



**TEMASEK**  
JUNIOR COLLEGE

PRELIMINARY EXAMINATIONS

HIGHER 1

CANDIDATE  
NAME

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CIVICS  
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**CHEMISTRY**

**8872/02**

Paper 2

**11 September 2017**

**2 hours**

Candidates answer section **A** on the Question Paper.

Additional Materials:            Answer Paper

   Data Booklet

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**READ THESE INSTRUCTIONS FIRST**

Write your Civics Group, centre number, index number and name on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

**Section A**

Answer **all** questions.

**Section B**

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

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
<b>A1</b>	/ 15
<b>A2</b>	/ 13
<b>A3</b>	/ 12
<b>Section B</b>	/ 40
<b>Paper 1</b>	/ 30
<b>Total</b>	

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This document consists of **18** printed pages.

## Section A

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

1 This question is on the elements in period 3 of the Periodic Table.

- (a) Describe what you see when phosphorus and sulfur are separately burned in air or oxygen.

[2]

- For phosphorus, it burns with a white flame on heating in air or oxygen to form white phosphorus(V) oxide,  $P_4O_{10}$ .



- For sulfur, it burns slowly with a blue flame on heating in air or oxygen to form colourless sulfur dioxide,  $SO_2$ .



[Equations not necessary]

**Note : need to describe clearly what is observed.**

- (b) The oxides  $MgO$ ,  $Al_2O_3$  and  $SiO_2$  are all used as refractory materials due to their high melting points. The last two are major constituents of gemstones, such as rubies, sapphires and amethysts.

If a sample of one of the oxides was provided as a white powder, describe the reactions you could carry out on the powder to determine which of the three oxides it was. Write balanced equations where appropriate.

[3]

- Step 1

Add  $NaOH(aq)$  to the solid. If the solid dissolves, it is  $Al_2O_3$ , otherwise it is either  $MgO$  or  $SiO_2$



If solid does not dissolve in  $NaOH$ ,

- Step 2

Add  $HCl(aq)$  to the solid. If the solid dissolves, it is  $MgO$  otherwise it is  $SiO_2$ .

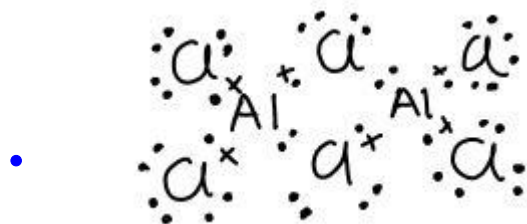


2 equations : 1m

**Note :  $MgO$  is basic,  $Al_2O_3$  is amphoteric.  $SiO_2$  is acidic but can only react with conc.  $NaOH$ .**

- (c) When dry chlorine is passed over heated aluminium foil in a hard glass tube, a vapour is produced which condenses to a yellow-white solid in the cooler parts of the tube. At low temperatures the vapour has the empirical formula  $AlCl_3$  and a  $M_r$  of 267.

- (i) Suggest the molecular formula of the vapour, and draw a dot-and-cross diagram to describe its bonding.



[2]

**Note : Do not draw arrows to show dative bonds for dot-cross diagram. Non-bonding valence electrons must be shown for all atoms.**

- (ii) When a large amount of water is added to the yellow-white solid, a clear, weakly acidic solution results.

Write equations to explain the observation.



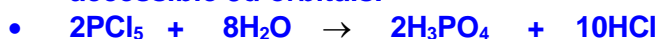
[2]



Chlorine also reacts with phosphorus under suitable condition to give phosphorus pentachloride.

- (iii) When phosphorus pentachloride is added to water, the resulting solution has a pH of 1. Explain with the aid of an equation. [2]

• **It undergoes hydrolysis with water because it has energetically accessible 3d orbitals.**



Silver chloride is an important photosensitive inorganic material widely used in photographic applications. It is industrially produced by mixing solutions of silver nitrate and sodium chloride.



- (d) (i) Use the data in the table to calculate x, the standard enthalpy change of formation of  $\text{Ag}^+(\text{aq})$ .

Species	$\Delta H_f^\circ$
$\text{Ag}^+(\text{aq})$	x
$\text{Cl}^-(\text{aq})$	-167
$\text{AgCl}(\text{s})$	-127

[2]

$$\Delta H_r^\circ = \sum n\Delta H_f^\circ(\text{products}) - \sum n\Delta H_f^\circ(\text{reactants})$$

$$\bullet -65.7 = -127 - (x + (-167))$$

$$x = \bullet + 106 \text{ kJ mol}^{-1}$$

**Note : Must indicate sign for endothermic enthalpy change.**

- (ii) Suggest whether a lower or higher temperature should be used to increase the yield of silver chloride. Explain your answer. [2]

- A lower temperature should be used.
- By Le Chatelier's Principle, the system will favour the forward exothermic reaction when temperature is lowered. Hence, the position of equilibrium shifts to the right increasing the yield of silver chloride.

