

**SRJC Prelim Exam 2014 H1 Chemistry Paper 2**

**Section A.**

Answer **ALL** questions

- 1 (a)** The greenhouse effect is an energy-trapping process in which the infra-red radiation reflected from the Earth's surface is absorbed by greenhouse gases (primarily CO<sub>2</sub> and H<sub>2</sub>O) and re-radiated back towards Earth. This is a natural phenomenon which helps to keep the earth comfortably warm.

The increase in the amount of CO<sub>2</sub> in the atmosphere has been largely attributed to an increase in human consumption of energy. The global power consumption was estimated to be  $7 \times 10^{11}$  W (watts) in 1900.

In 2004, with a global population about  $6 \times 10^9$ , the global power consumption has risen to  $15 \times 10^{12}$  W with 86% of the power supplied by burning fossil fuel such as coal, oil and natural gases.

The global carbon dioxide emission from consumption of coal is 10590 million tonnes in 2004. The global population is expected to hit  $9 \times 10^9$  in 2050.  
(1 tonne = 1000 kg)

Concerns over the effects of global warming have led to various actions by government bodies and individuals to avert what is perceived as a potential global disaster. Such actions include bills to reduce industrial emissions of CO<sub>2</sub>, worldwide concerts spreading the message on global warming and products designed to reduce electrical consumptions.

An example is the use of compact florescent light (CFL) in place of the incandescent light bulb. The CFL consumes only  $3.2 \times 10^{-2}$  kW of power per hour as compared to the  $1.5 \times 10^{-1}$  kW which the incandescent light bulbs consume. This not only translates to savings for the user, more importantly, it helps to reduce electrical consumption and CO<sub>2</sub> emissions.

- (i)** Use the data above to find the average power consumption per person for the year 2004.

$$\text{Average power consumption per person} = \frac{15 \times 10^{12}}{6 \times 10^9} = 2500 \text{ W}$$

- (ii)** Estimate the mass of fossil fuel that has to be burnt to meet a person's power consumption in the year 2004, assuming that burning 300 kg of fossil fuel is enough to generate 1000 W of power.

$$\begin{aligned} \text{Amount of power generated by burning fossil fuel} &= 2500 \times 0.86 = 2150 \text{ W} \\ \text{Mass of fossil fuel needed} &= \frac{2150}{1000} \times 300 = 645 \text{ kg} \end{aligned}$$

- (iii) Calculate the average carbon dioxide emission per person in 2004.

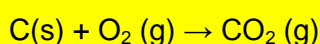
Assuming that the average carbon dioxide emission per person remains unchanged, hence, estimate the total coal consumption (in kilograms) for the year 2050.

(Assume coal is 100% carbon.)

Average CO<sub>2</sub> emission in 2004

$$= \frac{10590 \times 10^6 \times 10^3 \times 10^3}{6 \times 10^9} = 1.77 \times 10^6 \text{ g per person}$$

$$\text{Amount of CO}_2 = \frac{1.77 \times 10^6}{44.0} = 4.01 \times 10^5 \text{ mol}$$



$$\text{Amount of carbon} = 4.01 \times 10^5 \text{ mol}$$

$$\text{Estimated coal consumption in 2050} = 4.01 \times 10^5 \times 12.0 \times 9 \times 10^9 = 4.33 \times 10^{12} \text{ kg}$$

- (iv) Based on an average usage of 6 hours per day, determine how much you can save each day if you use a CFL instead of an incandescent light bulb.  
(PUB charges \$0.188 per kW per hour)

[6]

$$\text{Savings each day} = (1.5 \times 10^{-1} - 3.2 \times 10^{-2}) \times 6 \times 0.188 = \$0.13$$

- (b) Propanoic acid is found in trace amount in diesel oil. The acid dissociation constant,  $K_a$ , for propanoic acid has the value of  $1.35 \times 10^{-5} \text{ mol dm}^{-3}$  at 25 °C.

$$K_a = \frac{[\text{H}^+][\text{CH}_3\text{CH}_2\text{CO}_2^-]}{[\text{CH}_3\text{CH}_2\text{CO}_2\text{H}]}$$

- (i) Given that  $[\text{H}^+] = [\text{CH}_3\text{CH}_2\text{CO}_2^-]$ , find the pH of a  $0.117 \text{ mol dm}^{-3}$  aqueous solution of propanoic acid.

$$K_a = \frac{[\text{H}^+]^2}{[\text{CH}_3\text{CH}_2\text{CO}_2\text{H}]} = 1.35 \times 10^{-5} \text{ mol dm}^{-3}$$

$$[\text{H}^+] = \sqrt{(1.35 \times 10^{-5})(0.117)} = 1.26 \times 10^{-3} \text{ mol dm}^{-3}$$

$$\text{pH} = -\lg(1.26 \times 10^{-3}) = 2.90$$

- (ii) Calculate the degree of ionisation of propanoic acid.

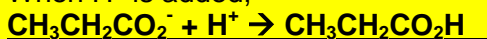
$$\text{Degree of ionisation} = \frac{1.26 \times 10^{-3}}{0.117} = 0.0107$$

- (iii) A buffer solution is formed by mixing propanoic acid and sodium propanoate.

Turn Over]

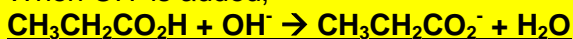
Explain, using suitable equations, how this buffer solution works to maintain fairly constant pH upon the addition of small amounts of  $\text{H}^+$  and  $\text{OH}^-$  separately.

