.

One student proposed the following reaction scheme to synthesis glycine from methanal.

$$\underset{\text{methanal}}{HCHO} \xrightarrow{\textbf{Step 1}} HOCH_2CN \xrightarrow{\textbf{Step 2}} HOCH_2CO_2H$$

$$HOCH_2CO_2H \xrightarrow{\textbf{Step 3}} ClCH_2CO_2H \xrightarrow{\textbf{Step 4}} \underset{\text{glycine}}{H_2NCH_2CO_2H}$$

(i) What is the state of hybridisation of the C atom in methanal? [1]

(ii) Describe the bonding in methanal in terms of orbital overlap. Draw diagram to illustrate your answer. [2]

(iii) For each step, state the reagents and conditions required. [4]

(iv) Give a reason to explain why **Step 4** gives a poor yield of glycine. [1]

(c) Compound **X** has the molecular formula $C_7H_{14}O$. **X** decolourises brown Br_2(aq).

Treating **X** with hot concentrated acidified $KMnO_4$(aq) produces two compounds **Y**, C_4H_8O, and **Z**, $C_3H_4O_3$.

Both **Y** and **Z** forms an orange precipitate with 2,4-dinitrophenylhydrazine and a yellow precipitate with alkaline aqueous iodine.

Z fizzes when added to aqueous sodium carbonate.

Deduce the structures of **X**, **Y** and **Z**. Include in your answers, the type of reaction that occurred and the functional groups deduced. [6]

[Total: 20]

JURONG JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME	

CLASS		EXAM INDEX NUMBER	

CHEMISTRY **8872/02**

Paper 2 Structured Questions

29 August 2017

2 hours

Candidates answer Section A on the Question Paper.

Additional Materials: Answer Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

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

Section A
Answer **all** questions.

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

A *Data Booklet* is provided. Do not write anything on the *Data Booklet*.

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		**Section B**	
1		**7**	
2		**8**	
3		**9**	
4			
5			
6			
Total			

This document consists of **14** printed pages.

Section A

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

1. **(a)** Complete the table to show the composition and identity of some ions.

name of element	Nucleon number	Atomic number	Number of protons	Number of neutrons	Number of electrons	Overall charge
	Diff isotopes diff mass number (diff from PT)	**Same in all isotopes (same as PT)**	**Same as atomic number**			
beryllium	9	4	**4** ✓	**5** ✓	**2** ✓	2+
helium	**3** ✓	**2** ✓	**2** ✓	1	1	**1+** ✓

7 ✓: [3]   6 - 4 ✓: [2]   3 - 2 ✓: [1]

[3]

(b) When passed through an electric field, a beam of protons is deflected by 2º.

The beam of beryllium ions in the table in **1(a)** is made to pass through the same electric field. Calculate the angle of deflection for the beam of beryllium ions.

Charge/mass of protons (which is H^+) = 1

Charge/ mass of Be^{2+}= 2/9

Angle of deflection by Be^{2+}= 2/9 × 2 = **0.444º** **[1]**

[1]

(c) Radiochemical reactions such as radioactive decay of isotopes, can be represented by equations in which the nucleon numbers and atomic numbers must be balanced.

In the first stage of the radioactive decay of $^{232}_{92}Th$, the products are an isotope of element **E** and two alpha particles $^{4}_{2}He$.

$$^{232}_{92}Th \rightarrow {}^{y}_{x}\mathbf{E} + 2\,{}^{4}_{2}He$$

What is the nucleon number, y, of **E**? **224**

What is the proton number, x, of **E**? **88**. **[1]**

[1]

[Total: 5]

2. The fifth to eighth ionisation energies of an element in the third period of the Periodic Table are given. The symbols used for reference is **not** the actual symbols of the elements.

	Ionisation energies, kJ mol^{-1}			
	fifth	sixth	seventh	eighth
G	6274	21269	25398	29855

(a) State and explain the group number of element **G**.

Group number : **15 or V** **[1]**

Explanation **From 5th to 6th IE**, **drastic increase** in IE. This implies G has **5 valence electrons**. Hence Group 15. **[1]** [2]

(b) Explain why the seventh IE of **G** is higher than its sixth IE.

6th IE: $G^{5+}(g) \rightarrow G^{6+} + e$
(electronic config of G^{5+}: $1s^22s^22p^6$) $\Rightarrow$2p e removed during 6th IE
7th IE: $G^{6+}(g) \rightarrow G^{7+} + e$
(electronic config of G^{6+}: $1s^22s^22p^5$) $\Rightarrow$2p e removed during 7th IE

More energy is needed to **remove electron from an increasingly positive ion**. **[1]**

Or

More energy is needed to **remove electron from G^{6+} than from G^{5+} ion** **[1]** [1]

(c) How would the first ionisation energy of **G** compare with that of the element on its right in the Periodic Table? Explain your answer.

