



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 isotope's diff mass number (diff from PT)	Same in all isotope's (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 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.

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

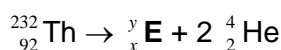
Charge/ mass of Be^{2+} = 2/9

Angle of deflection by Be^{2+} = $2/9 \times 2 = \underline{0.444^\circ}$ [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 ${}_{92}^{232}\text{Th}$, the products are an isotope of element **E** and two alpha particles ${}_2^4\text{He}$.



What is the nucleon number, y , of **E**? 224 } [1]
 What is the proton number, x , of **E**? 88.

[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+} : $1s^2 2s^2 2p^6$) \Rightarrow 2p e removed during 6th IE

7th IE: $G^{6+}(g) \rightarrow G^{7+} + e$

(electronic config of G^{6+} : $1s^2 2s^2 2p^5$) \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.

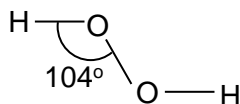
1st IE of P is higher than that of S [1]

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]

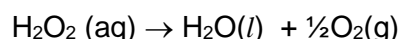
- (b) By considering the number of electron pairs around the O atom in H_2O_2 , explain why the H-O-O bond angle in H_2O_2 molecule is 104° .

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.



Calculate the volume strength of a $0.250 \text{ mol dm}^{-3}$ aqueous solution of H_2O_2 .

[2]

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

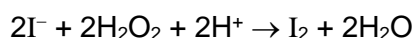
$$= 1/1000 \times 0.250$$

$$= \underline{2.50 \times 10^{-4} \text{ mol}} \quad \text{[1]}$$

$$\text{Amount of } \text{O}_2 \text{ produced} = \frac{1}{2} \times 2.50 \times 10^{-4} = 1.25 \times 10^{-4} \text{ mol}$$

$$\text{Volume of } \text{O}_2 \text{ produced} = 1.25 \times 10^{-4} \times 22400 = \underline{2.80 \text{ cm}^3} \quad \text{[1]}$$

- (d) Excess $\text{KI}(\text{aq})$ is added to another aqueous solution containing $0.800 \text{ mol H}_2\text{O}_2$ and brown iodine solution is produced.



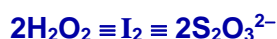
The resulting iodine solution is then titrated with $0.400 \text{ mol dm}^{-3} \text{Na}_2\text{S}_2\text{O}_3$.

- (i) Write an equation for the reaction between I_2 and $\text{Na}_2\text{S}_2\text{O}_3$.



[1]

- (ii) Calculate the volume of $\text{Na}_2\text{S}_2\text{O}_3$ solution required for the titration.



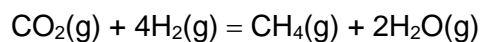
$$\text{Amount of } \text{S}_2\text{O}_3^{2-} \text{ needed} = 0.008 \text{ mol}$$

$$\text{Volume of } \text{S}_2\text{O}_3^{2-} \text{ needed} = 0.008 \div 0.400 \times 1000 = \underline{20 \text{ cm}^3} \quad \text{[1]}$$

[1]

[Total: 7]

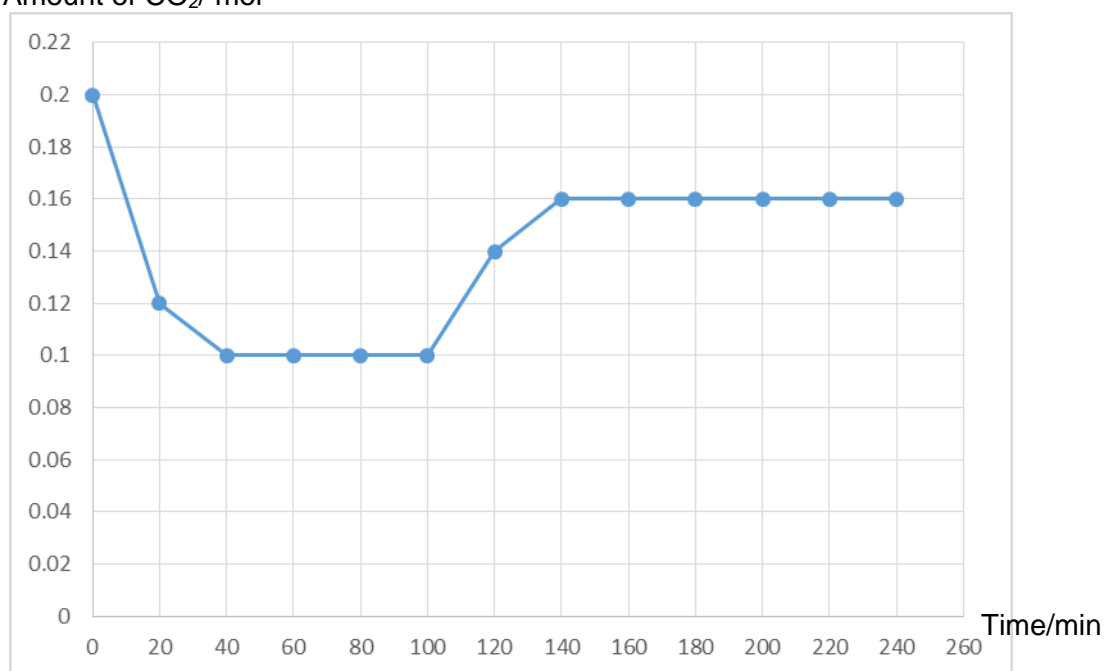
4. Growing concerns about global climate change have increased researchers' attention on the various approaches to reduce CO₂ emissions. A widely studied approach is the Sabatier reaction.