**Note :  $[\text{AgCl(s)}]$  is always a constant but yield increases when position of equilibrium shifts right.**

[Total: 15]

- 2 (a) In 1887, a Swedish scientist Svante Arrhenius postulated that acids and bases dissociate in water to form hydrogen ions,  $\text{H}^+$ , and hydroxide ions,  $\text{OH}^-$ , respectively.

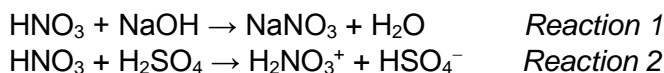
- (i) Suggest a limitation of the Arrhenius concept of acids and bases. [1]

**Accept any of the answers below**

- It applies only to aqueous solutions.
- It does not adequately explain why such compounds as ammonia are bases.
- The hydrogen ion,  $\text{H}^+$ , exists as hydronium ion,  $\text{H}_3\text{O}^+$ , in water.

A theory proposed by Danish chemist J.N. Brønsted and British chemist T.M. Lowry overcame the shortcomings of the Arrhenius theory.

- (ii) Using the Brønsted–Lowry model, explain the roles of nitric acid in the two reactions below. [2]



- In reaction 1,  $\text{HNO}_3$  is acting as an acid as it donated a proton,  $\text{H}^+$ , to  $\text{OH}^-$ .
- In reaction 2,  $\text{HNO}_3$  is acting as a base as it accepted a proton,  $\text{H}^+$ , from  $\text{H}_2\text{SO}_4$ .

- (b) Propanoic acid inhibits the growth of mold and some bacteria. Most propanoic acid produced is consumed as a preservative for both animal feed and food for human consumption.

The  $K_a$  values of propanol, propanoic acid and malonic acid are given below.

Compound	Formula	$K_{a1}$	$K_{a2}$
Propanol	$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$	$7.94 \times 10^{-17}$	—
Propanoic acid	$\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$	$1.35 \times 10^{-5}$	—
Malonic acid	$\text{HO}_2\text{CCH}_2\text{CO}_2\text{H}$	$1.41 \times 10^{-3}$	$2.00 \times 10^{-6}$

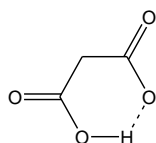
Suggest reason(s) why

(i)  $K_a$  of propanoic acid is higher than that of propanol. [2]

- Delocalisation of negative charge over two oxygen atoms in  $\text{CH}_3\text{CH}_2\text{CO}_2^-$  results in a more stable anion while the negative charge is localised on the O atom in  $\text{CH}_3\text{CH}_2\text{CH}_2\text{O}^-$ .
- The electron-releasing  $-\text{CH}_2\text{CH}_2\text{CH}_3$  group intensifies the negative charge on the O atom, thus destabilising the  $\text{CH}_3\text{CH}_2\text{CH}_2\text{O}^-$  anion.

(ii)  $K_{a1}$  of malonic acid is higher than  $K_a$  of propanoic acid. [1]

- This is due to the stabilisation of the monoanion by hydrogen bonding with the unionised  $-\text{CO}_2\text{H}$  group in malonic acid.



or

- The electron withdrawing  $-\text{CO}_2\text{H}$  group in  $\text{HOOC}-\text{CH}_2-\text{CO}_2^-$  helps to disperse the negative charge on oxygen, stabilising the anion.

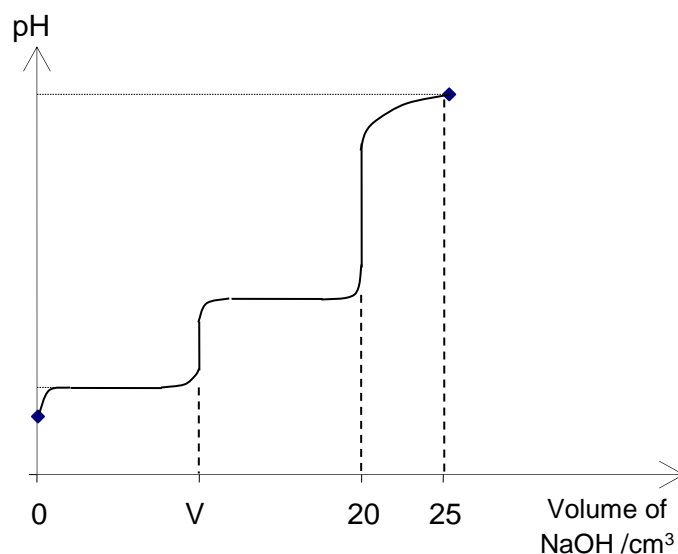
(iii)  $K_{a1}$  of malonic acid is higher than  $K_{a2}$  of malonic acid. [1]

- The stabilising hydrogen bonding in the monoanion of malonic acid would be destroyed by the ionisation of the second  $-\text{CO}_2\text{H}$  group.

or

- The removal of an  $\text{H}^+$  from  $\text{HO}_2\text{CCH}_2\text{CO}_2^-$  that already carries a negative charge would be electrostatically unfavourable.