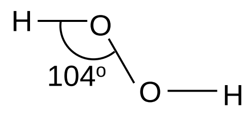
G is phosphorus. Element on the right is sulfur.

1st IE of P is higher than that of S **[1]**

because **in S**, the **inter-electronic repulsion between the paired 3p electrons makes it easier to remove one of them**. **[1]** [2]

[Total: 5]

3. Hydrogen peroxide, H_2O_2, is a colourless liquid with the structure shown below.



(a) Determine the oxidation number of O in hydrogen peroxide.

-1 **[1]** [1]

(b) By considering the number of electron pairs around the O atom in H_2O_2, explain why the H-O-O bond angle in H_2O_2 molecule is 104°.

Each O atom has **2 bond pairs and 2 lone pairs of electrons** **[1]**. **Since lp-lp repulsion > lp-bp repulsion > bp-bp repulsion, the bond angle is reduced from 109.5° to 104°** **[1]** (bond angle in tetrahedral shape) [2]

(c) Volume strength is a term used to indicate the concentration of hydrogen peroxide solution.

It may be defined as the volume of O_2 produced, in cm^3 at s.t.p, when 1 cm^3 of the H_2O_2 solution decomposes according to the following equation.

$$H_2O_2\,(aq) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$

Calculate the volume strength of a 0.250 mol dm^{-3} aqueous solution of H_2O_2. [2]

Amount of H_2O_2 in 1cm^3 0.250 mol dm^{-3} H_2O_2 solution

= 1/1000 × 0.250

= **2.50 × 10^{-4} mol** **[1]**

Amount of O_2 produced = ½ × 2.50 × 10^{-4} = 1.25 × 10^{-4} mol

Volume of O_2 produced = 1.25 × 10^{-4} × 22400 = **2.80** cm^3 **[1]**

(d) Excess KI(aq) is added to another aqueous solution containing 0.800 mol H_2O_2 and brown iodine solution is produced.

$$2I^- + 2H_2O_2 + 2H^+ \rightarrow I_2 + 2H_2O$$

The resulting iodine solution is then titrated with 0.400 mol dm^{-3} $Na_2S_2O_3$.

(i) Write an equation for the reaction between I_2 and $Na_2S_2O_3$.

$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$ **[1]** [1]

(ii) Calculate the volume of $Na_2S_2O_3$ solution required for the titration.

$2H_2O_2 \equiv I_2 \equiv 2S_2O_3^{2-}$

Amount of $S_2O_3^{2-}$ needed = 0.008 mol

Volume of $S_2O_3^{2-}$ needed = 0.008 ÷ 0.400 × 1000 = 20 cm^3 **[1]**

[1]

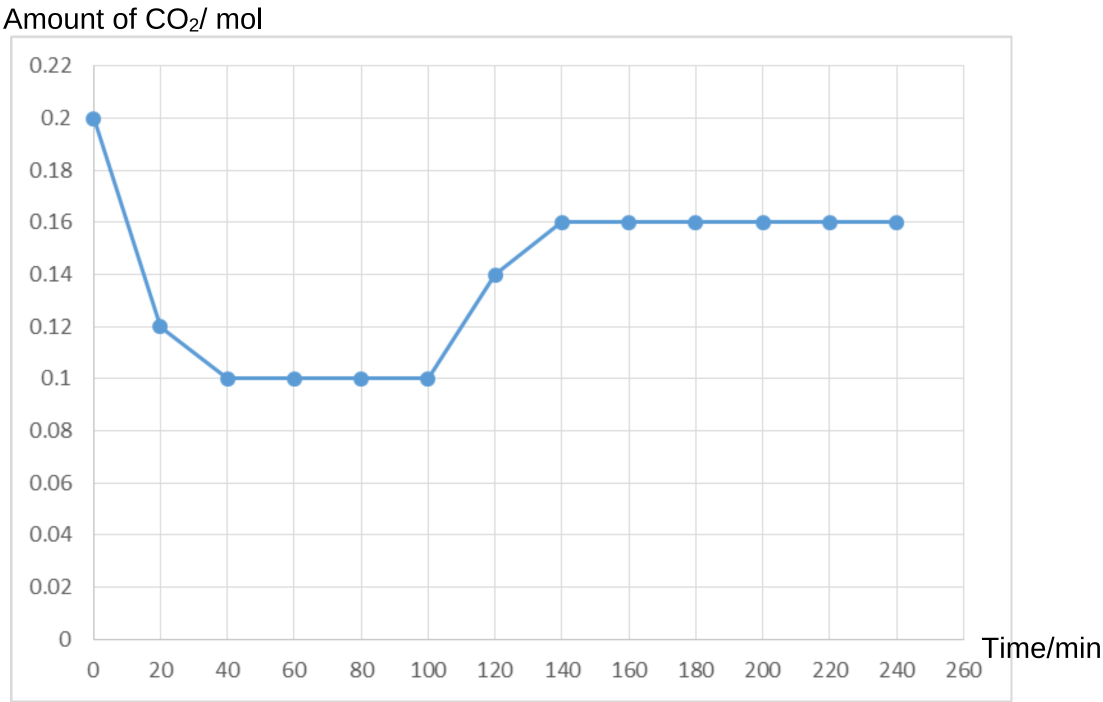
[Total: 7]

