**ANSWERS**

CANDIDATE
NAME

CLASS          2T

# CHEMISTRY
**Paper 2**

**8872/02**
**Thursday 27 August 2015**
**2 hours**

Candidates answer Section A on the Question Paper
Additional Materials: Answer Paper
Data Booklet
Graph Paper (2 sheets)

| For Examiner's Use | |
|---|---|
| Section A | |
| A1 | /7 |
| A2 | /14 |
| A3 | /7 |
| A4 | /3 |
| A5 | /9 |
| Section A | 40 |
| Section B | |
| B6 | /20 |
| B7 | /20 |
| B8 | /20 |
| Section B | 40 |
| P2 Total | 80 |
| P1 Total | 30 |
| Overall % | |
| Grade | |

### READ THESE INSTRUCTIONS FIRST

Write your name and HT group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

**Section A**
Answer **all** the questions.

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

**You are advised to spend not more than 1 hour for Section B.**

You are advised to show all working in calculations.
You may use a calculator.
The number of marks is given in brackets [ ] at the end of each question
or part question.

This document consists of **15** printed pages and **1** blank page.
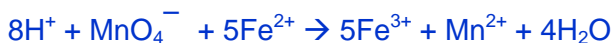
**[Turn over**

## Section A

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

**1** **(a)** Potassium manganate(VII), $KMnO_4$, can be reduced by iron (II) sulfate, $FeSO_4$. The relevant half-equations for the reaction are given below:

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

$$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$$
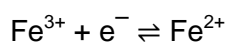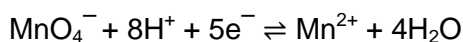
Write the balanced equation for the redox reaction which can occur.

$8H^+ + MnO_4^- + 5Fe^{2+} \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$

**(b)** Ketones can be reduced by lithium aluminium hydride, $LiAlH_4$, in dry ether to form secondary alcohols. State **another** set of reagents and conditions that can also be used for the reduction of ketones.

$NaBH_4$ in methanol

**(c)** Ketones are not easily oxidised. However, methyl ketones are a specific class of ketones with the acetyl functional group, $RCOCH_3$, and these can be easily oxidised in the **triiodomethane test**. State the conditions and reagents necessary for this test and write an equation for the reaction, using $RCOCH_3$. [2]

$I_2$ with aq. NaOH; heat under reflux

$RCOCH_3 + 3I_2 + 4NaOH \rightarrow RCOO^-Na^+ + CHI_3 + 3NaI + 3H_2O$

**(d)** Many organic compounds undergo oxidation, albeit to varying degrees. Compare the relative ease of oxidation of benzene and methylbenzene. Write appropriate equations and state reagents and conditions to illustrate your answer. [3]

Benzene does not undergo oxidation due to the stable ring structure but methyl benzene undergoes side-chain oxidation ;

Reagents and conditions for side-chain oxidation of methylbenzene: $KMnO_4$(aq), dilute $H_2SO_4$ (or $H_2SO_4$(aq),) heat under reflux ;



$$\text{C}_6\text{H}_5\text{CH}_3 + 3[O] \rightarrow \text{C}_6\text{H}_5\text{CO}_2\text{H} + \text{H}_2\text{O}$$
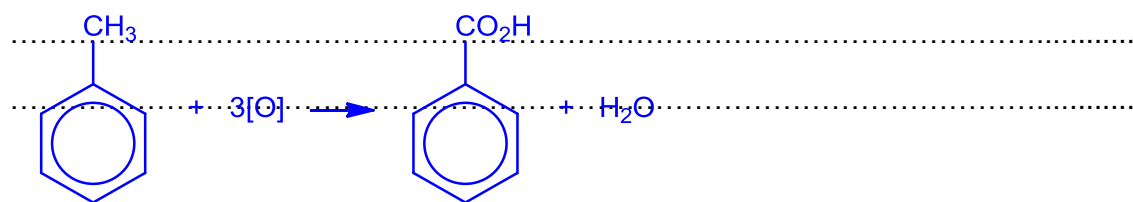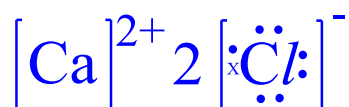
[Total: 7]

**2** **(a)** Define the term *relative atomic mass* of chlorine.

Relative atomic mass is ratio of the average mass of one atom of chlorine to 1/12 of the mass of one $^{12}C$ atom / isotope.

**(b)** Write the *spdf* electronic configuration of a chloride **ion**, $Cl^-$.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

**(c)** **(i)** Draw a dot-and-cross diagram to show the bonding in calcium chloride.

$$\left[ Ca \right]^{2+} 2 \left[ \overset{\bullet\bullet}{\underset{\bullet\bullet}{\overset{\bullet}{\underset{x}{Cl}}}} \right]^{-}$$

**(ii)** Explain how and why the lattice energies of calcium chloride, $CaCl_2$, and potassium chloride, $KCl$, have different numerical values. [4]

Lattice energy, $\Delta H_{latt} \propto -\dfrac{q_+ q_-}{r_+ + r_-}$

The charge on the ion $Ca^{2+}$ in $CaCl_2$ is higher than $K^+$ of $KCl$. Also, the ionic radius of $Ca^{2+}$ is smaller than the ionic radius of $K^+$.

Thus, $CaCl_2$ has a <u>more exothermic</u> lattice energy than $KCl$.

The first ionisation energies of the elements lithium to fluorine is shown below.
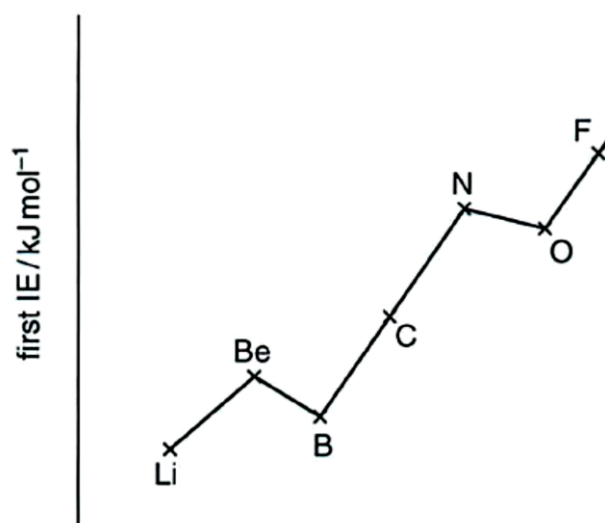


**(d)** **(i)** Describe and explain the **general** trend in first ionisation energies for the elements lithium to fluorine.