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

First, he mixed 0.2 mol of CO₂(g) and 0.8 mol of H₂(g) in a 3 dm³ vessel at 350 °C. At every 20 minutes interval, he monitored the amount of CO₂ present in the mixture using a gas chromatography. At 100th min, he raised the temperature to 500 °C and continued to monitor the amount of CO₂. The results are shown graphically below.

Amount of CO₂/ mol



- (i) Determine the amount of CO₂, H₂, CH₄ and H₂O in the mixture at the 80th minute.

	CO ₂ (g)	+	4H ₂ (g)	=	CH ₄ (g)	+	2H ₂ O(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 °C, stating its units.

$$K_c = \frac{[\text{CH}_4][\text{H}_2\text{O}]^2}{[\text{CO}_2][\text{H}_2]^4} \quad [1]$$

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

[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 100^{th} 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.

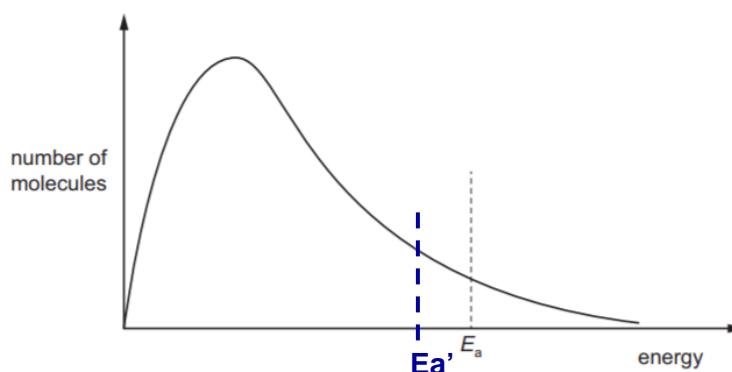
Research by NASA also shows that Ru is the most efficient catalyst for the Sabatier reaction.

- (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 E_a' 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.



- (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.

$\Delta H_c(\text{methane})$

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

= energy to break bonds – energy released when bonds formed

= $4E(\text{C-H}) + 2E(\text{O=O}) - [2E(\text{C=O}) + 4E(\text{O-H})]$ [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.