4. Growing concerns about global climate change have increased researchers' attention on the various approaches to reduce CO_2 emissions. A widely studied approach is the Sabatier reaction.

$$CO_2(g) + 4H_2(g) \rightleftharpoons CH_4(g) + 2H_2O(g)$$

(a) One researcher did some experiments to investigate the optimum temperature for the Sabatier reaction.

First, he mixed 0.2 mol of $CO_2(g)$ and 0.8 mol of $H_2(g)$ in a 3 dm^3 vessel at 350 ^oC. At every 20 minutes interval, he monitored the amount of CO_2 present in the mixture using a gas chromatography. At 100th min, he raised the temperature to 500 ^oC and continued to monitor the amount of CO_2. The results are shown graphically below.



(i) Determine the amount of CO_2, H_2, CH_4 and H_2O in the mixture at the 80th minute.

	$CO_2(g)$ +	$4H_2(g)$ $\rightleftharpoons$	$CH_4(g)$ +	$2H_2O(g)$
Initial amount/ mol	0.2	0.8	0	0
Change	0.1	0.4	0.1	0.2
Eqm amount/mol	**0.1**	**0.4**	**0.1**	**0.2**

[1]

(ii) Hence, calculate the value of the equilibrium constant, K_C for the Sabatier reaction at 350 ^oC, stating its units.

$$K_C = \frac{[CH_4][H_2O]^2}{[CO_2][H_2]^4} \quad \textbf{[1]}$$

$$= \frac{(0.1/3)(0.2/3)^2}{(0.1/3)(0.4/3)^4} = \underline{\mathbf{14.1\ mol^{-2}dm^6}} \quad \textbf{[1]}$$

[2]

4. **(a)** **(iii)** Use the graph to determine whether the CO_2 content in the equilibrium mixture increases or decreases when temperature is raised to 500 °C at 100th min.

Increase **[1]** [1]

(iv) Use your answer in **(a)(iii)**, predict and explain whether the Sabatier reaction is exothermic or endothermic.

When temperature is raised, CO_2 content increases. This means that when **temperature is raised, backward reaction is favoured to favour the endothermic reaction to use up some heat**. **[1]**

Thus the **forward reaction is exothermic**. **[1]** [2]

(b) The Sabatier reaction is also widely studied by NASA because water and methane are regenerated from the carbon dioxide produced by the cabin crew.

Some of the water produced by the reaction is then electrolysed to generate oxygen gas, a life support consumable, and hydrogen gas which is then passed into the Sabatier reactor to further produce more water and methane.

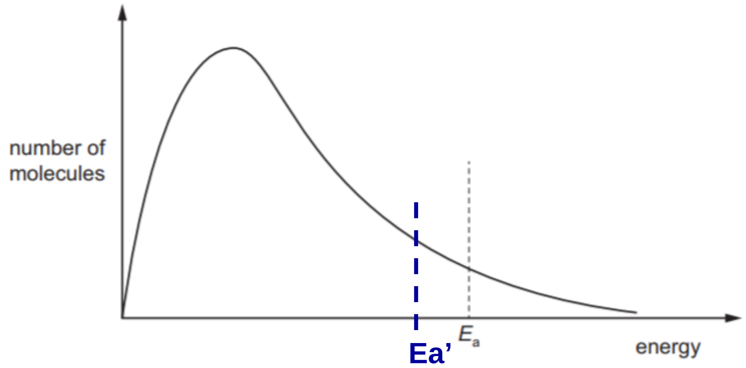
Research by NASA also shows that Ru is the most efficient catalyst for the Sabatier reaction.

(i) Explain the term *catalyst*.

A catalyst is a substance which increases the rate of reaction by providing an alternative pathway of lower activation energy, without itself undergoing any permanent chemical change. **[1]**

[1]

(ii) The Boltzmann distribution curve shows the distribution of energies in a mixture of CO_2 and H_2 at 350 °C.



Add a suitable label to the horizontal axis and use it to explain why a catalyst is used in the Sabatier reaction.

A catalyst provides an alternative reaction path of lower activation energy than that of the uncatalysed reaction. Thus, the **number of molecules with energy greater than Ea'** **increases**. **Frequency of effective collisions** **increases** and hence rate of reaction **increases**.
[1] [2]

4. **(c)** Methane produced from the Sabatier reaction can be stored and used as a rocket propellant.