The first ionisation energy **generally** increases across the period.

This general increase is due to the **increase in the nuclear charge** (or number of protons), the **decrease in atomic radius** across the period, while the **screening effect remains almost the same.** Therefore a greater attraction between nucleus and valence electron results in **more energy** required to remove the outermost electrons.

**(ii)** Describe and explain how the first ionisation energy for chlorine compares to that of fluorine. [4]

The first ionisation energy for chlorine is **<u>lower</u>** than that of fluorine.

The nuclear charge of chlorine is greater than that of fluorine, but the **<u>atomic radius of chlorine is larger</u>** than fluorine. Thus, the **<u>outermost electron is further from the nucleus</u>** and is **<u>better shielded</u>** by the inner shell of electrons. As a result, less energy is required to remove the outermost electron from chlorine than fluorine.

**Note: Cambridge insists on the mention of the distance of the valence electron from the nucleus is progressively greater.**

**(e)** **(i)** Solid iodine burns in fluorine gas to produce iodine pentafluoride which has the chemical formula of $IF_5$. Draw and state the shape of the $IF_5$ molecule.
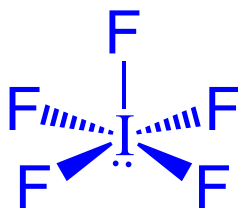


Non 3-D drawing is accepted as long as the shape is clear

Shape: ................................................ Square pyramidal / square-base pyramidal

When liquid $IF_5$ reacts with fluorine gas, a compound known as iodine (VII) fluoride is formed. This has the formula of $IF_7$ where all the fluorine atoms are evenly distributed around the central iodine atom as shown in the diagram below:
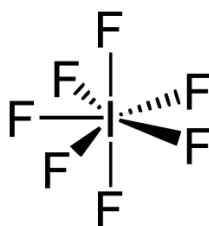


$IF_7$

$IF_5$ and $IF_7$ differ in their boiling points as shown in this table:

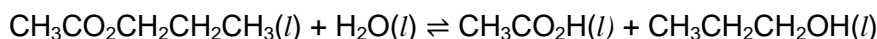| Compound | Boiling point /°C |
|----------|-------------------|
| $IF_5$ | 97.9 |
| $IF_7$ | 4.8 |

**(ii)** With reference to bonding, suggest an explanation for the difference in boiling points. [4]

Both compounds have simple molecular structures, but $IF_5$ is **polar** while $IF_7$ is **non-polar** (because $IF_7$ is perfectly symmetrical).

The permanent dipole – permanent dipole attractions between $IF_5$ is **stronger** than the van der Waals' forces of attraction between $IF_7$ molecules. Hence **more energy** is required to overcome the stronger permanent dipole – permanent dipole attractions, leading to a **higher** boiling point for $IF_5$.

**[Total: 14]**

**3** The hydrolysis of the ester, propyl ethanoate, gives ethanoic acid and propan-1-ol as the products. This hydrolysis is a reversible reaction which, given time, is able to achieve dynamic equilibrium.

$$CH_3CO_2CH_2CH_2CH_3(l) + H_2O(l) \rightleftharpoons CH_3CO_2H(l) + CH_3CH_2CH_2OH(l)$$

*propyl ethanoate*

**(a)** **(i)** Write an expression for the equilibrium constant, $K_c$ of the above reaction.

$$K_c = \boxed{\frac{[CH_3CH_2CH_2OH][CH_3CO_2H]}{[CH_3CO_2CH_2CH_2CH_3][H_2O]}}$$

**(ii)** State one factor which affects the value of equilibrium constant of the hydrolysis reaction.

temperature

**(iii)** Calculate the concentration of $H_2O(l)$ at equilibrium when the concentrations of $CH_3CO_2CH_2CH_2CH_3(l)$, $CH_3CO_2H(l)$ and $CH_3CH_2CH_2OH(l)$ are 1.357 mol dm$^{-3}$, 1.505 mol dm$^{-3}$ and 2.353 mol dm$^{-3}$ respectively.

$K_c$ for this reaction is 2.535. [3]

$$K_c = \boxed{\frac{[CH_3CH_2CH_2OH][CH_3CO_2H]}{[CH_3CO_2CH_2CH_2CH_3][H_2O]}} = \frac{(2.353)(1.505)}{(1.357)[H_2O]} = 2.535$$

$$\therefore [H_2O] = 1.03 \text{ mol dm}^{-3}$$

**(b)** **(i)** State the catalyst and the conditions that are used for the acidic hydrolysis of the ester.

Dilute sulfuric acid, $H_2SO_4$.
Heat under reflux.

**(ii)** Suggest why the base hydrolysis of esters might give a higher yield of the products compared to the acid hydrolysis of esters. [3]

The base used for hydrolysis of the esters can **react with the carboxylic acid** produced and **shifts the equilibrium position to the right**, increasing the yield of the products.

**(c)** Draw another ester that is a structural isomer of the ester, propyl ethanoate.
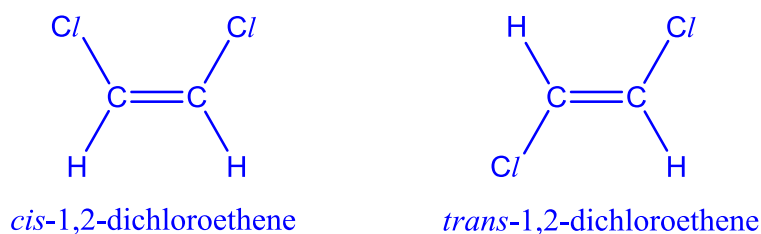


butyl methanoate          methyl butanoate          methyl 2-methylpropanoate
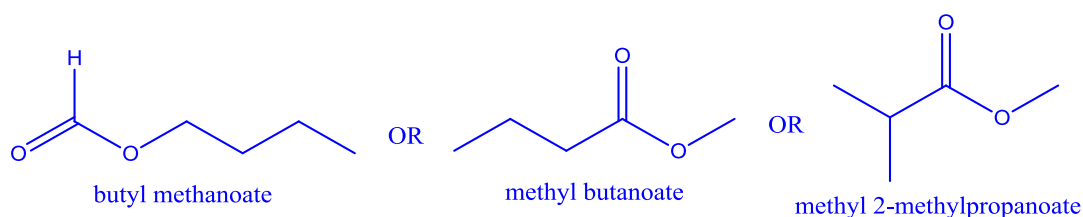
**[Total: 7]**