When  $\text{H}^+$  is added,



$\text{H}^+$  is removed, hence pH is approximately constant.

When  $\text{OH}^-$  is added,



$\text{OH}^-$  is removed, hence pH is approximately constant.

- (iv) Two drops of an indicator was added to  $25 \text{ cm}^3$  of the above mentioned buffer solution. When excess  $\text{NaOH}(\text{aq})$  was added, the indicator changed colour.

Suggest a value for the end point pH and hence, a suitable indicator.

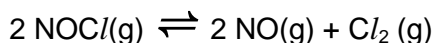
[6]

**Phenolphthalein**

**Any value between pH 8 to 10**

[Total: 12]

- 2 The decomposition of nitrosyl chloride,  $\text{NOCl}$  at  $227^\circ\text{C}$  is shown below:



- (a) (i) Write an expression for the equilibrium constant  $K_c$  for this reaction.

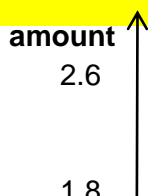
$$K_c = \frac{[\text{NO}]^2[\text{Cl}_2]}{[\text{NOCl}]^2}$$

- (ii) A 2.6 mol of  $\text{NOCl}$  was placed in a  $2 \text{ dm}^3$  reactor and heated to  $227^\circ\text{C}$  until the system reached equilibrium. It was found that 0.8 mol of  $\text{NO}$  was present at equilibrium. Calculate the  $K_c$  of the reaction.

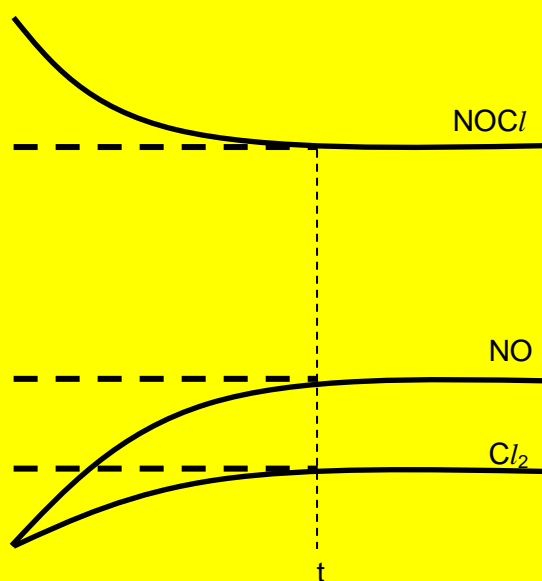
	$2 \text{NOCl}(\text{g}) \rightleftharpoons 2 \text{NO}(\text{g}) + \text{Cl}_2(\text{g})$		
Initial/ mol	2.6	0	0
change in amount / mol	-0.8	+0.8	+0.4
Final/ mol	1.8	0.8	0.4

$$K_c = \frac{\left[\frac{0.8}{2}\right]^2 \left[\frac{0.4}{2}\right]}{\left[\frac{1.8}{2}\right]^2} = 3.95 \times 10^{-2} \text{ mol dm}^{-3}$$

- (iii) Sketch and label, in the axes below, the amount of reactants and products from the start of the reaction to some time after equilibrium is established.

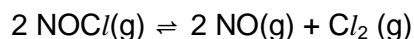


Turn Over]



[6]

- (b) When the temperature of the system at equilibrium was increased, the colour of the greenish yellow gas intensified.



Deduce if the enthalpy change of decomposition of NOCl is endothermic or exothermic. Explain your answer.

The enthalpy change of reaction is **endothermic**.

As temperature increases, the system **absorbs the excess heat**, favouring the endothermic reaction. Hence, the **position of equilibrium** shifts to the **right**, **increasing the concentration of Cl<sub>2</sub>**, causing the greenish yellow colour to be intensified.

[2]

[Total : 8]

- 3 3-bromopropene can be hydrolysed by aqueous sodium hydroxide to form alcohols.

Four sets of experiments were carried out to investigate the kinetics of this reaction:

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Experiment	$[\text{CH}_2=\text{CHCH}_2\text{Br}] / \text{mol dm}^{-3}$	$[\text{NaOH}] / \text{mol dm}^{-3}$	Relative initial rate
1	0.10	0.20	1.00
2	0.20	0.10	2.00
3	0.30	0.20	3.00
4	0.60	0.40	6.00

- (a) (i) Use the data in the table to deduce the order of reaction with respect to  $\text{CH}_2=\text{CHCH}_2\text{Br}$  and  $\text{NaOH}$ .

Let  $\text{rate} = k[\text{CH}_2=\text{CHCH}_2\text{Br}]^m[\text{NaOH}]^n$

Using results of experiments 1 and 3,

$$\frac{3.00}{1.00} = \frac{k(0.30)^m(0.20)^n}{k(0.10)^m(0.20)^n}$$

$$m = 1$$

Order of reaction with respect to  $\text{CH}_2=\text{CHCH}_2\text{Br} = \underline{1}$