(i) Write an equation for the complete combustion of methane.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ **[1]** [1]

(ii) Using appropriate bond energies from the *Data Booklet*, calculate the amount of energy evolved when 1 mole of methane is completely burnt in oxygen.

ΔH_c(methane)

= Amt of energy evolved by the complete combustion of 1 mol CH_4

= energy to break bonds – energy released when bonds formed

= **4E(C-H) + 2E(O=O) – [2E(C=O) + 4E(O-H)]** **[1]**

= 4(410) + 2(496) – [2(740) + 4(460)]

= –688 kJ mol^{-1}

Amount of energy evolved = 688 kJ **[1]** [1]

Q4 total [12] max [11]

[Total: 11]

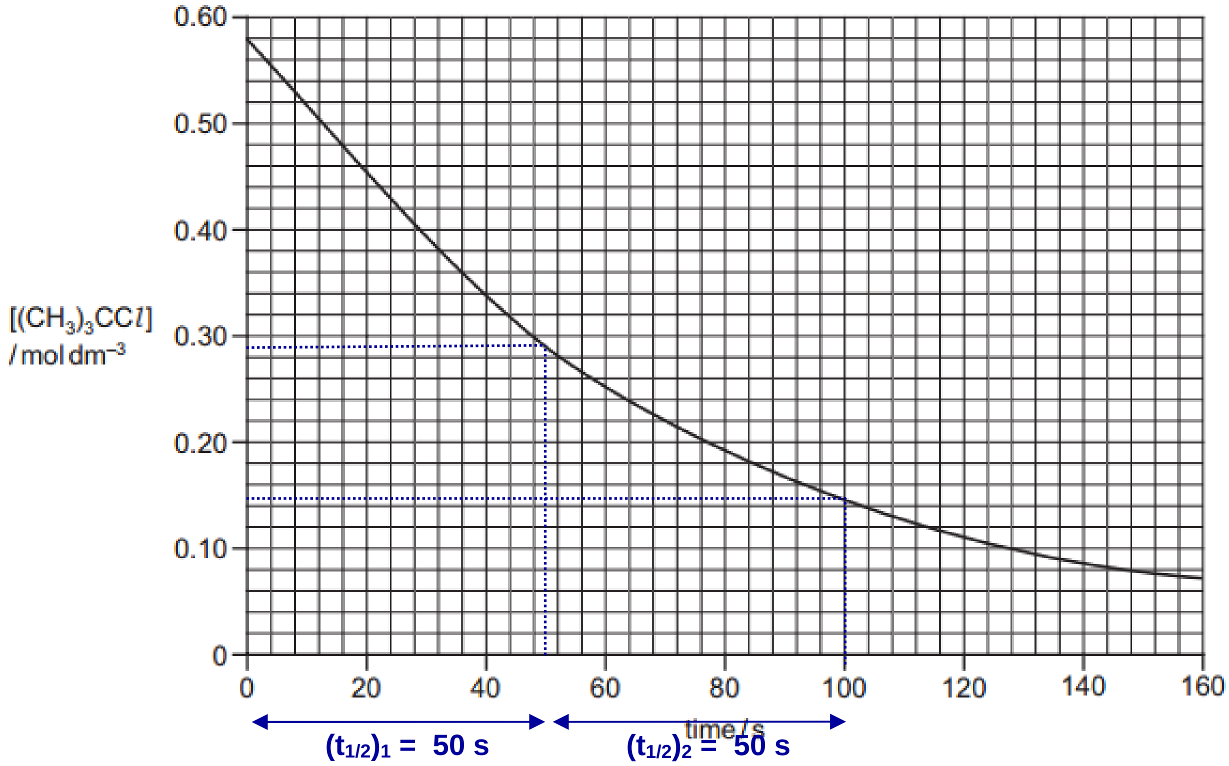
5. In aqueous solution, 2-chloro-2-methylpropane reacts with potassium hydroxide to form 2-methylpropan-2-ol.

(a) Write a balanced equation for the above reaction.

$(CH_3)_3CCl + KOH \rightarrow (CH_3)_3COH + KCl$ **[1]** [1]

The rate of this reaction was investigated using a **large excess** of sodium hydroxide.

(b) The graph below shows the results of the experiment.



The reaction is first order with respect to $[(CH_3)_3CCl]$. This can be confirmed from the graph using half-lives.

(i) Explain what is meant by the *half-life* of a reaction?

Half life is the **time taken for the concentration (or amount) of the reactant to reduce to half of its original concentration (or amount)**. **[1]** [1]

(ii) Determine the half-life for this reaction. Show all your working and show clearly any construction lines on the graph.

$t_{1/2}$ = **50 s** **[1] with units and workings on graph**

[1]

5. **(b)** **(iii)** It is known that the reaction is zero order with respect to [KOH].