**4** Ethene, $H_2C=CH_2$, is able to undergo electrophilic addition with chlorine to form 1,2-dichloroethane.

Eth**y**ne, HC≡CH, is also able to undergo electrophilic addition with chlorine in the same way as eth**e**ne does, but the products are a mixture of 1,2-dichloroeth**e**ne and 1,1,2,2-tetrachloroeth**a**ne.

**(a)** State the reagent and conditions necessary to have a good yield of 1,2-dichloroeth**e**ne, CHC*l*=CHC*l* from ethyne.

Limited chlorine gas at room temperature, in the dark [limited chlorine is needed to avoid forming tetrasubstituted chloroethane]

**(b)** 1,2-dichloroethene can exhibit geometric isomerism. Draw and label the **two** geometric isomers of 1,2-dichloroethene. [3]



*cis*-1,2-dichloroethene          *trans*-1,2-dichloroethene

**[Total: 3]**

**5** Honey does not spoil over time, unlike most types of food. In fact, the oldest known sample of honey was found in an Ancient Egyptian tomb and it was still perfectly edible.

A key factor is the low water content of honey. Its water content is too low to support bacteria growth, it dehydrates bacteria and makes honey resistant to spoiling. However, if honey is exposed to moisture in the air, bacteria growth can take place. The sugar in honey will get fermented and honey would taste and smell bad. This is why honey is usually stored in a sealed screw-top jar.

The water content of honey can be estimated by measuring the change in mass of the honey as it dries out. A student took a sample of honey and placed it in a clean and dry Petri dish. She recorded the mass of the dish containing the honey and placed the dish in an oven at about 30°C for 24 hours.

Her results were obtained below:

| | |
|---|---|
| Mass of empty Petri dish | = 32.34 g |
| Mass of Petri dish and honey before experiment | = 44.56 g |
| Mass of Petri dish and honey after experiment | = 42.47 g |

**(a)** Assuming all the water was evaporated from the honey sample at the end of the experiment, calculate the water content in honey. Express your answer as a percentage. [2]
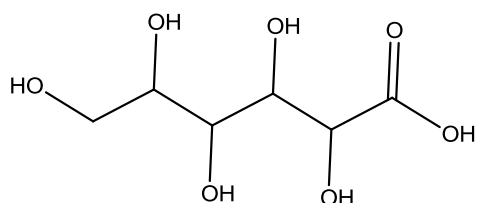
**Mass of honey used = 44.56 – 32.34 = <u>12.22 g</u>**

**Mass of water evaporated = 44.56 – 42.47 = <u>2.09 g</u>**

**Percentage of water content in the honey = $\frac{2.09}{12.22} \times 100\% = 17.1\%$**

The acidity of honey further boosts honey's antibacterial properties, as many bacteria thrive in neutral rather than acidic conditions. Hence its acidity is another factor that prevents the spoiling of honey. The average pH of honey is 4. The acidity of honey is contributed by a number of acids, including formic acid and citric acid present in honey. However, the dominant acid is gluconic acid which is produced by the action of bee enzymes on some of the glucose molecules in the honey.

The skeletal structure of gluconic acid is given below:



*gluconic acid*

**(b)** Calculate the [H⁺] concentration in honey.

**pH of acid = 4**

**-log [H⁺] = 4**

**[H⁺] = 10⁻⁴ mol dm⁻³**

**(c)** Apart from the carboxylic acid functional group, state all other functional groups present in a gluconic acid molecule. [2]
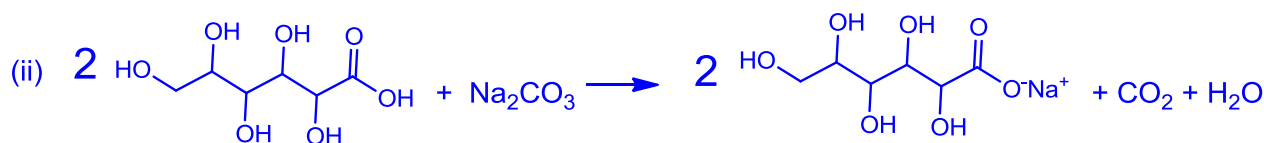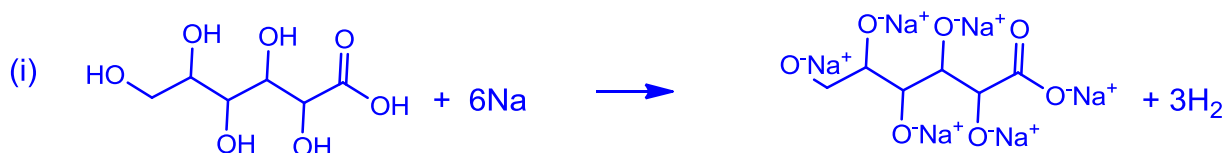
**Secondary alcohol and primary alcohol**

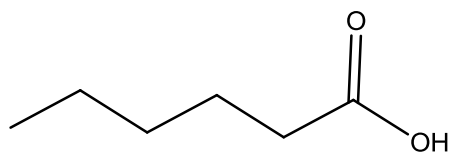**(d)** Write balanced equations for the reaction of gluconic acid with
   **(i)** Na
   **(ii)** Na₂CO₃ [2]



(i)



(ii)

**(e)** Explain in terms of structure why gluconic acid is a stronger acid than hexanoic acid. [2]



*hexanoic acid*

**Gluconic acid has several electron-withdrawing (-OH) groups.**

**This increases the polarisation of O–H bond in the carboxylic acid group, and so weakening it, making H⁺ loss easily**
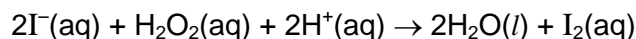
**OR**

**This disperses the negative charge on the carboxylate O-, making the carboxylate anion more stable.**

[Total: 9]

## Section B

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

**6** **(a)** Hydrogen peroxide is able to oxidise iodide ions to iodine and this reaction is represented by the following equation:

$$2I^-(aq) + H_2O_2(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + I_2(aq)$$

The rate of this reaction can be followed by monitoring how quickly a specific amount of iodine forms. A small, fixed amount of sodium thiosulfate solution and 1 cm³ of starch solution are also added to the reaction mixture. Iodine reacts with starch to give a deep blue-black colouration. The **rate of the reaction** is inversely proportional to the time taken for the blue-black colour to appear.