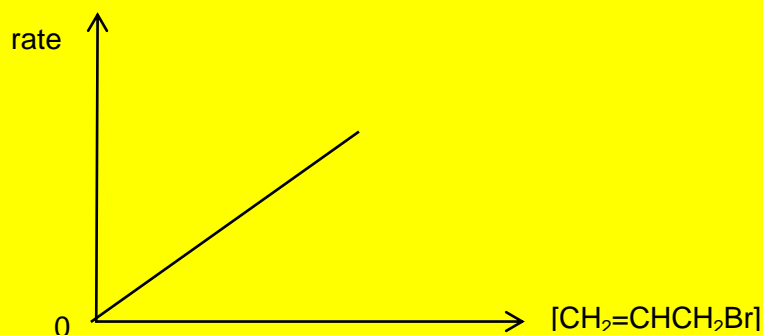
Using results of experiments 1 and 2,

$$\frac{2.00}{1.00} = \frac{k(0.20)^1(0.20)^n}{k(0.10)^1(0.10)^n}$$

$$n = 0$$

Order of reaction with respect to  $\text{NaOH} = \underline{0}$

- (ii) Sketch a graph of rate against  $[\text{CH}_2=\text{CHCH}_2\text{Br}]$  in the axes below.



- (iv) Given that the time taken for 75.0% of  $\text{CH}_2=\text{CHCH}_2\text{Br}$  to be used up is 10 minutes, calculate the time taken for 87.5% of  $\text{CH}_2=\text{CHCH}_2\text{Br}$  to be used up in the reaction.

Reactants left over time: 100%  $\rightarrow$  50%  $\rightarrow$  25%  $\rightarrow$  12.5%  
 Reactants used up over time: 0%  $\rightarrow$  50%  $\rightarrow$  75%  $\rightarrow$  87.5%

Half-life = 10 min / 2 = 5 min

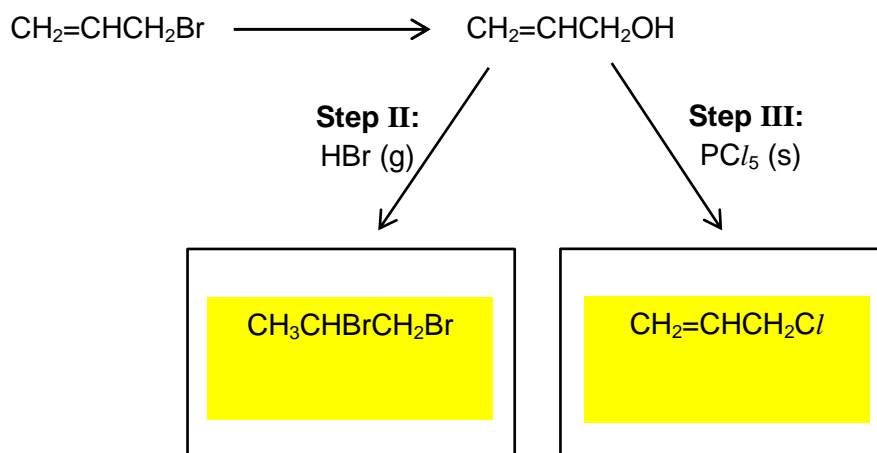
No. of half-lives for 87.5% of  $\text{CH}_2=\text{CHCH}_2\text{Br}$  to be used up = 3  
 Time taken = 5  $\times$  3 = **15min**

[5]

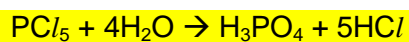
- (b) (i) Alcohols may also be converted back to halogeno compounds. In the reaction scheme illustrating this process below, fill in the major organic products formed upon reaction.

**Step I:**  
 $\text{NaOH (aq)}$   
 heat

Turn Over]



- (ii) By writing a chemical equation, illustrate why phosphorus pentachloride used in in Step III, must be anhydrous.



[3]

[Total: 8]

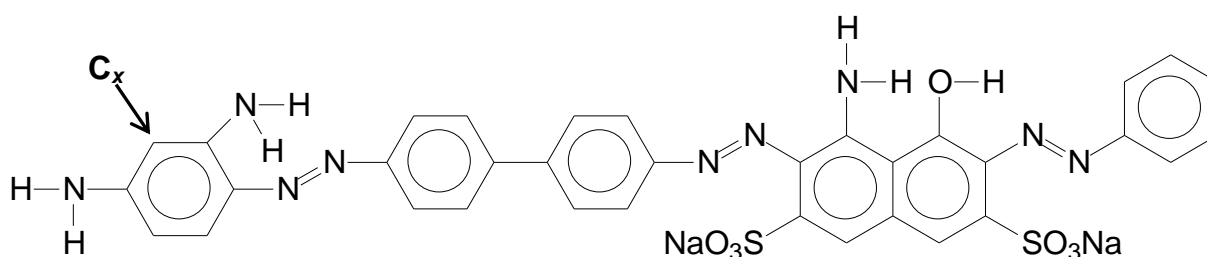
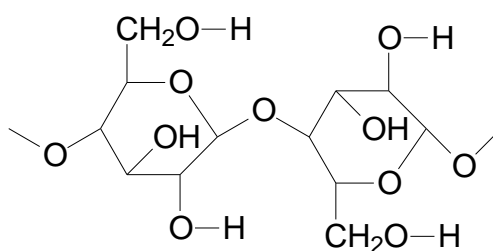
4 Cellulosic materials include cotton, rayon, and linen, all of which are very polar and hydrophilic.

Such materials require polar, water-soluble dyes for their colouration from a dyebath. In addition, dyes must be designed that maintain affinity when the cellulosic substrate is exposed to water.

Turn Over]

The diagram below shows a fragment of cellulose **A** and direct dye **B**.

cellulose **A**



direct dye **B**

- (a) Describe how the hybridised state of  $C_x$  is formed.