(c)  $25\text{ cm}^3$  of  $0.10\text{ mol dm}^{-3}$  of NaOH is gradually added to  $10\text{ cm}^3$  of  $0.10\text{ mol dm}^{-3}$  malonic acid.



(i) State the value for V. [1]

- $V = 10\text{ cm}^3$

- (ii) Calculate the pH of the mixture when 25 cm<sup>3</sup> of NaOH has been added. [2]

Volume of excess NaOH added = 25 - 20 = 5 cm<sup>3</sup>

• No. of moles of excess NaOH =  $\frac{5}{1000} \times 0.10 = 5.00 \times 10^{-4}$  mol

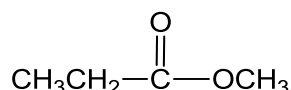
Total volume of solution = 10 + 25 = 35 cm<sup>3</sup>

$[\text{OH}^-] = \frac{5.00 \times 10^{-4}}{\frac{35}{1000}} = 0.0143 \text{ mol dm}^{-3}$

pOH = -log [OH<sup>-</sup>] = 1.85

• pH = 14 - pOH = 12.2

- (d) Compound **A** can be directly synthesised from propanoic acid.

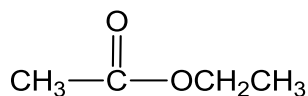


Compound **A**

- (i) Suggest reagents and conditions to form compound **A** from propanoic acid. [1]

- **CH<sub>3</sub>OH, conc H<sub>2</sub>SO<sub>4</sub>, heat**

Compound **B** is an isomer of compound **A**.



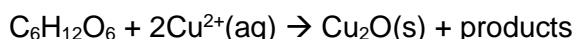
Compound **B**

- (ii) Suggest methods by which compounds **A** and **B** could be distinguished from each other by chemical tests. [2]

- **Heat each compound with aqueous sodium hydroxide. Add aqueous alkaline iodine with warming to the reaction products.**
  - **Yellow precipitate of CHI<sub>3</sub> is observed for hydrolysed products of compound B but not A.**
- or**
- **Heat each compound with aqueous sodium hydroxide, followed by heating the reaction products with acidified KMnO<sub>4</sub>.**
  - **CO<sub>2</sub> observed for hydrolysed product (CH<sub>3</sub>OH) of compound A but not B.**

[Total: 13]

- 3 (a) Glucose is a reducing sugar and can be identified using Benedict's reagent or Fehling's solution as shown by the following equation.



A 5.00 g sample of food was treated with an excess copper(II) ions and 0.286 g of copper(I) oxide precipitated was collected.

Calculate the percentage of glucose in the food sample assuming that all the sugar present in the food is in the form of glucose.

[2]

**Number of moles of  $\text{Cu}_2\text{O}$  =  $0.286 / ((2 \times 63.5) + 16) = 0.286 / 143 = 0.002 \text{ mol}$**

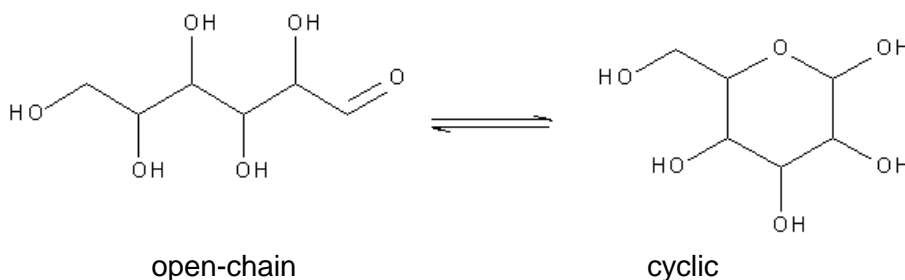
**• Number of moles of glucose = 0.002 mol**

**$M_r$  of glucose =  $6(12) + 12(1) + 6(16) = 180$**

**Mass of glucose =  $180 \times 0.002 = 0.360 \text{ g}$**

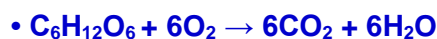
**• Percentage of glucose =  $0.360 / 5 \times 100\% = 7.20\%$**

- (b) Most of the energy our bodies need comes from carbohydrates and fat. Starch is broken down into glucose,  $\text{C}_6\text{H}_{12}\text{O}_6$ . Glucose exist mainly in cyclic forms with a small percentage in open chains.



Glucose is transported to the cells to react with oxygen via a series of steps to form carbon dioxide, water and energy.

- (i) Write a balanced equation for the reaction of glucose with oxygen. [1]



- (ii) Using data from the Data Booklet, calculate the amount of energy released per mole of glucose using the cyclic structure. [2]

**Using the cyclic structure of glucose,**

**Bond-breaking**

**5 x C – C**

**5 x O – H**

**7 x C – H**

**7 x C – O**

**6 x O = O**

**Bond-Forming**

**12 x C = O**

**12 x O – H**

**• Energy released**

**=  $+(5 \times 350 + 5 \times 460 + 7 \times 410 + 7 \times 360 + 6 \times 496) - (12 \times 740 + 12 \times 460)$**

**= - 1980 kJ mol<sup>-1</sup>**

**Note: O=O and C-H bonds often missed out.**

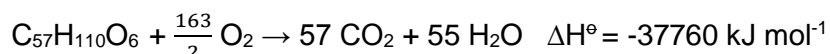
- (iii) The literature value for the amount of energy released per mole of glucose is – 2800 kJ.