The experiment was performed five times, each time with a different initial concentration of iodide ions. The total volume in each experiment is held constant. The results are given below.

| Experiment | Initial $[I^-(aq)]$ / mol dm$^{-3}$ | time (t) / s | Relative rate x 10$^{-2}$ (1/t) / s$^{-1}$ |
|---|---|---|---|
| I | 0.04 | 37 | 0.027 |
| II | 0.06 | 25 | 0.040 |
| III | 0.08 | 19 | *r* |
| IV | 0.10 | 15 | 0.067 |
| V | 0.12 | 12 | 0.083 |

**(i)** Define the term *rate of reaction*.

Rate of reaction is the change in the concentration of reactants or products per unit time.

**(ii)** In the experiments, the concentrations of the acid and hydrogen peroxide are far more concentrated than that of the iodide solution. Explain why this is necessary.

This is to ensure that [acid] and [H₂O₂] are effectively constant and only [I⁻] varies with time.

**(iii)** State the value of *r*. Hence, plot a graph of the relative rate of reaction (1/t) against the initial iodide concentration.
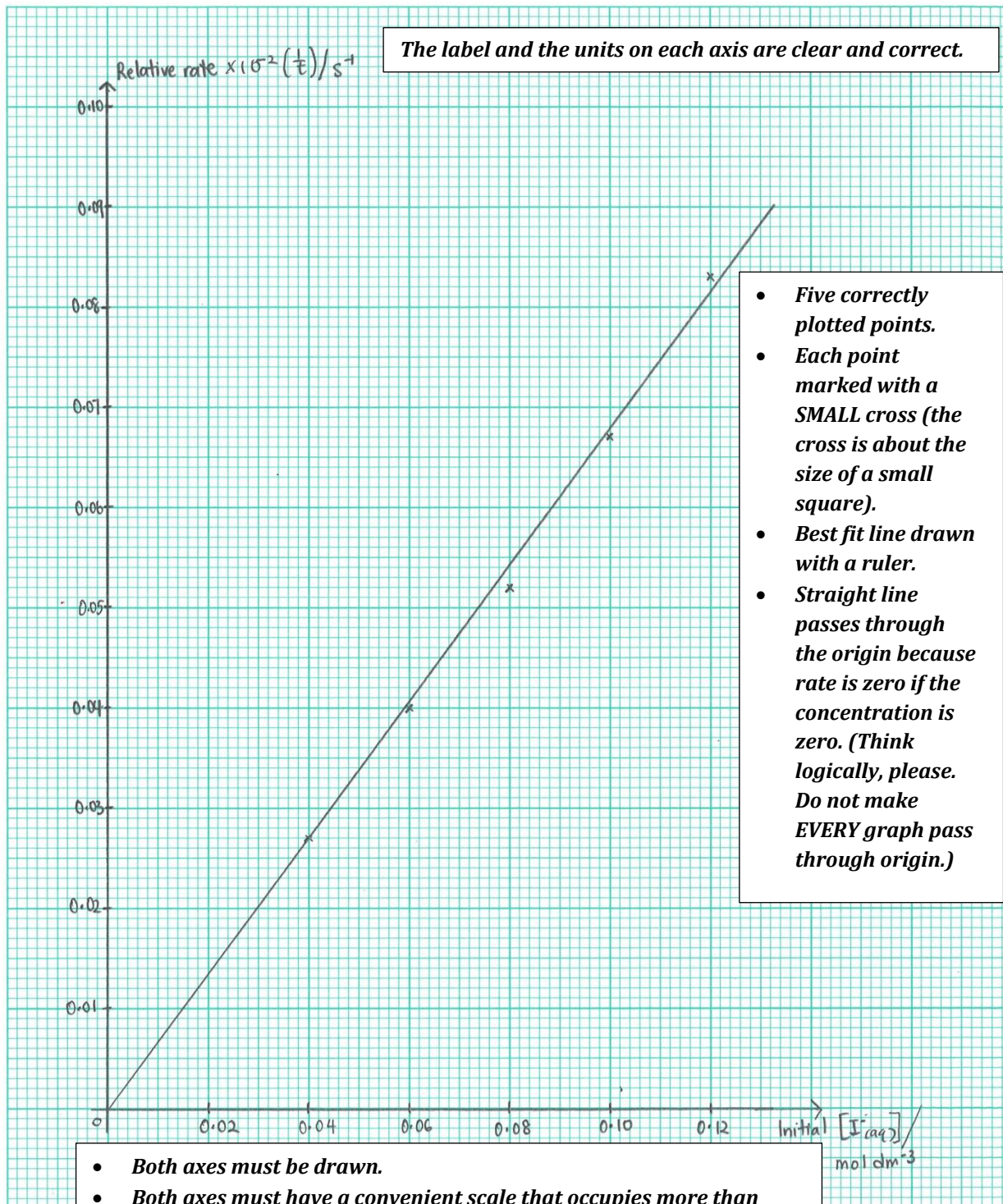
r = 5.3 x 10⁻²

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Question No. ...........



The label and the units on each axis are clear and correct.

Relative rate $\times 10^{-2} \left(\frac{1}{t}\right) / s^{-1}$

- Five correctly plotted points.
- Each point marked with a SMALL cross (the cross is about the size of a small square).
- Best fit line drawn with a ruler.
- Straight line passes through the origin because rate is zero if the concentration is zero. (Think logically, please. Do not make EVERY graph pass through origin.)