[2]

$C_x$  exhibits  **$sp^2$  hybridisation**. **One 2s** and **two 2p orbitals** are hybridised to form **three  $sp^2$  hybrid orbitals** arranged in a trigonal planar shape. One unhybridised p orbital lies perpendicular to the plane.

- (b) (i) Name the functional group that is present in cellulose **A**.  
You may ignore the  $-C-O-C-$  functional group.

**alcohol**

- (ii) Describe a chemical test which shows a positive result for alkenes but not the functional group identified in (b)(i).

[3]

Add  **$Br_2$  in  $CCl_4$**  at rtp.

Alcohol : **No decolourisation** observed

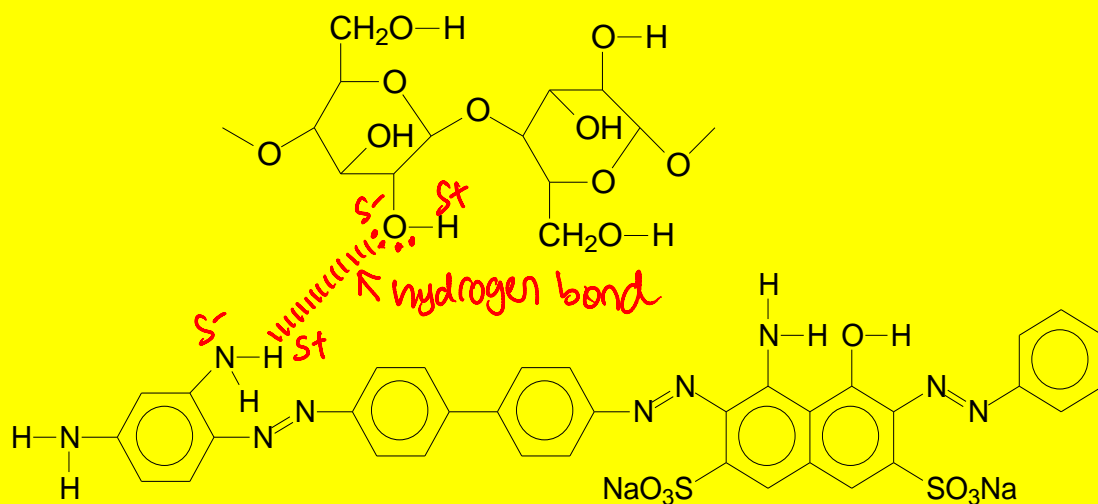
Alkene: **Reddish brown solution** decolourised.

- (c) Hydrogen bonding was found to exist between cellulose **A** and direct dye **B**.

Draw on the diagram above to show **one** hydrogen bond.

[1]

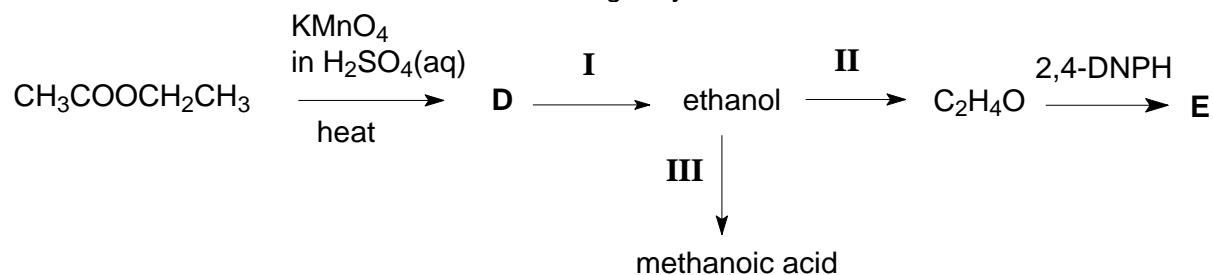
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[Total: 6 marks]

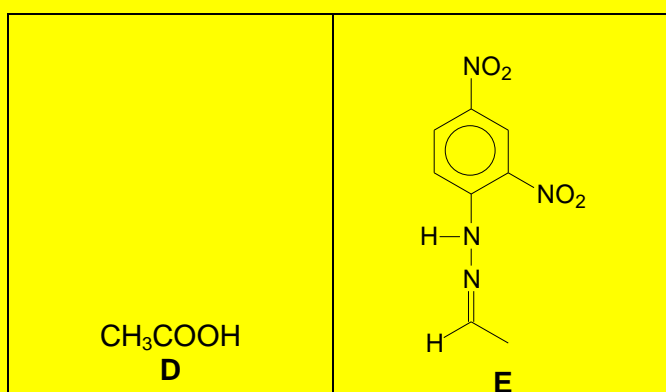
5 Ethyl ethanoate is commonly found in artificial fruit essences and aroma enhancers.

The reaction scheme shows reactions involving ethyl ethanoate.



(a) Draw the structural formulae for compounds **D** and **E**.

[2]



(b) State the reagents and conditions for reactions **I**, **II** and **III**.

Reaction **I**: \_\_\_\_\_

Reaction **II**: \_\_\_\_\_

Turn Over]



Reaction III: \_\_\_\_\_

[3]

Reaction I: LiAlH<sub>4</sub> in dry ether, rtpReaction II: K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>, dilute H<sub>2</sub>SO<sub>4</sub>, heat with distillationReaction III: I<sub>2</sub>(aq), NaOH(aq), warm followed by dilute H<sub>2</sub>SO<sub>4</sub>

(c) Suggest a reagent to test for the presence of methanoic acid.