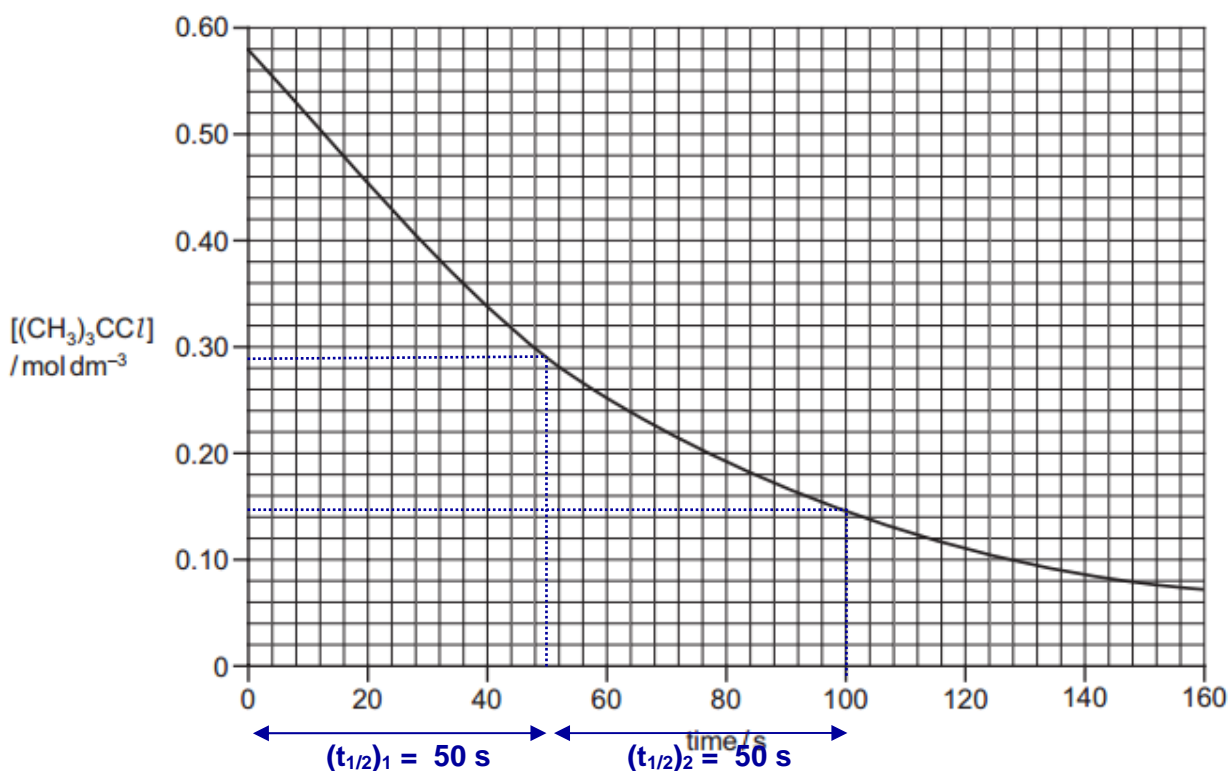
(a) Write a balanced equation for the above reaction.



[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 $[(\text{CH}_3)_3\text{CCl}]$. 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.

$t_{1/2} = 50 \text{ s}$ [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.

$$\text{rate} = k[(\text{CH}_3)_3\text{CI}]$$

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

[1]: value

[1]: unit

[2]

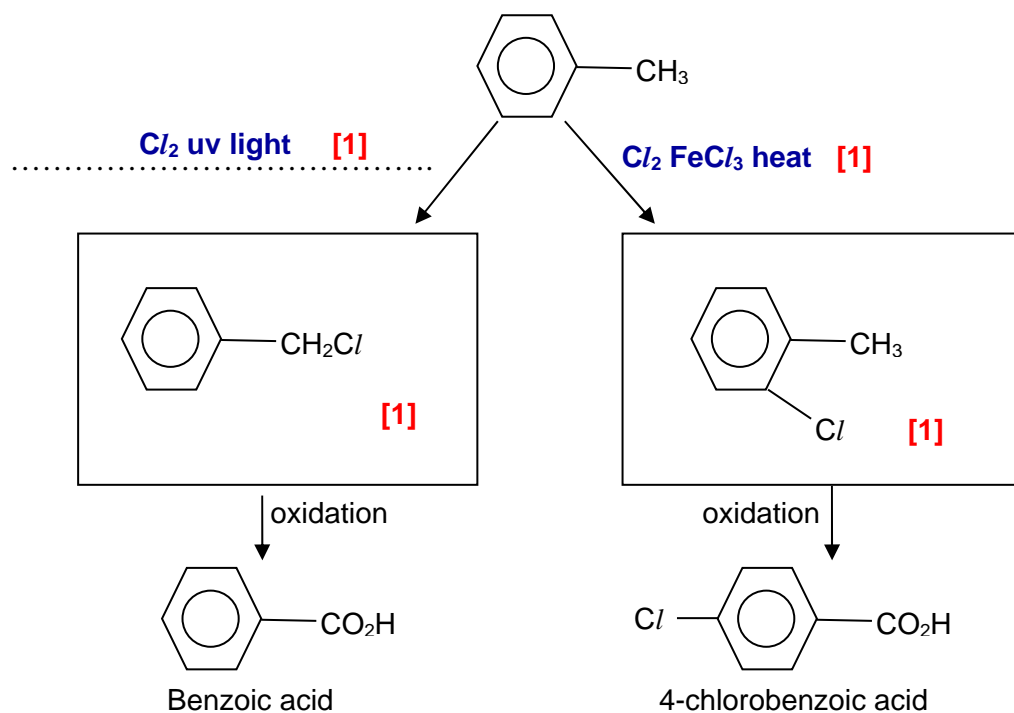
- (iv) What would be the effect on the half-life of this reaction if the initial concentration of 2-chloro-2-methylpropane was doubled.

