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.

……

……

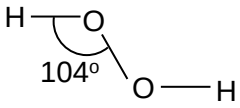
……

……

…… [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]

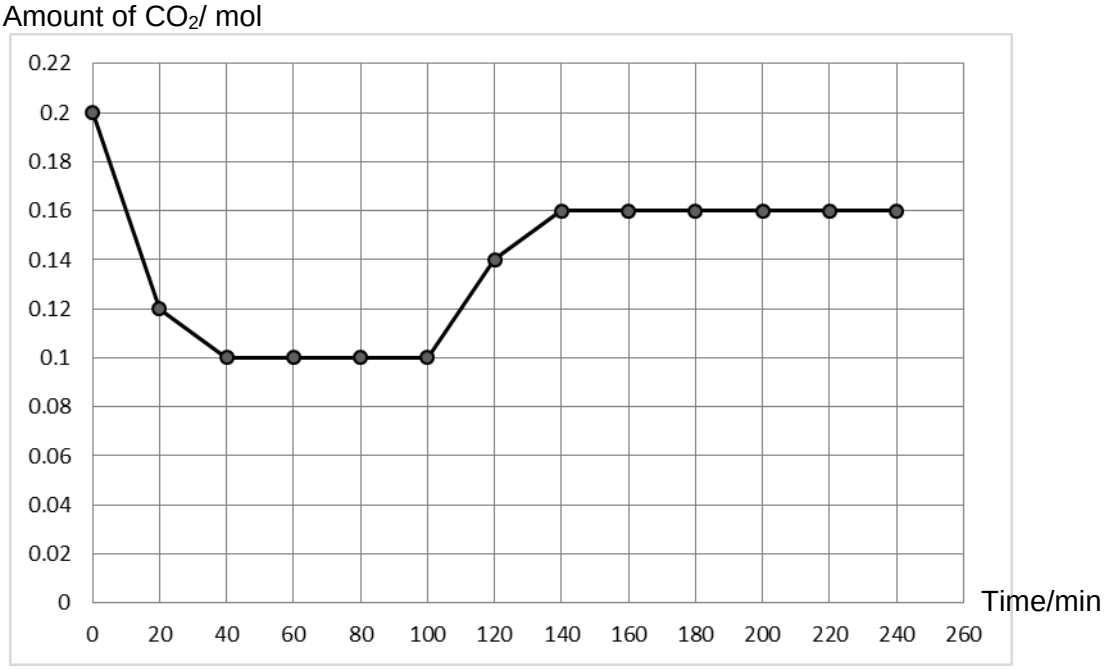
[Total: 7]

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.

$$CO_2(g) + 4H_2(g) = CH_4(g) + 2H_2O(g)$$

(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 ^oC.

……. [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.

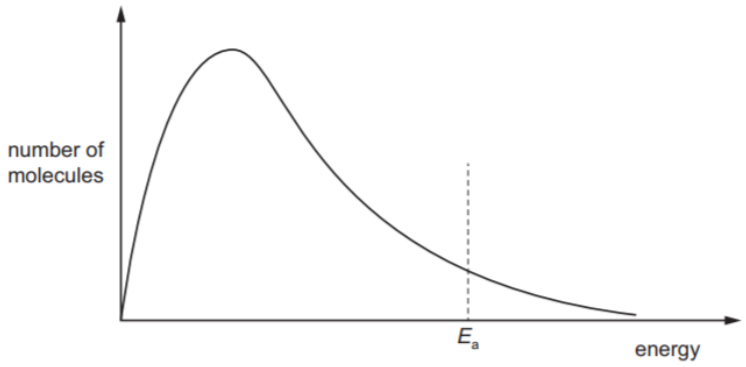
Research by NASA also shows that Ru is the most efficient catalyst for the Sabatier reaction.

(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 ^oC.