[1]

Na<sub>2</sub>CO<sub>3</sub>, PCl<sub>5</sub>, KMnO<sub>4</sub> / H<sub>2</sub>SO<sub>4</sub> (aq)

[Total: 6]

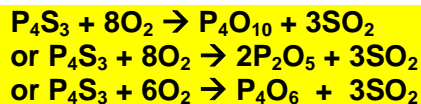
**Section B**Answer **two** questions from this section on separate answer paper.**6** Compounds of sulfur have many uses in our everyday life, such as in disinfectants, matches and

Turn Over]

in the making of paper.

- (a) Phosphorus sulfide,  $P_4S_3$ , is used in small amounts in the tip of a match stick. On striking a match stick, this compound burns to form sulfur dioxide and a solid oxide.

- (i) Construct an equation for this reaction.



- (ii) The melting point of sulfur dioxide differ significantly from that of silicon (IV) oxide,  $SiO_2$ .

Briefly relate this observation to the structure and bonding in each of the oxides.

$SO_2$  has simple molecular structures. Less amount of energy is required to overcome weak intermolecular van der Waals' forces of attraction.

$SiO_2$  has a giant molecular structure. Large amount of energy is required to overcome the strong covalent bonds between Si and O atoms.

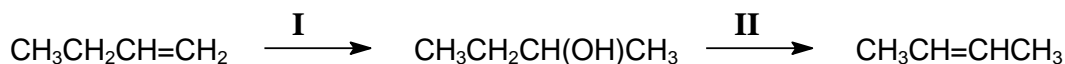
- (iii) Sulfur dioxide formed in (a)(i) dissolves in water to give an acidic solution. Construct an equation for the reaction of sulfur dioxide with water and give an approximate pH for the solution formed.

[5]



pH  $\approx$  any value between 1.5 to 2.5

- (b) Compounds of sulfur can also be used in organic synthesis. But-2-ene can be synthesised from but-1-ene via a 2-step reaction scheme as shown below.

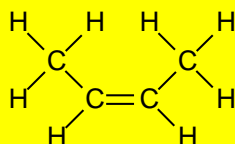


- (i) Describe the reagents and conditions necessary for reaction II.

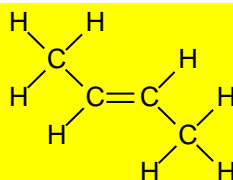
concentrated  $H_2SO_4$ , 170 °C /  $H_3PO_4$ , 200 °C /  
pass alcohol vapour over  $Al_2O_3$ , 350 °C

- (ii) But-2-ene occurs in two isomeric forms but cyclobutene occurs in only one form.

Draw the displayed formulae and state the geometry of two isomers.  
 Explain why such isomerism is not possible with cyclobutene.



cis but-2-ene



trans but-2-ene

Formation of trans cyclobutene will result in distortion of the cyclic ring / bond strain (or angle strain). Only the cis isomer is possible.

- (iii) An isomer of but-2-ene gives only one monobrominated product with  $Br_2$  under ultraviolet light.

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Suggest the structural formula of this isomer.



But-2-ene, on treatment with cold concentrated  $\text{H}_2\text{SO}_4$  followed by the addition of hot water, gives an addition product **J**,  $\text{C}_4\text{H}_{10}\text{O}$ . **J** produces a yellow precipitate on warming with alkaline aqueous iodine.

**J** turns orange hot acidified potassium dichromate green. The organic product, **K**, formed is then reacted with  $\text{HCN}$  to give compound **L**,  $\text{C}_5\text{H}_9\text{NO}$ .

Treatment of **L** with hot dilute sulfuric acid gives compound **M**. 0.590 g of **M** ( $M_r = 118.0$ ) reacts with excess sodium metal to give  $120 \text{ cm}^3$  of hydrogen gas (measured at room temperature and pressure).

On heating in the absence of air, **M** loses water to give a single compound **N** ( $\text{C}_{10}\text{H}_{16}\text{O}_4$ ). **N** no longer reacts with sodium metal.

- (iv) Deduce the structures of compounds **J**, **K**, **L**, **M** and **N** and explain the chemistry of the reactions described.  
[There is no need to comment on the chemistry of the formation of **J** from but-2-ene.]

$\begin{array}{c} \text{OH} \\   \\ \text{CH}_3-\text{CH}_2-\text{C}-\text{CH}_3 \\   \\ \text{H} \end{array}$	$\begin{array}{c} \text{O} \\    \\ \text{CH}_3-\text{CH}_2-\text{C}-\text{CH}_3 \end{array}$	$\begin{array}{c} \text{OH} \\   \\ \text{CH}_3-\text{CH}_2-\text{C}-\text{CH}_3 \\   \\ \text{CN} \end{array}$
<b>J</b>	<b>K</b>	<b>L</b>
$\begin{array}{c} \text{OH} \\   \\ \text{CH}_3-\text{CH}_2-\text{C}-\text{CH}_3 \\   \\ \text{CO}_2\text{H} \end{array}$		
<b>M</b>	<b>N</b>	