Apart from bond energies being average values, suggest another reason for the difference between this value and that calculated in (b)(ii).

[1]

• The  $\Delta H$  calculated using bond energies applies for the reactants and products in the gaseous phase but the reaction involves solid glucose and liquid  $H_2O$  rather than gaseous  $H_2O$ .

Like carbohydrates, fats are metabolised into carbon dioxide and water and when subjected to combustion in a bomb calorimeter. The reaction of tristearin,  $C_{57}H_{110}O_6$ , a typical fat is as follows:



The fuel value is the energy when one gram of the material undergoes combustion. The table below shows the fuel value of carbohydrates and protein and the food label of a cup noodle:

	Fuel Value / kJ g <sup>-1</sup>
Carbohydrate	17
Fat (Tristearin)	To be calculated
Protein	17



Nutrition Facts	
Serving Size 1 container (70g)	
Amount Per Serving	
Calories 310	Calories from Fat 100
% Daily Value*	
Total Fat 12g	18%
Saturated Fat	25%
Trans Fat	
Cholesterol 0mg	0%
Sodium 1010mg	42%
Total Carbohydrate 44g	15%
Dietary Fiber 4g	16%
Sugars 4g	
Protein 8g	

- (iv) Determine the fuel value of tristearin. ( $M_r$  of tristearin = 890)

No. of moles of tristearin in 1 g =  $1/890 = 1.12 \times 10^{-3} \text{ mol}$

• Fuel value of tristearin =  $1.12 \times 10^{-3} \times 37760 = 42.4 \text{ kJ/g}$

Hence deduce if tristearin or carbohydrate is a better source of energy.

[2]

• Since more energy is produced per gram, tristearin is a better source of energy than carbohydrate.



- (v) During reading or watching television, the average adult uses about 7 kJ/min. By considering only the total fat, carbohydrate and protein content, calculate the duration in minutes of such activity that can be sustained by one serving of cup noodle.

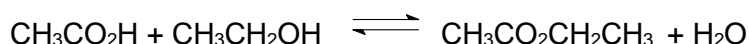
[1]

**Total energy provided by cup noodle =  $12 \times 42.4 + 44 \times 17 + 8 \times 17 = 1390$  kJ**

**• No. of minutes that can be sustained by energy =  $1390/7 = 199$  min**

- (c) In the body, glucose is also converted to energy via alcoholic fermentation. This process has been used in making beer and the side products such as esters contribute greatly to the taste and aroma of the beer.

Ethyl acetate can be formed as follows



1.51 mol of  $\text{CH}_3\text{CO}_2\text{H}$  and 1.66 mol of  $\text{CH}_3\text{CH}_2\text{OH}$  was allowed to reach equilibrium in a  $100 \text{ cm}^3$  solution.  $10 \text{ cm}^3$  of the equilibrium mixture was extracted and large amounts of cold water was added to quench the reaction. The mixture was then titrated with  $22.40 \text{ cm}^3$  of  $2 \text{ mol dm}^{-3}$  NaOH.

Calculate the  $K_c$  for the formation of ethyl acetate.

[3]

**$\text{NaOH} \equiv \text{CH}_3\text{CO}_2\text{H}$**

**No. of moles of  $\text{CH}_3\text{CO}_2\text{H}$  in  $10 \text{ cm}^3 = (22.40/1000) \times 2 = 0.0448$  mol**

**• No. of moles of  $\text{CH}_3\text{CO}_2\text{H}$  in  $100 \text{ cm}^3 = 0.0448 \times 10 = 0.448$  mol**

•	$\text{CH}_3\text{CO}_2\text{H} + \text{CH}_3\text{CH}_2\text{OH} \rightleftharpoons \text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3 + \text{H}_2\text{O}$			
Initial amount/mol	1.51	1.66	0	0
Change in amount/mol	-1.06	-1.06	+1.06	+1.06
Eqm amount/mol	0.448	0.600	1.06	1.06

$$\bullet K_c = \frac{[\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3][\text{H}_2\text{O}]}{[\text{CH}_3\text{CO}_2\text{H}][\text{CH}_3\text{CH}_2\text{OH}]} = \frac{\left(\frac{1.06}{0.1}\right)\left(\frac{1.06}{0.1}\right)}{\left(\frac{0.448}{0.1}\right)\left(\frac{0.6}{0.1}\right)} = 4.18$$

[Total: 12]

## Section B

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

- 4 (a) (i) Define the term *empirical formula*.