Remains the same. [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.



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).

4-chlorobenzoic acid is the stronger acid. [1]

Cl is electron withdrawing. It helps to disperse the negative charge on the O⁻ of C₆H₄Cl/COO⁻. Thus C₆H₄Cl/COO⁻ is more stable than C₆H₅COO⁻.

[1]

[2]

[Total: 6]

10
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.

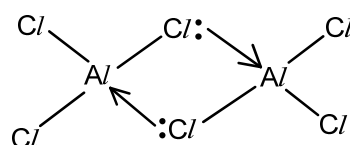
- (i) Determine the empirical formula of the chloride, showing your working clearly. [2]

	Cl	Al
mass	79.7	20.3
mol	$79.7 \div 35.5$ $= 2.24$	$20.3 \div 27.0$ $= 0.752$
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 NaCl, a neutral solution is obtained.

Using relevant data from the *Data Booklet*, explain why this solid chloride forms an acidic solution but not NaCl. 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 $\text{Al}^{3+} \propto 3 / 0.050 = 60.0$

Charge density of $\text{Na}^+ \propto 1 / 0.095 = 10.5$ both correct [1]

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



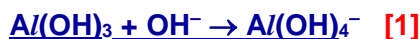
- (c) LiAlH_4 is a reducing agent used commonly in organic synthesis. It reacts vigorously with water to produce H_2 , LiOH and an amphoteric hydroxide. Hence LiAlH_4 must be stored under dry condition and its reaction must be carried out in anhydrous organic solvents such as diethyl ether, $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$.

- (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]



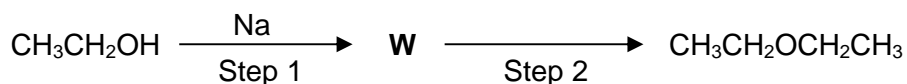
- (d) CH_3CHO $\text{CH}_3\text{CO}_2\text{H}$ $\text{CH}_2=\text{CHOH}$

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

CH_3CHO $\text{CH}_3\text{CO}_2\text{H}$ both correct [1] [1]

7. (e) Reactions involving LiAlH_4 are carried out in anhydrous organic solvents such as diethyl ether, $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$.

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



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

Redox reaction [1]

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

$\text{CH}_3\text{CH}_2\text{O}^-\text{Na}^+$ 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]

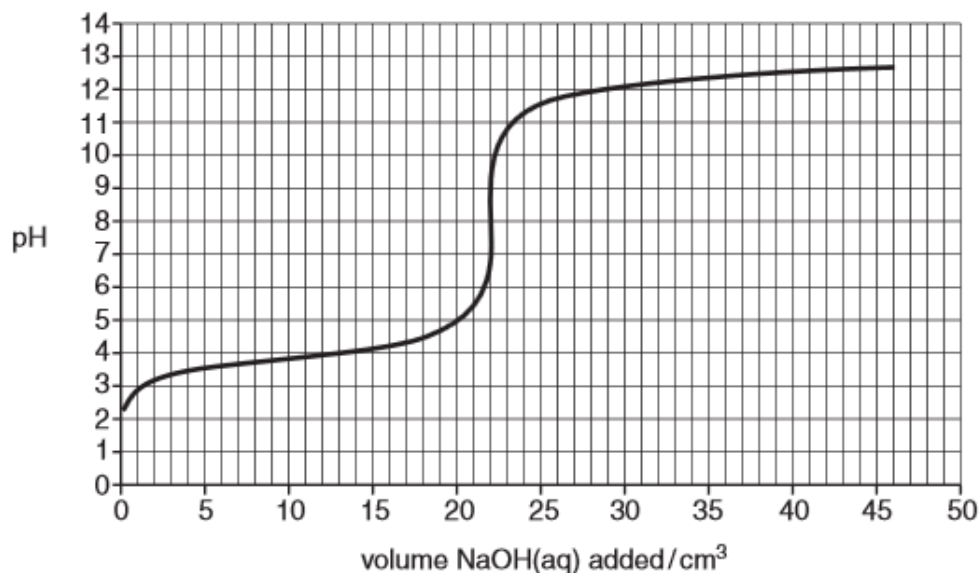
$\text{CH}_3\text{CH}_2\text{Br}$ or any ethyl halide [1]

[Total: 20]

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

A student dissolved 2.29 g of **R** in 250 cm³ of deionised water and pipetted 25.0 cm³ 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 cm³ of solution **R**.

