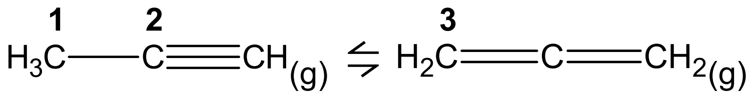
# VJC 2009 H1 Chemistry 8872/2 Suggested Answers

## Section A

Answer **all** questions in the space provided.

**1 (a)** Methylacetylene is an alkyne with the chemical formula $CH_3C≡CH$. It is a component of MAPP gas along with its isomer propadiene, which is commonly used in gas welding. Methylacetylene exists in equilibrium with its isomer, the mixture of methylacetylene and propadiene being called MAPD:



$$\overset{1}{H_3C}-\overset{2}{C}\equiv CH_{(g)} \rightleftharpoons H_2\overset{3}{C}=C=CH_{2(g)}$$

Methylacetylene propadiene,

**(i)** State the type of hybridisation, shape and number of sigma and pi bonds about

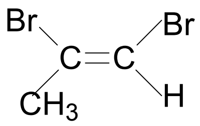
**I.** $C_1$ and $C_2$ of methylacetylene, and
**II.** $C_3$ of propadiene
in the table below.

| **Carbon** | **Hybridisation** | **Shape** | **No. of sigma bonds** | **No. of pi bonds** |
|---|---|---|---|---|
| **$C_1$** | $sp^3$ | Tetrahedral | 4 | 0 |
| **$C_2$** | sp | Linear | 2 | 2 |
| **$C_3$** | $sp^2$ | Trigonal planar | 3 | 1 |

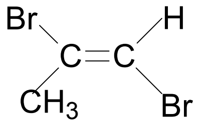
**(ii)** When methylacetylene reacts with $Br_2$ in $CCl_4$, a compound having the molecular formula of $C_3H_4Br_2$ is formed. Name the type of isomerism shown by the compound and draw all its possible isomers.

[5]

**Cis-trans isomerism or geometric isomerism**



**cis**



**trans**

**(b)** An experiment was carried out as follows to determine the standard enthalpy change of combustion of methylacetylene contained in the gas cylinder of a gas stove.

A large beaker of water was placed on the stove and heated. The temperature rise was recorded. The cylinder was weighed before and after the experiment to determine the mass of methylacetylene used. This process was known to be only 70% efficient. The following results were obtained.

Mass of methylacetylene before heating = 4.66 g
Mass of methylacetylene after heating = 2.16 g
Mass of water heated = 750 g
Temperature rise = 25.8$^{o}$C

Assume the heat capacity of water = 4.2 J $K^{-1}$ $cm^{-3}$

Based on the given data, calculate

**(i)** the heat absorbed by water

**Heat absorbed by water = $Vc\Delta T$**
**= 750(4.2)(25.8)**
**= 81270 J**
**= 81.3 kJ**

**(ii)** the heat given out by methylacetylene in the experiment

**Assuming 100% heat transfer,**

**Heat given by heating methylacetylene = 81270 x 100/70**
**= 116 100 J**
**= 116 kJ**

**(iii)** enthalpy change of combustion of methylacetylene

**enthalpy change of combustion of methylacetylene**
**= -116 100 / [(4.66- 2.16)/40]**
**= $-1.86 \times 10^{6}$ J $mol^{-1}$**
**= -1860 kJ $mol^{-1}$**

**(iv)** Hence, use the answer in **(b)(iii)** to calculate the enthalpy change of reaction for the conversion of methylacetylene to propadiene, given that the enthalpy change of combustion of propadiene is -1830 kJ $mol^{-1}$.

[5]

$$\Delta H_{rxn} = \sum \Delta H_c(\text{reactants}) - \sum \Delta H_c(\text{products})$$
$$= -1860 - (-1830)$$
$$= \underline{-30\ kJmol^{-1}}$$

[Total: 10]

**2** In nature, chlorine is abundantly found as the chloride ion, a component of the salt that is deposited in the earth or dissolved in the oceans.