[1]

**Empirical formula is the simplest formula that shows the relative number of atoms of each element in the compound.**

- (ii) Hydrocarbon **P** with  $M_r = 70$  contains 85.7% by mass of carbon. Determine the empirical formula and hence the molecular formula of **P**.  
[2]

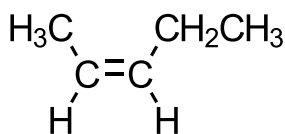
	C	H
Mole ratio	85.7/12	14.3/1
	7.14	14.3
Simplest ratio	1	2

- Empirical formula :  $\text{CH}_2$

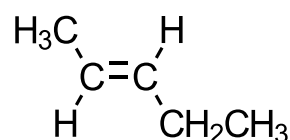
$$\begin{aligned} (\text{CH}_2)_n &= 70 \\ 14n &= 70 \\ n &= 5 \end{aligned}$$

- Molecular formula :  $\text{C}_5\text{H}_{10}$

- (iii) Hydrocarbon **P** exhibits stereoisomerism. Draw and label the stereoisomers of **P**.  
[2]

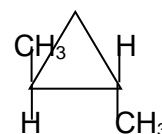
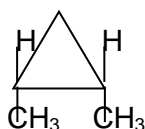


cis



trans

or



- (b) Organic compound **Q**, with molecular formula  $\text{C}_6\text{H}_8\text{O}_4$ , can be found in most leather products and is used as a mould inhibitor.

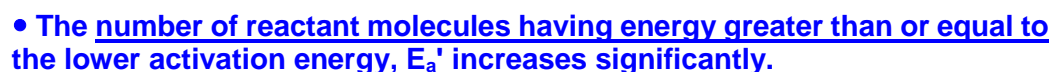
**Q** decolourises aqueous bromine. On heating one mole of **Q** with dilute acid, two organic products **R**,  $\text{C}_4\text{H}_4\text{O}_4$ , and methanol are obtained. Vigorous effervescence was observed when **R** reacted completely with sodium carbonate in equimolar proportions.

**[Turn over**

- [6]

- (i) Explain what is meant by *rate of reaction*. [1]

(ii) Explain with the aid of a Boltzmann distribution curve, how a catalyst speeds up the rate of the reaction. [3]



Hence the frequency of effective collisions increases and the rate increases.

- (d) A kinetics study was conducted on the reaction of  $\text{S}_2\text{O}_8^{2-}$  and  $\text{I}^-$  to determine the rate equation. Varying volumes of  $\text{S}_2\text{O}_8^{2-}$  and  $\text{I}^-$  were added to a mixture containing sodium thiosulfate and starch indicator, followed by topping up with suitable volume of water.

As the reaction of  $\text{S}_2\text{O}_8^{2-}$  and  $\text{I}^-$  proceeds, the iodine produced will be consumed by the  $\text{Na}_2\text{S}_2\text{O}_3$ . When all  $\text{Na}_2\text{S}_2\text{O}_3$  has reacted, the remaining iodine will react with the starch indicator, forming a blue-black complex. The rate of reaction is determined by the time taken for the blue-black colouration to appear.

Experiment	Volume of KI / $\text{cm}^3$	Volume of $\text{Na}_2\text{S}_2\text{O}_8$ / $\text{cm}^3$	Volume of $\text{Na}_2\text{S}_2\text{O}_3$ / $\text{cm}^3$	Volume of water / $\text{cm}^3$	Time for blue-black colour / s	rate $\propto 1/t$
1	10	20	10	10	50	0.02
2	5	20	10	15	100	0.01
3	30	10	10	0	33	0.03
4	20	40	20	20	x	

- (i) Determine the order of reaction with respect to iodide and peroxodisulfate. [2]

For expt 1 to 3, total volume is kept constant, so volume of reactant  $\propto$  concentration.

Since thiosulfate is the limiting reagent and volume is constant, relative rate  $\propto 1/t$ , so relative rates for expt 1, 2 and 3 are 0.02, 0.01 and 0.03.

• Comparing expt 1 and 2, when conc of KI decreases by 2 times, rate decreases by 2 times  $\rightarrow$  1<sup>st</sup> order with respect to  $\text{I}^-$ .

• Comparing expt 1 and 3,

$$\text{Rate}_{\text{expt1}} = k[\text{KI}][\text{S}_2\text{O}_8^{2-}]^n$$

$$\text{Rate}_{\text{expt3}} = k[\text{KI}][\text{S}_2\text{O}_8^{2-}]^n$$

$$\frac{0.02}{0.03} = \frac{k[10][20]^n}{k[30][10]^n}$$

$$\frac{0.02}{0.03} = \frac{10 \times 20^n}{30 \times 10^n}$$

Solving,  $n = 1$

- (ii) Hence, construct a rate equation for the above reaction, and determine the units of the rate constant. [2]

• Rate =  $k[\text{I}^-][\text{S}_2\text{O}_8^{2-}]$

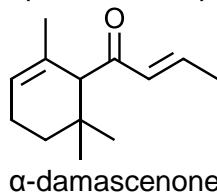
• Units of k is  $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$

- (iii) Deduce the time taken, x, for the blue-black colouration to appear for experiment 4. [1]