Initial $[I^-_{(aq)}]$ / mol dm$^{-3}$

- Both axes must be drawn.
- Both axes must have a convenient scale that occupies more than half the graph paper.
- Intervals on each axis are uniform and indicated clearly.

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**(iv)** Determine the order of the reaction, $n$, with respect to iodide ions. State clearly your reasoning.

n= 1

The graph is a **straight line** graph which indicates that **rate is directly proportional** to the concentration of iodide ions.

**[Inspection method is also acceptable.]**

**(v)** Other experiments show that the order of reaction with respect to $[H_2O_2(aq)]$ is 1 and with respect to $[H^+(aq)]$ is zero. Write the rate equation for the reaction and state the units of the rate constant.

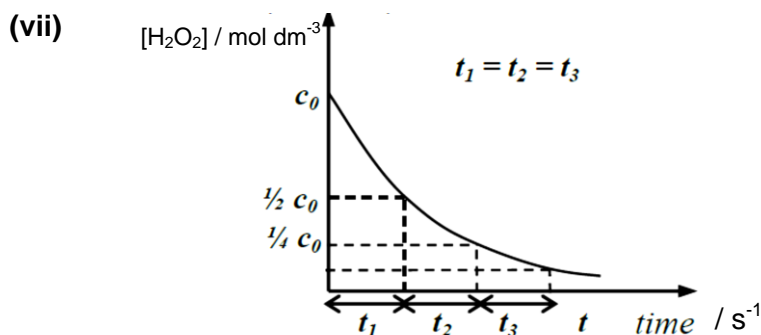rate = $k\,[I^-(aq)]\,[H_2O_2(aq)]$

units of $k = \dfrac{\text{units of rate}}{(\text{units of conc})^2} = \dfrac{\text{mol dm}^{-3}s^{-1}}{(\text{mol dm}^{-3})^2} = $ dm$^3$ mol$^{-1}$ s$^{-1}$

**OR** units of $k = \dfrac{\text{units of rate}}{(\text{units of conc})^2} = \dfrac{s^{-1}}{(\text{mol dm}^{-3})^2} = $ dm$^6$ mol$^{-2}$ s$^{-1}$

**(vi)** Sketch the shape of the graph of $[H_2O_2(aq)]$ against time. [9]

**(vii)**



**(b)** Phosphorus, sulfur and chlorine are consecutive elements in the periodic table. All their oxides, $P_4O_{10}$, $SO_3$ and $Cl_2O$, react with water to form acids. In each reaction, the period 3 elements do not change their oxidation states.

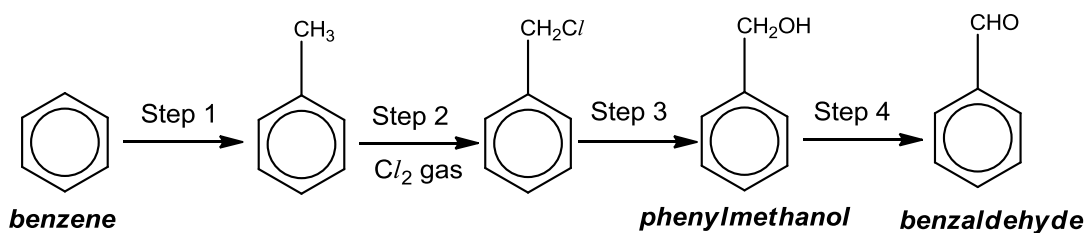**(i)** Write balanced equations to show how $P_4O_{10}$ and $SO_3$ react with water.

**$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$**

**$SO_3 + H_2O \rightarrow H_2SO_4$**

**(ii)** Hence, suggest a balanced equation to show how $Cl_2O$ reacts with water.

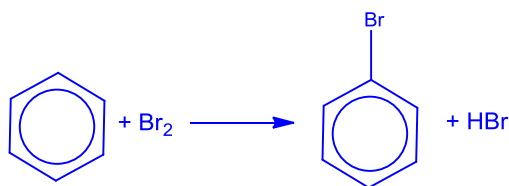**$Cl_2O + H_2O \rightarrow 2HClO$**

[3]

**(c)** Benzaldehyde is the simplest aromatic aldehyde. It is a colourless liquid with a pleasant almond-like odour. Benzaldehyde can be synthesised from benzene via the following schematic route:

**(i)** Step 1 is a substitution reaction. Why does benzene undergo substitution reactions instead of addition reactions?

To retain its stable ring structure / retain the stability of the aromatic nucleus.
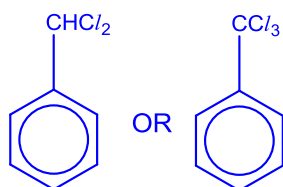
**(ii)** Write a balanced equation to show benzene undergoing substitution with bromine. State the conditions for the reaction.
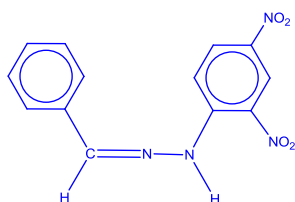


Condtion:  Fe or **Anhydrous** $FeBr_3$ catalyst.

**(iii)** State the condition necessary for Step 2 and identify another possible product that may be formed from Step 2.

uv light



**(iv)** An orange precipitate is formed when benzaldehyde is heated with 2,4-dinitrophenylhydrazine. Draw the molecular structure of the orange precipitate.



**(v)** Apart from using 2,4-dinitrophenylhydrazine, describe a simple chemical test to show that benzaldehyde is an aldehyde but phenylmethanol is not.

To samples of each compound in separate test-tubes, add **Tollen's reagent and warm.**

Benzaldehyde will produce a **silver mirror** and phenylmethanol will not.

[8]

**[Total: 20]**

**7** **(a)** The Contact Process is one of the most important industrial processes in the modern world due to its production of sulfuric acid which is a common laboratory reagent. One of the steps requires a vanadium catalyst and the equation is shown below.
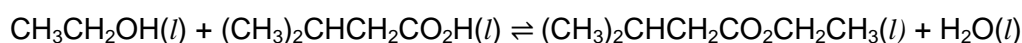
$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$
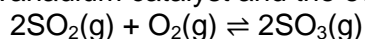
**(i)** Explain the effect of increasing the concentration of oxygen on the yield of $SO_3$.