Using your answer in **(b)(ii)**, calculate the value of the rate constant, *k*, for this reaction and give its units.

rate = k[$(CH_3)_3Cl$]

Since it is a first order reaction, k = $\frac{\ln 2}{t_{1/2}}$ = **<u>0.0139 s^{-1}</u>**

[1]: value **[1]: unit**

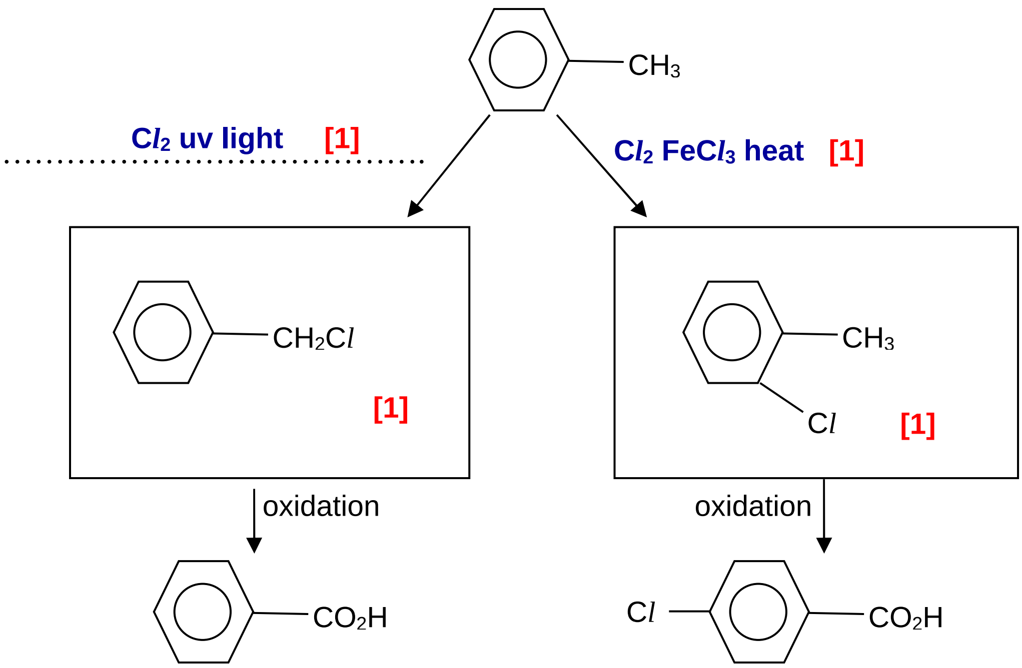
[2]

(iv) What would be the effect on the half-life of this reaction if the initial concentration of 2-chloro-2-methylpropane was doubled.

<u>Remains the same</u>. **[1]** [1]

[Total: 6]

6. **(a)** Methylbenzene undergoes monochlorination under two different conditions to form two isomers. These two isomers then undergo oxidation to form carboxylic acids.



Benzoic acid

4-chlorobenzoic acid

In the boxes and space provided above, draw the structural formula of the monochlorinated products formed and state the reagent and conditions needed. [4]

(b) Compare and explain the relative acidity of benzoic acid and 4-chlorobenzoic acid formed in **(a)**.

<u>4-chlorobenzoic acid is the stronger acid.</u> **[1]**

<u>Cl is electron withdrawing</u>. It helps to <u>disperse the negative charge on the O^-</u> <u>of $C_6H_4ClCOO^-$</u> . Thus <u>$C_6H_4ClCOO^-$ is more stable</u> than $C_6H_5COO^-$. [1] [2]

[Total: 6]

Section B

Answer **two** questions from this section on separate answer paper.

7. This question is about aluminium and its compounds.

(a) **(i)** State and describe the structure and bonding of solid aluminium. [2]

Giant metallic structure. [1]

Al^{3+} and mobile valence electrons are held by strong electrostatic forces of attraction [1]

(ii) A common use of aluminium is to make the electrical cables in long distance overhead power lines.

Suggest **two** properties of aluminium that make it suitable for this use. [2]

Good electrical conductor

Highly corrosion resistant

low density

ductile

Any one [1].
Two reasons needed.

(b) Aluminium reacts with chlorine to form a white solid chloride that contains 79.7% chlorine and sublimes at 180 °C.

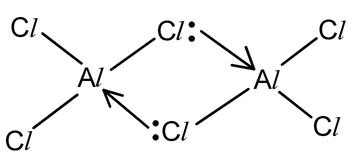
(i) Determine the empirical formula of the chloride, showing your working clearly. [2]

	C*l*	A*l*
mass	79.7	20.3
mol	79.7 ÷ 35.5 = 2.24	20.3 ÷ 27.0 =0.752
ratio	3	1

Empirical formula is **$AlCl_3$** **[1]** **working [1]**

(ii) Given that the molar mass of the chloride is 267 g mol^{-1}, determine the molecular formula of the chloride. Draw a labelled diagram to illustrate the bonding in the chloride. [2]

Molecular formula is **Al_2Cl_6** **[1] with working**



[1] must show dative bond

(iii) Explain, in terms of structure and bonding, why this chloride has a low sublimation temperature. [2]

It has a simple covalent structure ✓. Small amount of energy ✓ needed to overcome the weak intermolecular forces /instantaneous dipole-induced dipole interactions between the molecules ✓.