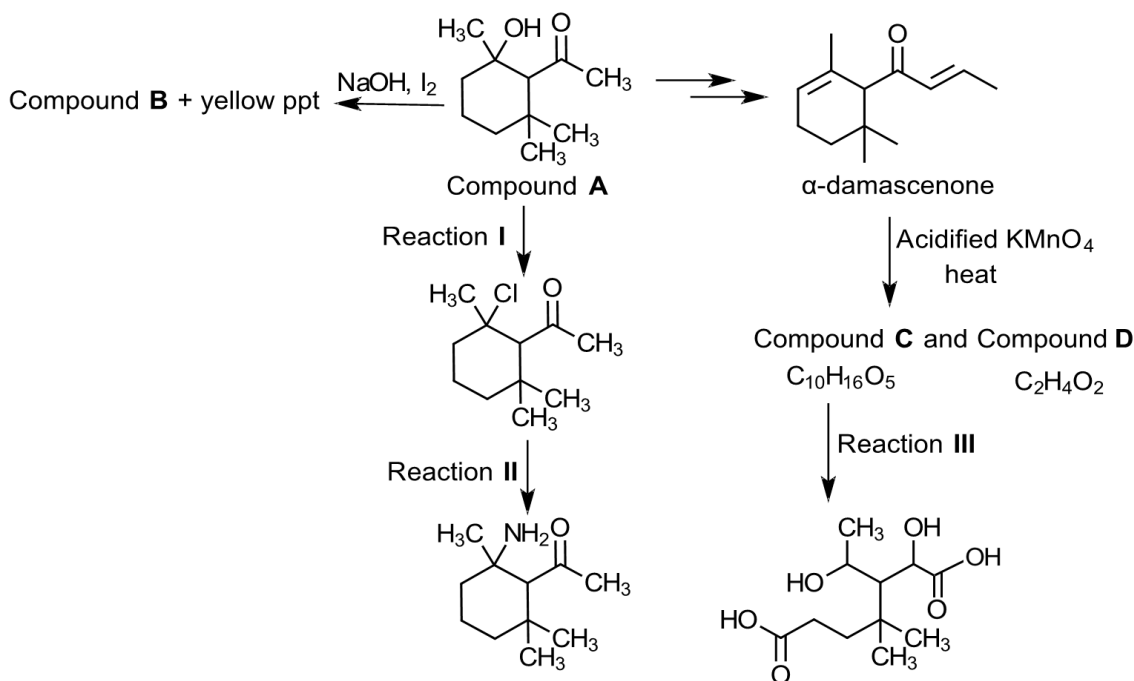
Since volume of all reactants double and total volume of mixture doubles, concentration of KI, Na<sub>2</sub>S<sub>2</sub>O<sub>8</sub> and Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> remain the same. Rate of reaction remains constant, so  $x = 50$  s.

[Total: 20]

- 5 In the synthesis of damascenones, which are active ingredients in the characteristic smell of Bulgarian rose oil, it was found that compound B is a possible pre-cursor.



Compound A and  $\alpha$ -damascenone can undergo a series of chemical reactions as shown in the flow chart below:



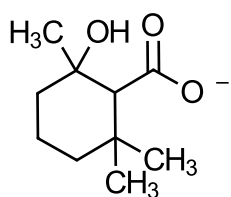
- (a) (i) State the reagents and conditions for Reaction I, II and III.

[3]

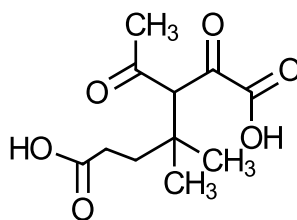
- Reaction I: PCl<sub>5</sub> (s), room temp
- Reaction II: Excess concentrated NH<sub>3</sub>, heat in a sealed tube
- Reaction III: NaBH<sub>4</sub>, alcohol as solvent, room temp

(ii) Draw the structural formulae of Compound B, C and D.

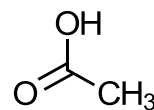
[3]



•Compound B



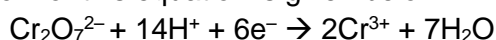
•Compound C



• Compound D

(b) Methanol reacts with acidified potassium dichromate(VI) to form methanoic acid.

Relevant half-equation for this equation is given below:



(i) Explain in terms of the change in oxidation number, why potassium dichromate(VI) is an oxidising agent in the reaction with methanol.

[2]

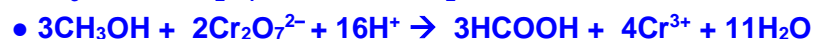
- $\text{Cr}_2\text{O}_7^{2-}$  acts as an oxidising agent because it oxidises methanol and the oxidation number of C increases from -2 in  $\text{CH}_3\text{OH}$  to +2 in  $\text{HCOOH}$ , and
- itself is being reduced as oxidation number of Cr decreases from +6 in  $\text{Cr}_2\text{O}_7^{2-}$  to +3 in  $\text{Cr}^{3+}$ .