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]

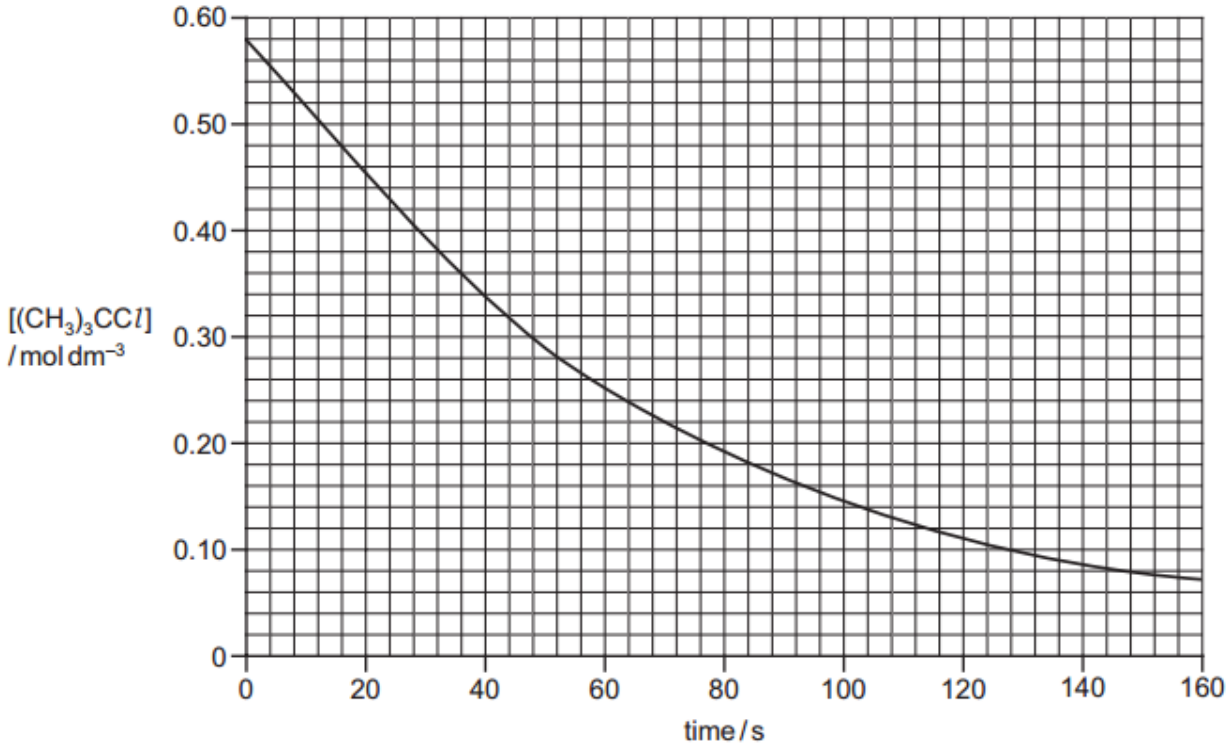
5. In aqueous solution, 2-chloro-2-methylpropane reacts with potassium hydroxide to form 2-methylpropan-2-ol.

(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.

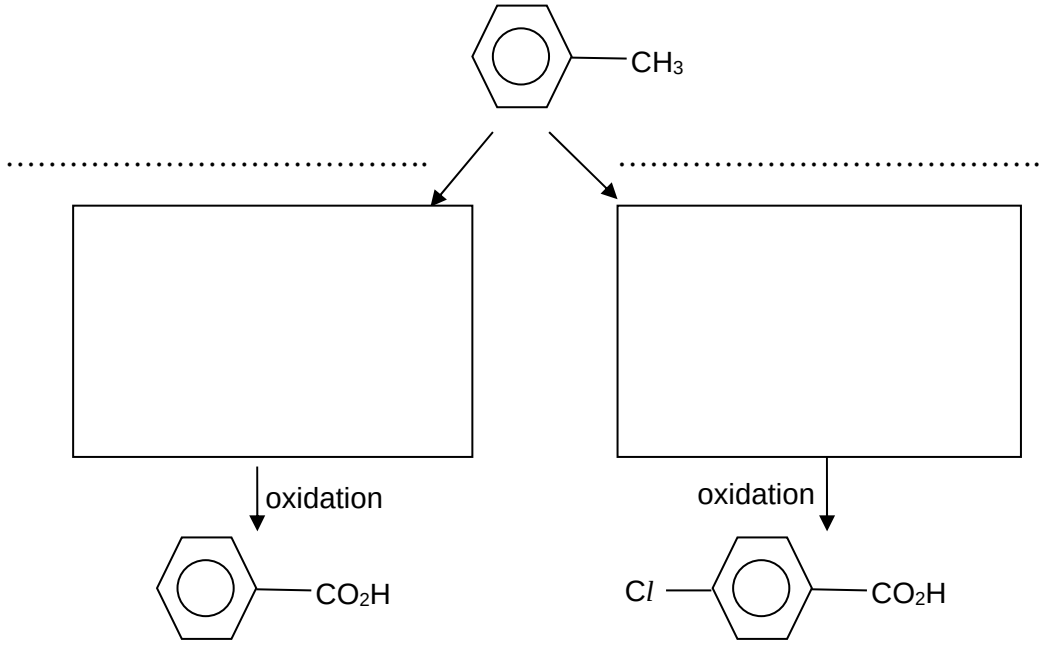
[2]