1-2 ✓: [1] 3 ✓: [2]

7 **(b)** **(iv)** When water is added to the solid chloride, it dissolves to form an acidic solution. However, when water is added to solid NaC*l*, a neutral solution is obtained.

Using relevant data from the *Data Booklet*, explain why this solid chloride forms an acidic solution but not NaC*l*. Write equation to illustrate the reaction that occurred.

You may use the empirical formula determined in **(b)(ii)** to write the equation. [3]

Charge density of Al^{3+} α 3/ 0.050 = 60.0

Charge density of Na^{+} α 1/ 0.095 = 10.5 **both correct [1]**

Al^{3+} has high charge density. Hence it hydrolyses in water to form acidic solution. **[1]**

$$AlCl_3(s) + 6H_2O(l) \rightarrow [Al(H_2O)_6]^{3+}(aq) + 3Cl^-(aq)$$

$$[Al(H_2O)_6]^{3+}(aq) \rightleftharpoons [Al(H_2O)_5OH]^{2+}(aq) + H^+(aq) \quad \textbf{[1]}$$

(c) $LiAlH_4$ is a reducing agent used commonly in organic synthesis. It reacts vigorously with water to produce H_2, LiOH and an amphoteric hydroxide. Hence $LiAlH_4$ must be stored under dry condition and its reaction must be carried out in anhydrous organic solvents such as diethyl ether, $CH_3CH_2OCH_2CH_3$.

(i) Write a balanced equation for the reaction between $LiAlH_4$ and water. [1]

$LiAlH_4 + 4H_2O \rightarrow 2H_2 + LiOH + Al(OH)_3$ **[1]**

(ii) The above reaction produced an amphoteric hydroxide.

Write two equations to show that it is amphoteric [2]

$Al(OH)_3 + OH^- \rightarrow Al(OH)_4^-$ **[1]**

$Al(OH)_3 + 3H^+ \rightarrow Al^{3+} + 3H_2O$ **[1]**

(d) CH_3CHO CH_3CO_2H $CH_2{=}CHOH$

From the above compounds, identify the compounds that can be reduced by $LiAlH_4$ to form ethanol.

CH_3CHO **CH_3CO_2H** **both correct [1]** [1]

7. **(e)** Reactions involved $LiAlH_4$ are carried out in anhydrous organic solvents such as diethyl ether, $CH_3CH_2OCH_2CH_3$.

Diethyl ether can be prepared from ethanol in two steps as shown below.

$$CH_3CH_2OH \xrightarrow[\text{Step 1}]{\text{Na}} \mathbf{W} \xrightarrow[\text{Step 2}]{} CH_3CH_2OCH_2CH_3$$

(i) State the type of reaction that occurred in Step 1. [1]

Redox reaction **[1]**

(ii) Draw the displayed formula of **W**. [1]

$CH_3CH_2O^-Na^+$ in displayed formula [1]

(iii) Given that **W** acts as a nucleophile in Step 2, draw the structural formula of the organic reactant required in Step 2. [1]

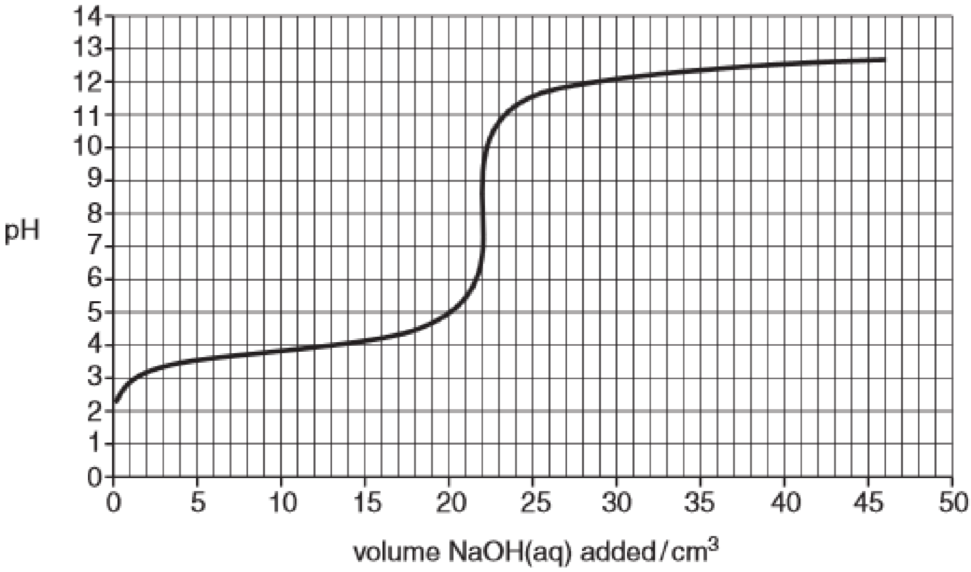
CH_3CH_2Br or any ethyl halide **[1]**

[Total: 20]

8. **(a)** Compound **R** is a weak monobasic acid.