When the concentration of oxygen is increased, by Le Chatelier's Principle, the position of equilibrium to shift to the **right** so as to remove some of the oxygen added. **The new equilibrium mixture will contain more $SO_3$, / The yield of $SO_3$ will increase.**

**(ii)** The equilibrium amounts in a 1 dm³ flask consists of 0.65 mol of $SO_2$, 0.30 mol of $O_2$ and 5.20 mol of $SO_3$ at 650 °C. Calculate the value for the equilibrium constant, $K_c$, for the reaction at 650 °C.

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

$$K_C = \frac{(\frac{5.20}{1})^2}{(\frac{0.65}{1})^2(\frac{0.30}{1})} = 213 \text{ mol}^{-1}\text{dm}^3$$

**(b)** **(i)** Ethyl isovalerate, is an ester that is miscible in water and also some non-polar solvents. As this ester has an odour similar to apples, it is commonly used as a favouring agent in beverages and confectionary products.

An experiment was carried out to make ethyl isovalerate in the laboratory. Some ethanol was mixed with 3-methylbutanoic acid and the mixture was heated to 80°C in the presence of a suitable catalyst. The equation for the reaction is shown below.

$$CH_3CH_2OH(l) + (CH_3)_2CHCH_2CO_2H(l) \rightleftharpoons (CH_3)_2CHCH_2CO_2CH_2CH_3(l) + H_2O(l)$$

With the aid of an energy distribution diagram, explain how the catalyst increases the rate of the reaction.
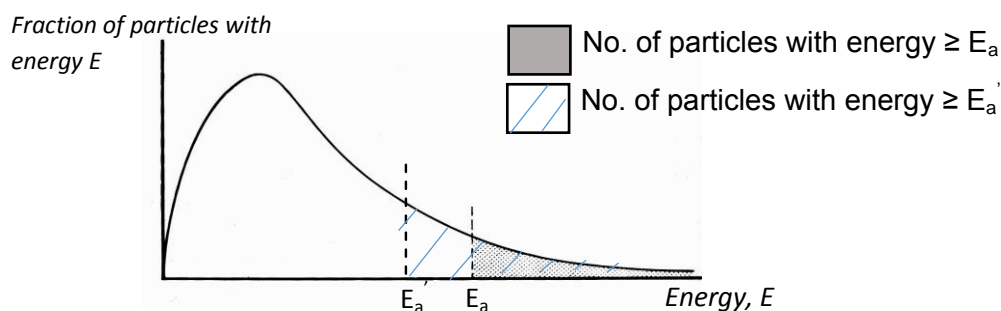
The catalyst speeds up the reaction by <u>providing an alternative pathway with a lowered activation energy, $E_a$'</u>. <u>More particles will have energy equal or greater than the lowered activation energy for reaction</u>. This <u>increases the frequency of effective collisions</u> and hence increases the rate of reaction.

**(ii)** Using the bond energy values in the *Data Booklet*, calculate the enthalpy change, ΔH, for the esterification reaction between ethanol and 3-methylbutanoic acid.
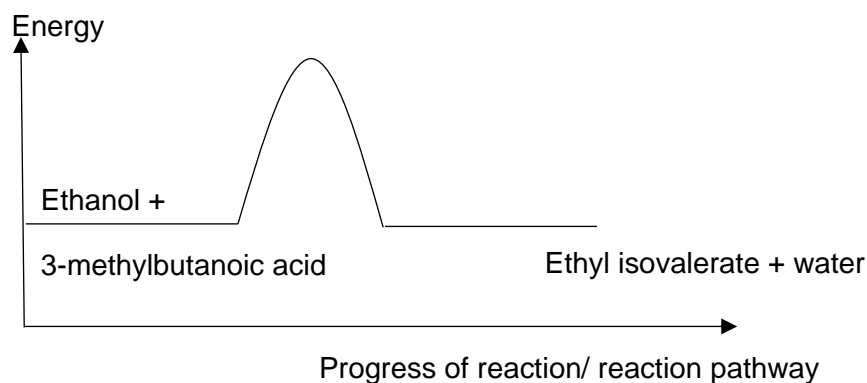
<u>Bonds broken</u>        <u>Bonds formed</u>
 C-O (in carboxylic acid)   C-O (in ester)
 O-H (in alcohol)      O-H (in water)

ΔH = 0 kJ mol$^{-1}$

**(iii)** Using your answer in **b(ii)**, draw an energy profile diagram for the esterification reaction between ethanol and 3-methylbutanoic acid assuming that it is a 1 step reaction.
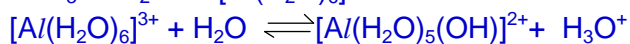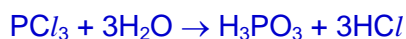


Energy

Ethanol +

3-methylbutanoic acid       Ethyl isovalerate + water

Progress of reaction/ reaction pathway

[10]

**(c)** Describe the reactions of $AlCl_3$ and $PCl_3$ with water. State the pH of the resulting solutions formed and write equations for the reactions.

[3]

$AlCl_3$ **hydrolyses** in water to form **an acidic solution of pH 3**.
$AlCl_3$ + $6H_2O \rightarrow [Al(H_2O)_6]^{3+}$ + $3Cl^-$
$[Al(H_2O)_6]^{3+}$ + $H_2O \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}$ + $H_3O^+$
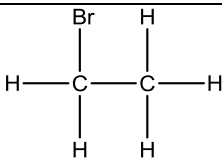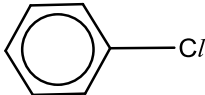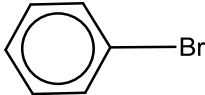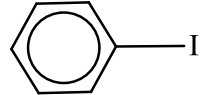
$PCl_3$ **hydrolyses** in water to form **an acidic solution of pH 2 (and steamy fumes of HCl.)**

$PCl_3$ + $3H_2O \rightarrow H_3PO_3$ + $3HCl$

**(d)** Compound **Y** has the molecular formula, $C_{10}H_{10}X_2$ (where **X** can be C$l$, Br or I). Equal quantities of each of compound **Y** and 4 other organic halides were treated with excess ethanolic silver nitrate solution and left to stand for 30 min at room temperature conditions. The table below summaries the observations and deductions of the reactions of the above five compounds.

| Organic Halide | Observations | Deductions |
|---|---|---|
| $C_{10}H_{10}X_2$<br><br>Compound **Y** | precipitate was formed after 3 minutes | |
| <br>*Bromoethane* | cream coloured precipitate was formed after 7 minutes | precipitate is silver bromide |
| <br>*Chlorobenzene* | no silver halide precipitate was formed | |
| <br>*Bromobenzene* | no silver halide precipitate was formed | carbon-halide bonds did not break hence no precipitate was formed in each case. |
| <br>*Iodobenzene* | no silver halide precipitate was formed | |

Using the information above, suggest the colour of the silver halide precipitate which was formed in the reaction of compound **Y** with ethanolic silver nitrate. Explain your answer.