Observation	Deductions
<b>J</b> undergoes <u>oxidation</u> to produce yellow ppt with alkaline aqueous iodine.	$\begin{array}{c} \text{OH} \\   \\ \text{CH}_3-\text{C}- \\   \\ \text{H} \end{array} \quad \text{OR} \quad \begin{array}{c} \text{O} \\    \\ \text{CH}_3-\text{C}- \end{array}$
	<b>J</b> contains

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<b>J</b> undergoes <b>oxidation</b> with hot acidified potassium dichromate.	<b>J</b> is an <b>alcohol</b> .
<b>K</b> undergoes <b>nucleophilic addition</b> with HCN to give <b>L</b> .	<b>K</b> is a <b>ketone</b> . <b>L</b> is a <b>cyanohydrin/ hydroxynitrile</b> .
<b>L</b> undergoes <b>acid hydrolysis</b> with dilute sulfuric acid to give <b>M</b> .	<b>M</b> is a <b>carboxylic acid</b> .
<b>M</b> reacts with Na via <b>redox</b> to give 120 cm <sup>3</sup> of H <sub>2</sub> (g)	$n(\text{H}_2) = \frac{120}{24000} = 5.000 \times 10^{-3} \text{ mol}$ $n(\text{M}) = \frac{0.590}{118.0} = 5.000 \times 10^{-3} \text{ mol}$ <p>Since <b>M</b> <math>\equiv</math> H<sub>2</sub>, there is <b>presence of 2 –OH group / an alcohol and a carboxylic acid</b> in <b>M</b></p>
<b>M</b> in absence of air, undergoes (self) <b>esterification</b> / <b>condensation</b> to form <b>N</b> .	<b>N</b> contains <b>ester</b>
<b>N</b> no longer reacts with Na via <b>redox</b> .	<b>N</b> <b>do not contain acid / alcohol</b> group.

[15]

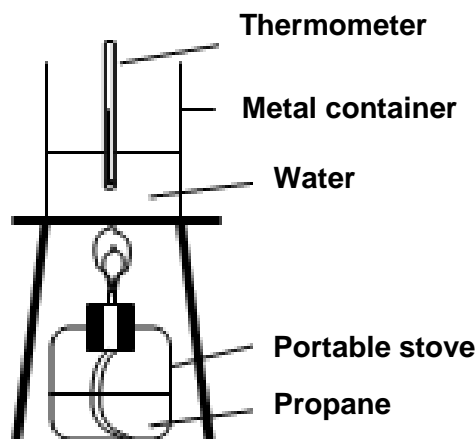
[Total: 20]

7 Propane is used in blow torches, portable stoves and in outdoor heaters.

The theoretical standard enthalpy change of combustion of propane is  $-2220 \text{ kJ mol}^{-1}$ .

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- (a) A propane portable stove was used during a barbecue to boil water. It took 10 minutes to boil the water.



The following information was known.

Mass of metal container / g	850
Mass of metal container containing water / g	1600
Initial temperature of water / °C	32

- (i) Define the term *standard enthalpy change of combustion* of propane.

The standard enthalpy change of combustion of propane is the **enthalpy change (heat evolved)** when **1 mole** of propane is **completely burnt in oxygen** / burnt in excess oxygen under **standard conditions/ 298K and 1 atm.**

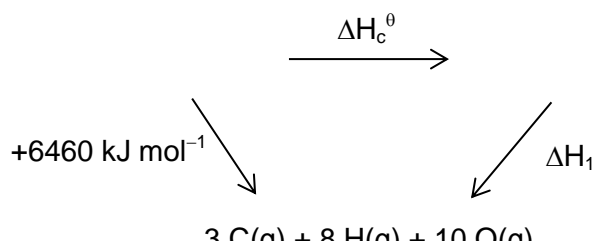
- (ii) Calculate the mass of propane needed to boil the water during the barbecue.

$$\begin{aligned}
 \text{Amount of heat gained by water, } Q &= (1600 - 850) \times 4.18 \times (100 - 32) \\
 &= 2.132 \times 10^5 \text{ J} \\
 &= 213.2 \text{ kJ}
 \end{aligned}$$

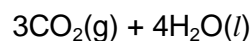
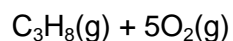
$$\text{Amount of propane needed} = 213.2 \div 2220 = \underline{\underline{0.09603 \text{ mol}}}$$

$$\text{Mass of propane required} = 0.09603 \times 44.0 = \underline{\underline{4.23 \text{ g}}}$$

- (iii) Another value of the standard enthalpy change of combustion of propane,  $\Delta H_c^\theta$ , can be calculated using bond energies and the energy cycle below.



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Use suitable bond energies given in the *Data Booklet* to calculate  $\Delta H_1$ .

$$\begin{aligned}\Delta H_1 &= 6E(\text{C}=\text{O}) + 8E(\text{O}-\text{H}) \\ &= 6 \times 740 + 8 \times 460 \\ &= \underline{\underline{8.12 \times 10^3 \text{ kJ mol}^{-1}}}\end{aligned}$$

(iv) Hence, calculate  $\Delta H_c^\theta$ .

$$\begin{aligned}\Delta H_c &= +6460 - (+8120) \\ &= \underline{\underline{-1.66 \times 10^3 \text{ kJ mol}^{-1}}}\end{aligned}$$

(v) Suggest why the value of  $\Delta H_c^\theta$  calculated in **a(iv)** differs from the theoretical value.

The bond energy values obtained from the *Data Booklet* are average values.