(ii) Write the half-equation for the oxidation reaction of methanol to methanoic acid, and using the half-equation given above, construct an ionic equation for the reaction between  $\text{Cr}_2\text{O}_7^{2-}$  and  $\text{CH}_3\text{OH}$  in acid solution.

[2]

- Oxidation:  $\text{CH}_3\text{OH} + \text{H}_2\text{O} \rightarrow \text{HCOOH} + 4\text{H}^+ + 4\text{e}^-$

Overall:



(c) (i) Define second ionisation energy of aluminium. [1]

- 2<sup>nd</sup> IE of aluminium is the minimum amount of energy to completely remove 1 mole of valence electrons from 1 mole of ground state gaseous  $\text{Al}^+$  ions to form 1 mole of gaseous  $\text{Al}^{2+}$  ions.

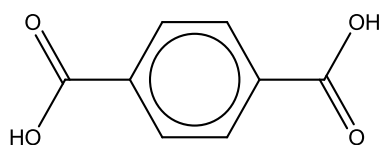
(ii) Explain why the second ionisation energy of aluminium is greater than that of silicon. [1]



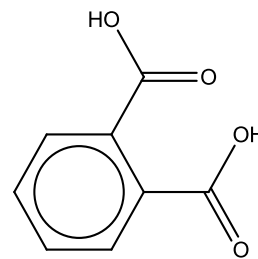
Si has a higher nuclear charge than Al. However, • 2<sup>nd</sup> IE of Al involves the removal of 3s electron which is more strongly attracted and closer to the

nucleus than the removal of 3p electron for Si. Hence, more energy is needed to remove the 3s electron.

- (d) Terephthalic acid (TPA) and phthalic acid (PA) both have the molecular formula  $C_6H_4(COOH)_2$ . While TPA is used principally to make clothing and plastic bottles, PA has limited commercial application. The structures of TPA and PA are shown below.



TPA

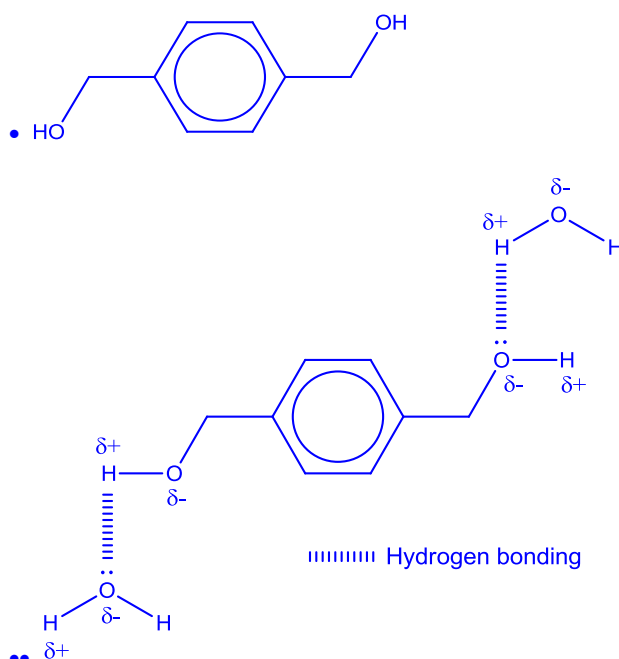


PA

- (i) TPA and PA melts at 300 °C and 207 °C, respectively. With reference to intermolecular interactions, explain why TPA has a higher melting point than PA. [2]

- Due to the close proximity of the 2 -COOH groups in PA, intramolecular hydrogen bonding occurs. This reduces the extent of intermolecular hydrogen bonding between PA molecules.
- In TPA, the 2 -COOH groups are further away hence only intermolecular hydrogen bonding occurs. Thus, more heat energy is needed to overcome the more extensive hydrogen bonding.

- (ii) TPA can be reduced to a diol for the synthesis of a renewable polymer. Draw the structure of this diol and illustrate with a diagram, its interaction with water. [3]



- (iii) Hence, explain why the diol in (d)(ii) is soluble in water. [1]

• Formation of hydrogen bonds between the diol and water releases sufficient energy to overcome the hydrogen bonding between diol molecules and hydrogen bonding between water molecules.

- (e) In selecting a suitable material for the manufacture of bulletproof armour, it is necessary to ensure that the material does not shatter upon high impact force from a bullet. With reference to the structures of gold and fluorite,  $\text{CaF}_2$ , explain why gold is more suitable for the lining of bulletproof armour. [2]

• When hit with a high impact force, the layers of close-packed gold atoms can slide over one another without breaking the non-directional metallic bonds.

However, for an ionic compound  $\text{CaF}_2$ , a • high impact force would cause layers of ions to shift and causes ions to same charge to slide next to each other, forcing the layers to come apart and shatter.

[Total: 20]

- 6 High octane fuels that are free from lead additives often contain aromatic hydrocarbons such as benzene, which can be obtained from hexane by the process of “reforming”.