A student dissolved 2.29 g of **R** in 250 cm^3 of deionised water and pipetted 25.0 cm^3 of this solution into a conical flask. He added 0.100 mol dm^{-3} NaOH(aq) solution from a burette and monitored the pH of the reaction mixture in the conical flask using a pH meter.

The pH curve obtained by the student is shown below.



(i) Using the data provided below, choose the most suitable indicator for the above titration. State the colour change of the solution at endpoint.

Indicator	pH at which colour changes	Acid colour	Base colour
Tetrabromophenol blue	3 – 5	yellow	blue
Methyl red	5 – 6	yellow	red
phenolphthalein	8 – 10	colourless	red

[2]

phenolphthalein [1]

colourless to PALE pink [1]

(ii) Use the titration curve above to calculate the amount of NaOH required to completely neutralise 25.0 cm^3 of solution **R**. [1]

Vol of NaOH needed to completely neutralise R = 22 cm^3

Amount of NaOH needed to completely neutralise R

= 22/1000 × 0.100 = **2.20×10^{-3} mol** **[1]**

(iii) Hence, calculate the M_r of **R**. [2]

Amount of **R** present in 250 cm^3 = **2.20×10^{-2} mol** **[1] ecf from (ii)**

M_r of R = 2.29 ÷ 2.20 × 10^{-2} = **104** **[1] ecf from (ii)**

(b) Three monobasic weak acids are shown below.

S	T	U
$CH_3CH{=}CHCO_2H$	$CH_3CH(OH)CH(OH)CO_2H$	$CH_3CH(OH)CH_2CO_2H$

It is possible to convert **S**, **T** or **U** into one another **in a single step.**

State the reagents and conditions that would be used for the following conversions.

(i) **S** into **T** [1]

Cold alkaline/acidic/dilute $KMnO_4$ **[1]**

(ii) **S** into **U** [1]

H_2O(g), H_3PO_4 catalyst, 300°C, 65 atm **[1]**

(iii) **U** into **S** [1]

Excess conc H_2SO_4, heat **[1]**

(c) State the type of reaction that occur in the following conversion.

(i) **S** into **U** [1]

Electrophilic addition **[1]**

(ii) **U** into **S** [1]

Elimination **[1]**

(d) **(i)** The acid **S** shows cis-trans isomerism. Draw diagrams to illustrate this type of isomerism, labelling each isomer clearly. [2]

[1] for each correct structure and label

(ii) Draw the skeletal formula of the organic product formed when acid **S** reacts with H_2 in the presence of Pt. [1]

$CH_3CH_2CH_2CO_2H$ in skeletal formula **[1]**

(iii) With the aid of an equation, explain why **S** is miscible with water. [2]

[1] for diagram to show hydrogen bonding btw S and H_2O

S is soluble in water because it can form hydrogen bonding with water molecules. [1]

(e) **(i)** Acid **T** reacts with dry PCl_5. Draw the structural formula of the organic product formed. [1]

$\underline{CH_3CH(Cl)CH(Cl)COCl}$ **[1]**

(ii) Explain, with the aid of an equation, why the reaction must be carried out using **dry** PCl_5. [1]

With limited water: $\underline{PCl_5(s) + H_2O(l) \rightarrow POCl_3(l) + 2HCl(g)}$ **[1]**

Compare with the equations below:
With excess hot water: $PCl_5(s) + 4H_2O(l) \rightarrow H_3PO_4(aq) + 5HCl(aq)$
With excess cold water: $PCl_5(s) + H_2O(l) \rightarrow POCl_3(aq) + 2HCl(aq)$

(f) When **U** is heated with ethanoic acid and a small amount of concentrated sulfuric acid, an organic product, $C_6H_{10}O_4$, is obtained.

(i) State the type of reaction that occurred. [1]

Condensation **[1]**

(ii) Write a balanced equation for this reaction. Include the structural formula of the organic product in the equation. [2]

$CH_3CH(OH)CH_2CO_2H + CH_3COOH$

$= CH_3CH(OCOCH_3)CH_2CO_2H + H_2O$ **[1] eqn**

[1] structure of product

[Total: 20]

9. Oxygen-containing compounds, both organic and inorganic, are essential to our life.

(a) One example is the phosphate buffer system that operates in biological cells. The buffer contains dihydrogen phosphate, $H_2PO_4^-$, which acts as a weak acid.