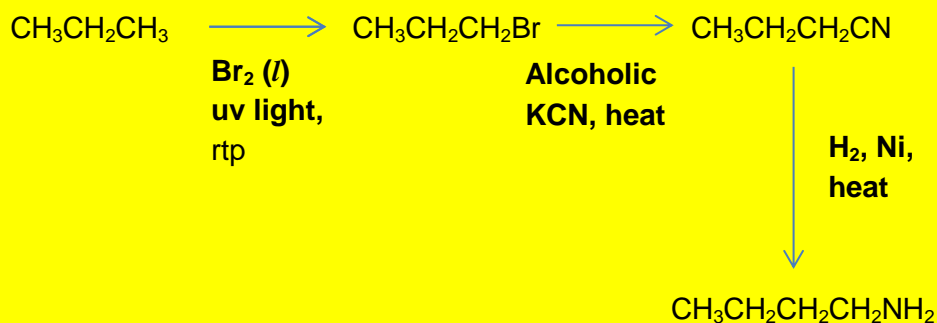
or

$\Delta H_{\text{vap}}$  of water was not taken into consideration

[7]

(b) Besides being used as fuel, propane can also be used to synthesise other organic compounds.

(i) Outline a three step synthesis of 1-aminobutane,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$ , from propane. State clearly the reagents and conditions used and draw any intermediate products formed.



(ii) Describe a chemical test, other than redox, to distinguish between propane and propan-1-ol.

Add  $\text{PCl}_5$  to propane and propan-1-ol separately at **rtp**.

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Propane: **No white fumes** observed.

Propan-1-ol: **White fumes** observed.

- (iii) State, with reasoning, whether propan-1-ol or 2-bromopropan-1-ol is a stronger acid.

**Electron-withdrawing/ Electronegative bromo** group **disperses negative charge** on the **conjugate base** hence **stabilising** the conjugate base.

2-bromopropan-1-ol is a **stronger** acid than propan-1-ol.

- (iv) 2-bromopropan-1-ol and 2-iodopropan-1-ol are reacted separately with hot aqueous potassium hydroxide followed by the addition of silver nitrate.

State the observations and explain the relative rate of reactions.

2-bromopropan-1-ol: **Cream** ppt

2-iodopropan-1-ol: **Yellow** ppt

**Strength of C-X bond: C-Br > C-I**

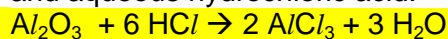
**Ease of cleavage: C-Br < C-I**

Relative rate of reaction: **R-Br < R-I**

[10]

- (c) Propane is a common feedstock and aluminium oxide is one of the possible catalyst used in the steam cracking process.

- (i) Write equations for the reactions of aluminium oxide with aqueous sodium hydroxide and aqueous hydrochloric acid.



- (ii) Derive the equation when beryllium metal reacts with aqueous sodium hydroxide, given that beryllium and aluminium shares a diagonal relationship in the periodic table.



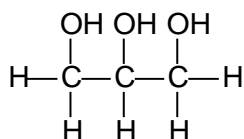
[3]

[Total: 20]

- 8 Food additives are substances added to food to preserve its flavour or enhance its taste and appearance.

- (a) In food and beverages, glycerol acts as food additive to keep food moist and may help to preserve foods.

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### Glycerol

Suggest, with reference to structure and bonding, how glycerol keeps food moist.

[1]

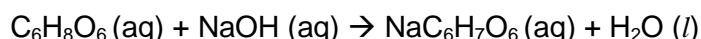
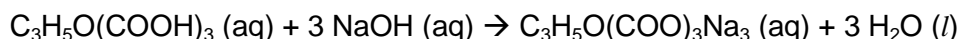
Glycerol is a **simple molecular** compound with is capable for forming **favourable hydrogen bonds with water**. This allows water molecules to be trapped within the food.

- (b) Citric acid is a natural preservative and is also used to add a sour taste to food and drinks.

A sample of commercial powdered drink mix is analysed for the concentrations of citric acid and vitamin C (also known as ascorbic acid). 4.23 g of the powdered drink mix is dissolved in water and made up to 250 cm<sup>3</sup>.

A 25.0 cm<sup>3</sup> aliquot requires 30.30 cm<sup>3</sup> of 0.200 mol dm<sup>-3</sup> of sodium hydroxide for complete neutralisation.

Citric acid, C<sub>3</sub>H<sub>5</sub>O(COOH)<sub>3</sub>, is a triprotic acid and ascorbic acid, C<sub>6</sub>H<sub>8</sub>O<sub>6</sub> is a monoprotic acid. Their reactions with sodium hydroxide are as shown below:

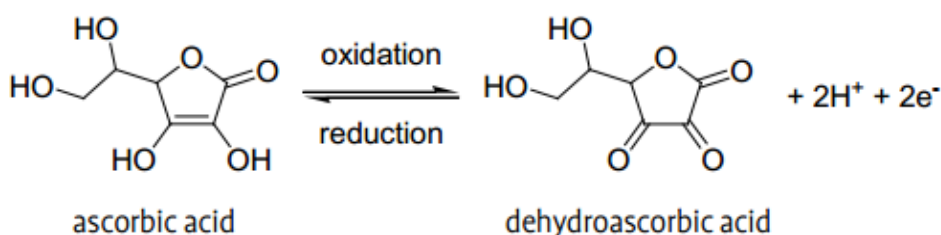


- (i) Calculate the total amount of protons, H<sup>+</sup> present in 4.23 g of the powdered drink mix.