(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 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)(i)** to write the equation. [3]

(c) Li$Al$$H_4$ is a reducing agent commonly used in organic synthesis. It reacts vigorously with water to produce H_2, LiOH and an amphoteric hydroxide. Hence Li$Al$$H_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 Li$Al$$H_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 Li$Al$$H_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.

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

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

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

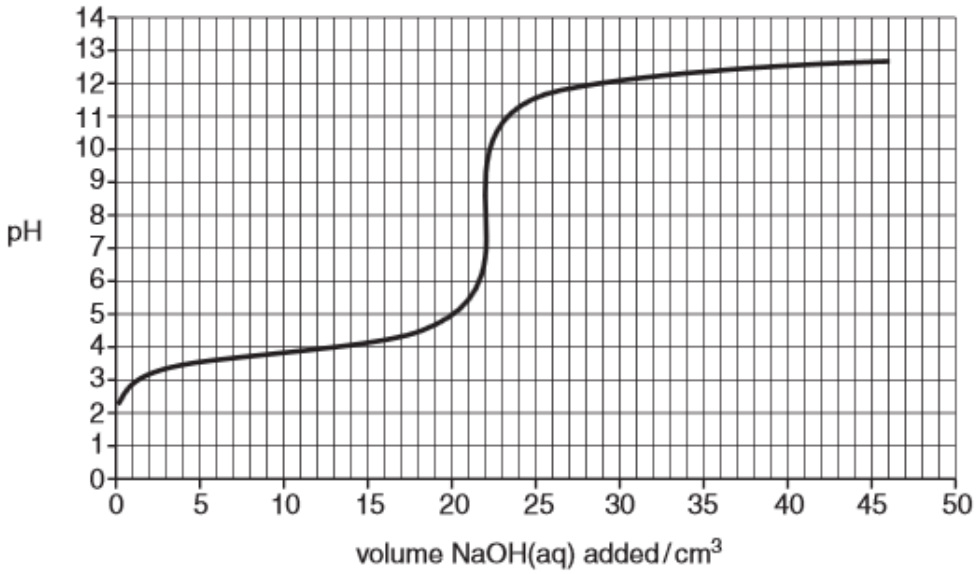
(iii) Given that **W** acts as a nucleophile in Step 2, draw the structural formula of the organic reactant required in Step 2. [1]

[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]

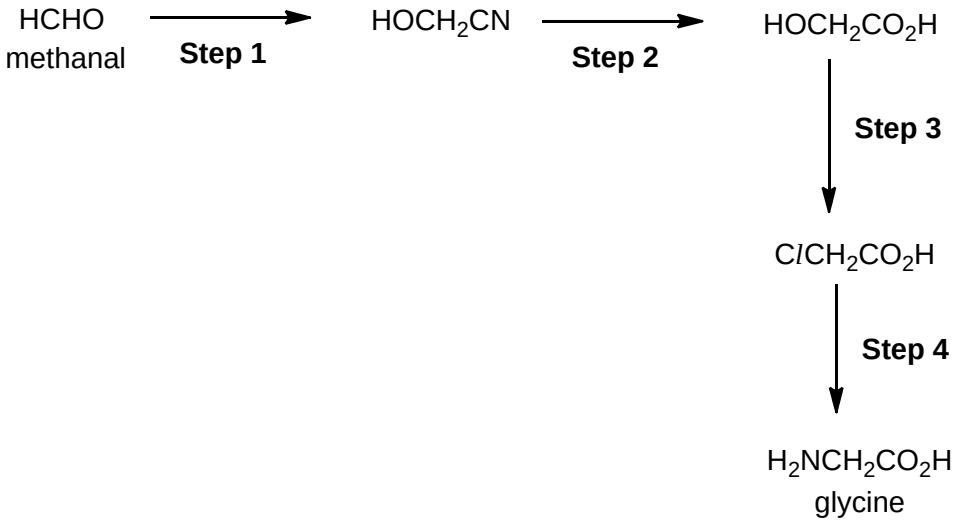
(iii) The pH in many living cells is 7.40.

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.



(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]