The colour of the silver halide is yellow (the silver halide is silver iodide)

Compound Y contains a C-I bond is which is weaker than the C-Br bond present in bromoethane, as the C-I bond is more easily broken, the precipitation of silver iodide will take a shorter time than the precipitation of silver bromide when bromoethane reacted.

[2]

**(e)** *The information in part (d) is relevant for solving this question.*
Compound **Z** is an isomer of compound **Y** and can exhibit geometric isomerism. When 1 mole of **Z** reacts with excess KCN in the presence of heat, 1 mole of **A**, $C_{11}H_{10}NX$, is formed.

When aqueous hot NaOH is added to **Z,** compound **B**, $C_{10}H_{11}OX$ is formed. **B** reacts with thionyl chloride, $SOCl_2$, to form steamy fumes of HC$l$ and **B** also reacts with aqueous alkaline iodine to form yellow precipitate of $CHI_3$.

Deduce the structure of compound **Z**. Explain the reactions that occurred.

[5]

| Observations | Type of reactions | Type of functional groups |
|---|---|---|
| 1) Z can exhibit geometric isomerism | - | 1) Z contains 1 C=C bond and 2 different substituents are bonded to each carbon atom in the C=C bond |
| 2) When 1 mole of **Z** reacts with excess KCN, 1 mole of **A**, $C_{11}H_{10}NX$, is formed | Z undergoes substitution reaction of halogen | Only 1 halogen is substituted which suggested that 1 of the halogen is directly bonded to the benzene. |
| 3) **B**, $C_{10}H_{11}OX$, is formed when aqueous NaOH is added to **Z** | Z undergoes substitution (hydrolysis accepted) reaction of halogen | Only 1 halogen is substituted which suggested that 1 of the halogen is directly bonded to the benzene. |
| 4) **B** reacts with thionyl chloride to form steamy fumes of HC$l$ and it reacts with aqueous alkaline iodine to form yellow precipitate of $CHI_3$. | B undergoes substitution of –OH group<br><br>B undergoes triiodomethane test (oxidation) | B is an alcohol with $CH_3CH(OH)$- group |
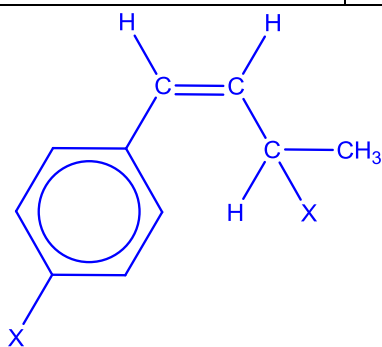


compound **Z**

**[Total: 20]**

**8** **(a)** The enthalpy change of solution, $\Delta H_{sol}$, is defined as the enthalpy change when one mole of a substance is dissolved in large volume of solvent such that further addition of the solvent produces no more heat changes.

In an experiment to determine the enthalpy change of solution of sodium hydroxide, 2.3 g of sodium hydroxide pellets was dissolved in 200 cm$^3$ of water. The temperature of water was found to increase by 3.0 $^o$C.

**(i)** Explain in terms of structure and bonding, why sodium hydroxide is soluble in water.

Sodium hydroxide has <u>giant ionic structure</u> with <u>strong electrostatic forces of attraction between oppositely charged sodium ions and hydroxide ions</u>. In presence of <u>polar water molecules</u>, both sodium ions and hydroxide ions are able to form <u>strong ion-dipole forces of attraction with</u> <u>the water molecules.</u> The energy released is able to compensate for the energy needed to overcome the attraction between sodium ions and hydroxide ions enabling sodium hydroxide to dissolve in water.

**(ii)** Calculate the enthalpy change of solution of sodium hydroxide. The specific heat capacity of the solution is 4.18 J g$^{-1}$ K$^{-1}$. [5]

No. of moles of sodium hydroxide $= \frac{2.3}{23.0+16.0+1.0} = 0.0575$ mol

Heat evolved = 200 x 4.18 x 3.0 = 2508 J = 2.508 kJ

$\Delta H_{sol} = -\frac{2508}{0.0575}$
$= -43.6$ kJ mol$^{-1}$                    Note: answer + sign + units

**(b)** An acid, HX, was used to determine the concentration of the sodium hydroxide solution which was formed in **(a)**. 25.0 cm$^3$ of 0.100 mol dm$^{-3}$ of HX was used for the titration. The pH of HX was found to be 3.75.

**(i)** Show that HX is a weak acid and hence suggest a suitable indicator which can be used for the titration between sodium hydroxide and HX. Explain your choice of indicator.

pH of HX = 3.75, hence [H$^+$] = <u>1.78 x 10$^{-4}$ mol dm$^{-3}$ < [HX]</u> which is 0.100 mol dm$^{-3}$ . This <u>indicates that HX only partially dissociated.</u> Hence HX is a weak acid
Phenolphthalein indicator (or any suitable indicator)
Hence for weak acid-strong base titration, phenolphthalein can be used as indicator as it <u>changes colour within the pH range of rapid change during titration.</u>

**(ii)** The titration was halted after 5 cm$^3$ of sodium hydroxide was added to the weak acid HX. The pH of the resulting mixture was slightly higher than the initial pH of the weak acid.

Explain what will happen to the pH of the mixture if 0.1 cm$^3$ of 0.100 mol dm$^{-3}$ of hydrochloric acid is now added to the mixture. Write an equation for any reaction that occurs. [5]

The resulting mixture formed after 5 cm$^3$ of sodium hydroxide was added to 25.0 cm$^3$ of 0.100 mol dm$^{-3}$ of HX is an <u>acidic buffer.</u> Thus it will maintain <u>a fairly constant pH</u> when small amount of hydrochloric acid is added.