- (a) (i) Suggest reasons for the following statements

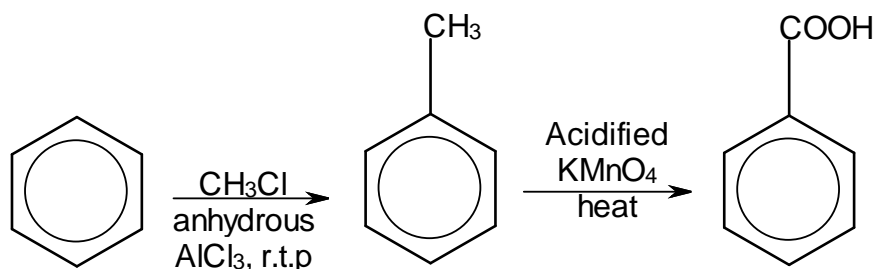
- Alkane is generally unreactive.
- Benzene undergoes substitution reaction rather than addition reaction. [3]

• Alkanes are saturated and contain only C–H and C–C bonds, which are relatively strong and difficult to break.

• In addition, alkane molecules are non-polar due to similar electronegativity of carbon and hydrogen atoms.

• Due to the extra stability of having a  $\pi$  electrons delocalised system, benzene undergoes substitution rather than addition reactions

- (ii) State the reagents and conditions required for the formation of benzoic acid from benzene. [2]



- 1m for formation of methylbenzene with correct reagent and condition.
- 1m for formation of benzoic acid with correct reagent and condition.



- (b) Chlorine-37 is an isotope of chlorine.  
Benzene can react with the electrophile  $^{37}\text{Cl}^+$  to form dichlorobenzene

(i) Define the term *isotope*.

- Atoms of the same element having same number of protons but different number of neutrons [1]

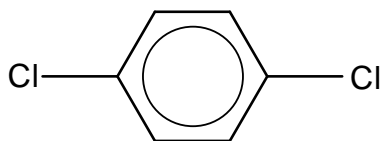
(ii) Write the electronic configuration for  $^{37}\text{Cl}^+$ . [1]

- $1s^2 2s^2 2p^6 3s^2 3p^5$

(iii) State the number, charge and location of the sub-atomic particles in  $^{37}\text{Cl}^+$ . [3]

- 17 positively charged protons and
- 20 neutrons (no charge) in the nucleus
- 16 negatively charged electrons surrounding the nucleus

(iv) Draw the non-polar isomer of dichlorobenzene. [1]



- (d) Hexane and benzene undergoes combustion to form carbon dioxide.

(i) For each of the three compounds, hexane, benzene and carbon dioxide, state

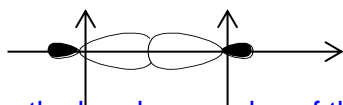
- Hybridization state and
- Shape and bond angle about carbon.

[3]

	Hexane	Benzene	Carbon dioxide
• Hybridisation	$sp^3$	$sp^2$	$sp$
• Bond angle	$109.5^\circ$	$120^\circ$	$180^\circ$
• Shape	Tetrahedral	Trigonal planar	Linear

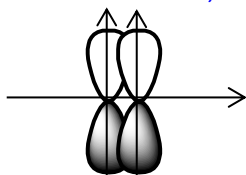
(ii) Describe the bonding that occurs in hexane and carbon dioxide in terms of the overlap of the orbitals. Draw diagrams to illustrate your answer. [3]

- In hexane, the type of covalent bond formed is  $\sigma$ -bond. It is formed by the head-on overlap of  $sp^3$  orbitals to form C-C  $\sigma$ -bond.



[or the head on overlap of the C-H bond represented by overlap of  $sp^3$  orbital with s orbital of H]

- In  $\text{CO}_2$ , the types of covalent bonds formed are  $\sigma$ -bond and  $\pi$ -bond. A  $\pi$ -bond is formed by the sideways overlap of p orbitals. (This occurs only after a  $\sigma$ -bond is formed)



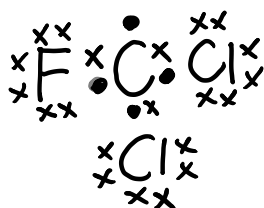
- 1m for diagrams

(e) In the stratosphere, chlorofluorocarbons (CFC) such as  $\text{CCl}_3\text{F}$  can form radicals such as  $\bullet\text{CCl}_2\text{F}$ , which deplete the ozone layer.

(i) Explain what is meant by the term *radical*. [1]

- A radical is a species that contain an odd number of electrons and has a single unpaired electron in one of its orbital.

(ii) Draw the dot-and-cross diagram of the  $\bullet\text{CCl}_2\text{F}$  free radical. [1]



(iii) Hydrofluorocarbons (HFC) such as  $\text{CH}_2\text{FCF}_3$ , does not deplete the ozone layer compared to CFCs. Suggest why this is so. [1]

- Hydrofluorocarbons are inert. This is because C-F and C-H bonds are very strong and are unlikely to cleave to form free radicals hence they do not deplete the ozone layer.

[Total: 20]