[1]

Vol of NaOH needed to completely neutralise **R** = 22 cm³

Amount of NaOH needed to completely neutralise **R**

$$= 22/1000 \times 0.100 = \underline{2.20 \times 10^{-3} \text{ mol}} \quad [1]$$

- (iii) Hence, calculate the M_r of **R**.

[2]

Amount of **R** present in 250 cm³ = $\underline{2.20 \times 10^{-2} \text{ mol}}$ [1] ecf from (ii)

$$M_r \text{ of } R = 2.29 \div 2.20 \times 10^{-2} = \underline{104} \quad [1] \text{ ecf from (ii)}$$

- (b) Three monobasic weak acids are shown below.

S	T	U
$\text{CH}_3\text{CH}=\text{CHCO}_2\text{H}$	$\text{CH}_3\text{CH}(\text{OH})\text{CH}(\text{OH})\text{CO}_2\text{H}$	$\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CO}_2\text{H}$

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]

$\text{H}_2\text{O}(\text{g})$, 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]

$\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$ 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]

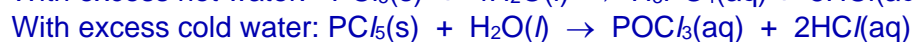
- (e) (i) Acid **T** reacts with dry PCl_5 . Draw the structural formula of the organic product formed. [1]



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



Compare with the equations below:



- (f) When **U** is heated with ethanoic acid and a small amount of concentrated sulfuric acid, an organic product, $\text{C}_6\text{H}_{10}\text{O}_4$, 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]



[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]



(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]



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

Given that the K_a of H_2PO_4^- is $6.31 \times 10^{-8} \text{ mol dm}^{-3}$, calculate the value of $[\text{HPO}_4^{2-}]/[\text{H}_2\text{PO}_4^-]$ needed to give a pH of 7.40 in the cells. [2]

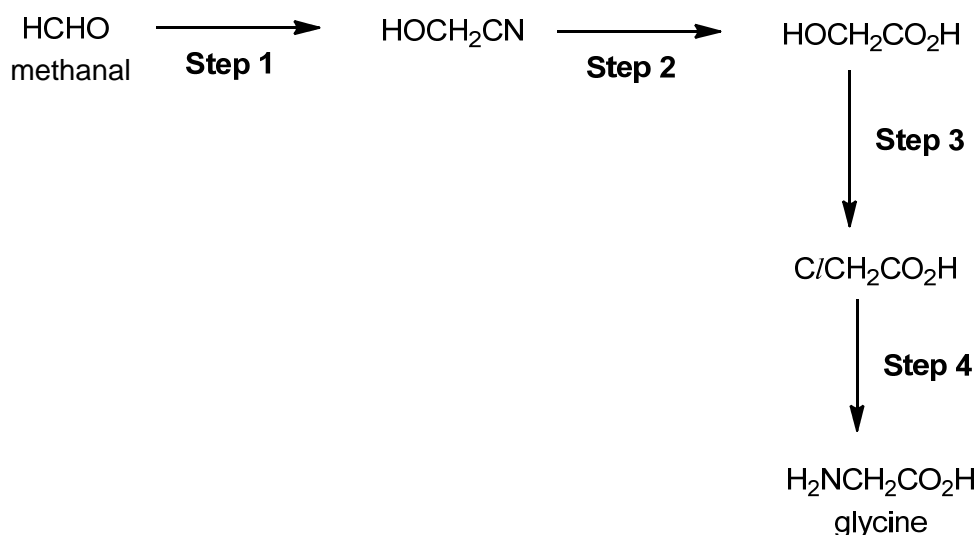
$[\text{H}^+] = 3.98 \times 10^{-8} \text{ mol dm}^{-3}$ [1]

$[\text{HPO}_4^{2-}]/[\text{H}_2\text{PO}_4^-] = K_a/[\text{H}^+] = 6.31 \times 10^{-8} \div 3.98 \times 10^{-8} = 1.59$ [1]

(b) The α -amino acids $\text{RCH}(\text{NH}_2)\text{COOH}$ are essential building blocks for proteins in our body.

The simplest α -amino acids is glycine, $\text{H}_2\text{NCH}_2\text{COOH}$.

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



(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 H₂SO₄ or HCl(aq), heat under reflux [1]

Step 3: HCl, ZnCl₂ catalyst, heat [1]

Step 4: excess NH₃, 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 ClCH₂COOH, giving secondary amine, tertiary amine and even quaternary ammonium salt.

Or NH₃, being a base, will react with glycine to form NH₂CH₂COO⁻NH₄⁺

[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]