X$^-$ + H$^+$ → HX
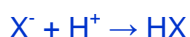
**(c)** The oxides, MgO and P$_4$O$_{10}$, vary considerably in their physical and chemical properties. Describe the acid-base natures of both oxides and write equations for reactions with acid or base. [2]

MgO is a <u>basic oxide</u> and reacts with acid to form a salt

MgO + 2H$^+$ → Mg$^{2+}$ + H$_2$O

P$_4$O$_{10}$ is an acidic <u>oxide</u> and reacts with base to form a salt

P$_4$O$_{10}$ + 12OH$^-$ → 4PO$_4$$^{3-}$ + 6H$_2$O

**(d) (i)** Alcohols may be used as biofuels to generate energy for locomotion. However due to their high costs, they are more often used as additives in fossil fuels to improve the combustion process.

Give the **environmental advantage** of burning fossil fuels added with biofuels (eg: a mixture of octane and ethanol) compared to burning fossil fuels that contain other anti-knock agents such as Tetraethyl Lead (TEL).
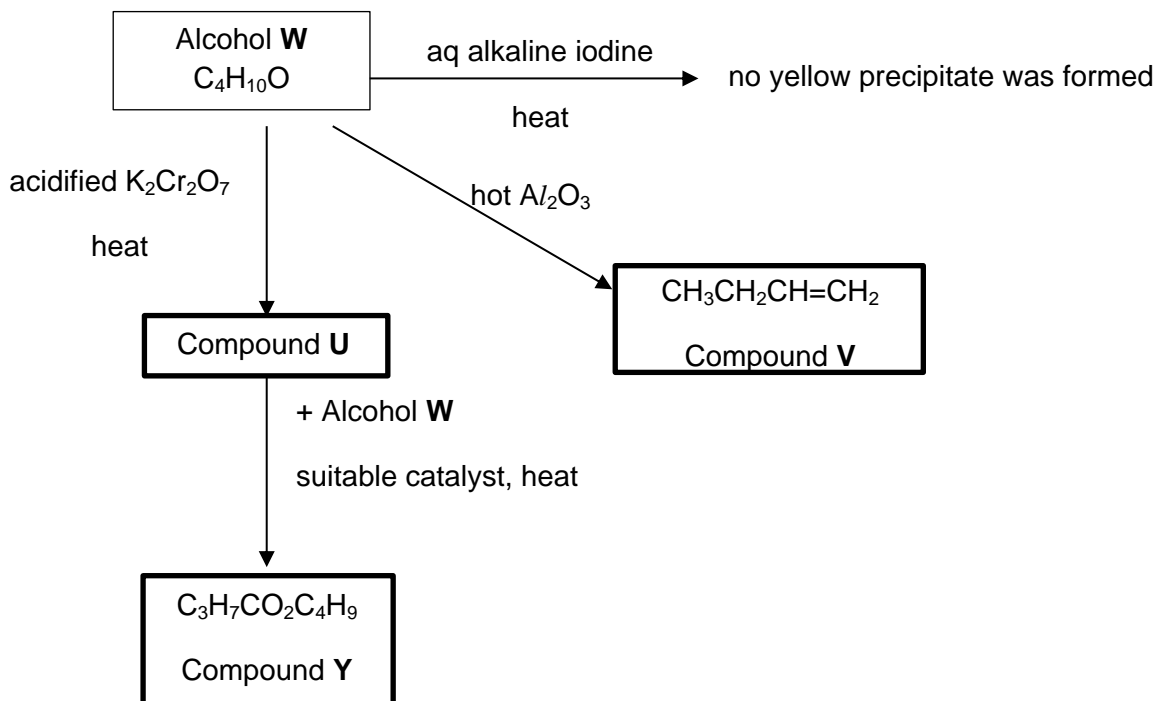
Burning fossil fuels added with biofuels does not produce poisonous lead vapours which affects the central nervous system and can cause brain damage.

**OR**

Burning fossil fuels added with biofuels does not poison the catalysts in the catalytic converter of the exhaust, causing the catalysts to lose their catalytic properties.

Do not accept "less polluting" as this term is too generic.

**(ii)** Alcohols are also widely used in chemical industry as solvents or as precursors (reagents) for synthesis of pharmaceutical products. The flowchart below shows some common reactions of one such alcohol, **W**, that has the molecular formula of $C_4H_{10}O$.

Alcohol **W** $C_4H_{10}O$

— aq alkaline iodine / heat → no yellow precipitate was formed

acidified $K_2Cr_2O_7$ / heat

hot $Al_2O_3$

Compound **U**

$CH_3CH_2CH=CH_2$ Compound **V**

+ Alcohol **W** / suitable catalyst, heat

$C_3H_7CO_2C_4H_9$ Compound **Y**

(I) Based on the information presented in the flowchart, deduce the following:
   - the name and classification of alcohol **W**
   - the names and skeletal structures of compounds **U** and **Y**
   - The type of reaction that converts alcohol **W** to compound **V.**

**W** is butan-1-ol , **W** is a primary alcohol

**U** is butanoic acid

**Y** is butylbutanoate
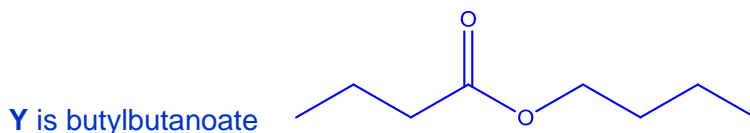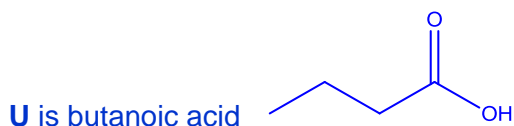
Dehydration / Elimination

(II) Write an equation for the reaction that occurs when alcohol **W** is heated with acidified potassium dichromate(VI) followed by immediate distillation.

[8]

$CH_3CH_2CH_2CH_2OH + [O] \rightarrow CH_3CH_2CH_2CHO + H_2O$

Molecular formula is NOT accepted
**[Total: 20]**