(i) Write an equation to show that $H_2PO_4^-$ is a weak Bronsted acid. [1]

$\underline{H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}}$ **[1]**

(ii) Explain the term *buffer* solution and write **two** equations to show how a solution containing $H_2PO_4^-$ and HPO_4^{2-} function as a buffer. [3]

A buffer is a solution that **resists pH changes when a small amount of acid or alkali is added.** **[1]**

$\underline{H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_2O}$ **[1]**

$\underline{HPO_4^{2-} + H^+ \rightarrow H_2PO_4^-}$ **[1]**

(iii) The pH in many living cells is 7.40.

Given that the K_a of $H_2PO_4^-$ is 6.31×10^{-8} mol dm^{-3}, calculate the value of $[HPO_4^{2-}]/[H_2PO_4^-]$ needed to give a pH of 7.40 in the cells. [2]

$\underline{[H^+] = 3.98 \times 10^{-8} \text{ mol dm}^{-3}}$ **[1]**

$[HPO_4^{2-}]/[H_2PO_4^-] = K_a/[H^+] = 6.31 \times 10^{-8} \div 3.98 \times 10^{-8} = \underline{\mathbf{1.59}}$ **[1]**

(b) The α-amino acids $RCH(NH_2)COOH$ are essential building blocks for proteins in our body.

The simplest α-amino acids is glycine, H_2NCH_2COOH.

One student proposed the following reaction scheme to synthesis glycine from methanal.

$$\underset{\text{methanal}}{HCHO} \xrightarrow{\textbf{Step 1}} HOCH_2CN \xrightarrow{\textbf{Step 2}} HOCH_2CO_2H$$

$$HOCH_2CO_2H \xrightarrow{\textbf{Step 3}} ClCH_2CO_2H \xrightarrow{\textbf{Step 4}} \underset{\text{glycine}}{H_2NCH_2CO_2H}$$

(i) What is the state of hybridisation of the C atom in methanal? [1]

sp^2 **[1]**

(ii) Describe the bonding in methanal in terms of orbital overlap. Draw diagram to illustrate your answer.

[2]

σ bond formed by head-on overlap of orbitals

π bond formed by side-way overlap of p orbitals **[1]**

Diagram [1]

(iii) For each step, state the reagents and conditions required. [4]

Step 1: **HCN, trace amount of NaCN** **[1]**

Step 2: **dilute H_2SO_4 or HC*l*(aq), heat** under reflux **[1]**

Step 3: **HC*l*, ZnC*l*$_2$ catalyst, heat** **[1]**

Step 4: **excess NH_3, ethanol, heat in sealed tube** **[1]**

(iv) Give a reason to explain why **Step 4** gives a poor yield of glycine. [1]

Glycine may act as nucleophile and react with $ClCH_2COOH$, giving secondary amine, tertiary amine and even quarternary ammonium salt.

Or NH_3, being a base, will react with glycine to form $NH_2CH_2COO^-NH_4^+$

[1]

9. **(c)** Compound **X** has the molecular formula $C_7H_{14}O$. **X** decolourises brown $Br_2(aq)$.

Treating **X** with hot concentrated acidified $KMnO_4(aq)$ produces two compounds **Y**, C_4H_8O, and **Z**, $C_3H_4O_3$.

Both **Y** and **Z** forms an orange precipitate with 2,4-dinitrophenylhydrazine and a yellow precipitate with alkaline aqueous iodine.

Z fizzes when added to aqueous sodium carbonate.

Deduce the structures of **X**, **Y** and **Z**. Include in your answers, the type of reaction that occurred and the functional groups deduced. [6]

Test	Functional group deduced	Type of reaction
X decolourises brown $Br_2(aq)$.	**X** is an alkene ✓	Electrophilic addition ✓
X + $KMnO_4(aq)$ produces **Y**, C_4H_8O, and **Z**, $C_3H_4O_3$.	Y is ketone Z has –COOH group	Oxidation ✓
Y and **Z** forms an orange precipitate with 2,4-DNPH	**Y** is ketone ✓ **Z** has ketone group (cannot be aldehyde bcos Z is a product of oxidation) ✓	Condensation ✓
Y and **Z** forms yellow precipitate with alkaline aqueous iodine	Y and Z has CH_3CO- group ✓	Iodoform test ✓
Z fizzes when added to aqueous sodium carbonate	Z has –COOH group ✓	Acid-carbonate reaction ✓

10 ✓ : [4] 9-7 ✓ :[3] 6-4✓ : [2] 3-2✓ :[1]

Z: CH_3COCO_2H [1]

Y: $CH_3COCH_2CH_3$ [1]

X: $CH_3(CH_2OH)C{=}C(CH_3)CH_2CH_3$ [1]

Total [21] max [20]

[Total: 20]