Amount of NaOH = 30.30/1000 x 0.200 = **0.00606 mol**

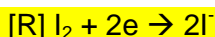
Amount of H<sup>+</sup> in 250 cm<sup>3</sup> = 0.00606 x 10 = **0.0606 mol**

Ascorbic acid is a mild reducing agent with the following oxidation equation.



Another 25.0 cm<sup>3</sup> aliquot requires 34.70 cm<sup>3</sup> of 0.009 mol dm<sup>-3</sup> iodine solution for complete redox reaction.

- (ii) State the reacting ratio of ascorbic acid and iodine.



1 mol of Ascorbic acid reacts with 1 mol of iodine

- (iii) Calculate the amount of ascorbic acid present in the 4.23 g of the powdered drink mix.

Amount of ascorbic acid in 4.23 g powdered drink  
 = [(34.7/1000) x 0.009] x 10  
 = 0.003123



$$= \underline{0.00312 \text{ mol}}$$

- (iv) Hence, calculate the mass of citric acid in the powdered drink mix.  
( $M_r$  of citric acid = 192.0)

[6]

$$\text{Amount of citric acid} = (0.0606 - 0.003123)/3 = 0.01916 \text{ mol}$$

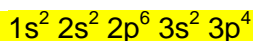
$$\text{Mass of citric acid} = 0.01916 \times 192.0 = \underline{3.68 \text{ g}}$$

- (c) The process of preserving food with sulfur dioxide is intended to provide a longer shelf life. However, sulfur dioxide is also considered as a toxic gas and it may trigger asthma. Sulfur dioxide can be produced by the combustion of sulfur in oxygen.

The element sulfur has four naturally occurring isotopes.

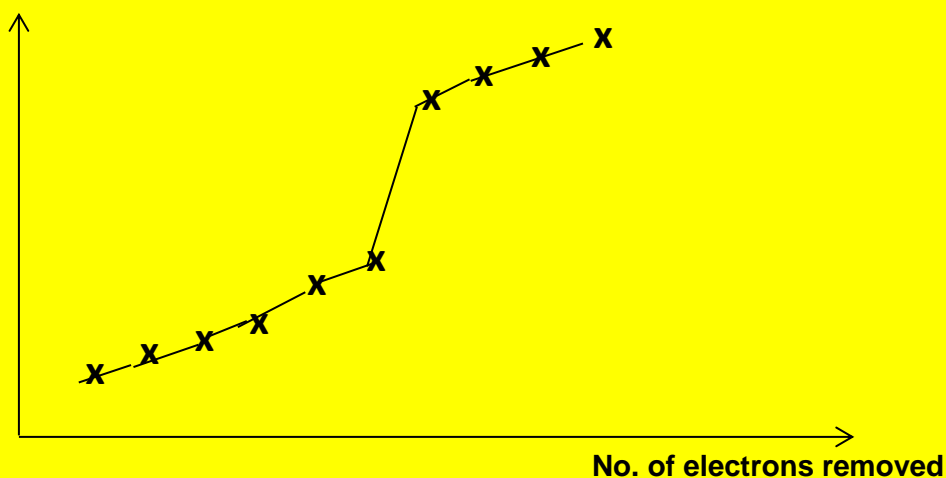
isotope	Relative abundance / %
$^{32}\text{S}$	94.93
$^{33}\text{S}$	0.76
$^{34}\text{S}$	4.29
$^{35}\text{S}$	0.02

- (i) Write the full electronic configuration of sulfur.



- (ii) Sketch the trend of the successive ionisation energies of the first 10 electrons of a sulfur atom. Explain the shape of your sketch.

$\log_{10}(\text{IE} / \text{kJ mol}^{-1})$



- There is an increase in successive IE as **more** energy is required to overcome the **stronger** electrostatic forces of attraction between the nucleus and the **remaining** electrons.
- The first large increase is from the 6<sup>th</sup> to 7<sup>th</sup> IE.
  - The 7<sup>th</sup> electron is removed from an **inner principal quantum shell**.
  - There are **6** electrons in the valence shell.

- (iii) Define the term 'isotope'.

Isotopes are atoms of the **same element** that contain the **same number of protons and electrons** but **different number of neutrons**.

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- (iv) Use the relative abundance data to calculate the relative atomic mass of sulfur to 4 significant figures. Show your working.

$$A_r \text{ of S} = \frac{(94.93 \times 32 + 0.76 \times 33 + 4.29 \times 34 + 0.02 \times 36)}{100}$$

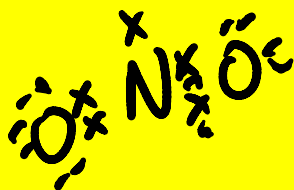
$$= \underline{32.09} \text{ (4 sf)}$$

- (v) Draw the dot and cross diagram for  $\text{SO}_2$  and the Lewis structure of  $\text{SO}_2$ , stating the shape of the molecule.



- (vi) The bond angle of  $\text{SO}_2$  is  $119^\circ$ . Hence, draw the dot and cross diagram of  $\text{NO}_2$  and suggest, with reasoning, the O-N-O bond angle.

[13]



$$119^\circ < \text{Bond angle} < 170^\circ$$

The unpaired electron in  $\text{NO}_2$  exerts lesser repulsion than the lone pair of electrons in  $\text{SO}_2$ . Hence the O-N-O bond angle is greater than that of  $\text{SO}_2$ .

[Total: 20]