The pH of the solutions of chlorides for the elements sodium to phosphorus is given below.

| compound | Sodium chloride | Magnesium chloride | Aluminium chloride | Silicon tetrachloride | Phosphorus pentachloride |
|---|---|---|---|---|---|
| pH of solution | 7 | 6.5 | 3 | 2 | 2 |

**(a)** Suggest the type of structure and bonding present in sodium chloride and silicon tetrachloride.

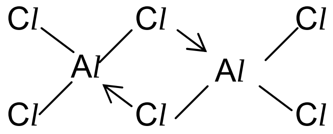
**NaC*l*** **: giant ionic structure; ionic bonding**
**SiC*l*$_4$** **: Simple molecular structure; covalent bonding**

[2]

**(b)** When solid aluminium chloride is heated above 180°C, a vapour is formed which has $M_r$ = 267. When this vapour is heated above 800°C, the vapour has $M_r$ = 133.5.

Draw the displayed formula of the vapour at 180°C to show its bonding.

[1]



**(c)** Write equations to account for the pH of aqueous solutions of

**(i)** Aluminium chloride :

$$[\mathrm{Al(H_2O)_6}]^{3+} + \mathrm{H_2O} \rightleftharpoons [\mathrm{Al(H_2O)_5(OH)}]^{2+} + \mathrm{H_3O^+}$$

**(ii)** Phosphorus pentachloride :

$$\mathrm{PCl_5} + 4\,\mathrm{H_2O} \rightarrow \mathrm{H_3PO_4} + 5\,\mathrm{HCl}$$

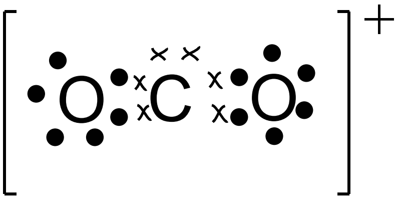
[2]

Chlorine forms various oxides and oxoanions as shown in the following.

| Chlorine oxides | $Cl_2O$ | $ClO_2$ | $Cl_2O_6$ | $Cl_2O_7$ |
|---|---|---|---|---|
| Chlorine oxoacids | $HClO$ | $HClO_2$ | $HClO_3$ | $HClO_4$ |

**(d)** $Cl_2O_6$ exists as singly charged ions in the solid state. The oxidation states of chlorine are +5 and +7 in the cation and anion respectively. Suggest the formulae of the ions and draw the dot-and-cross diagram for the **cation**.

Formulae of the ions: **$[ClO_2]^+$ and $[ClO_4]^-$**



[2]

**(e)** When chlorine gas reacts with water, hypochlorous acid, $HClO$ is formed according to the equation below.

$$Cl_2(aq) + H_2O(l) \rightleftharpoons HClO(aq) + H^+(aq) + Cl^-(aq)$$

At 25°C, 0.1 mole of the chlorine gas is bubbled into 2 $dm^3$ of distilled water. 55% chlorine remains in the equilibrium solution.

**(i)** Write an expression for $K_c$, stating its units.

$$\mathbf{K_c = \frac{[HClO][H^+][Cl^-]}{[Cl_2]} \quad mol^2dm^{-6}}$$

**(ii)** Calculate the value of $K_c$ for this reaction.

| | **$Cl_2(aq)$** | **$HClO(aq)$** | **$H^+(aq)$** | **$Cl^-(aq)$** |
|---|---|---|---|---|
| **Initial no. of moles** | **0.1** | **-** | **-** | **-** |
| **Change** | **-0.045** | **+0.045** | **+0.045** | **+0.045** |
| **Equilibrium** | **0.055** | **0.045** | **0.045** | **0.045** |
| **Concentration, mol $dm^{-3}$** | **0.055/2** | **0.045/2** | **0.045/2** | **0.045/2** |

**Show working**

$$K_c = [HClO][H^+][Cl^-] / [Cl_2]$$
$$= \frac{0.0225^3}{0.0275}$$
$$= 4.14 \times 10^{-4}\ mol^2dm^{-6}$$

[3]

[Total: 10]

Hydrogen cyanide was first isolated from a blue dye (Prussian blue) which had been known from 1704 and is now known to be a coordination polymer, $Fe_4[Fe^*(CN)_6]_3$.

In the year 2000, 732,552 tonnes of HCN were produced in the US. The most important process is the Andrussov oxidation invented by Leonid Andrussow at IG Farben in which methane and ammonia react in the presence of oxygen and platinum at about 1200 °C:

$$2\ CH_4 + 2\ NH_3 + 3\ O_2 \rightarrow 2\ HCN + 6\ H_2O$$

The energy needed for the reaction is provided by the partial oxidation of methane and ammonia. (1 tonne = 1 000 kg)

HCN is also obtainable from fruits that have a pit, such as cherries, apricots, apples, and bitter almonds, from which almond oil and flavoring are made. Many of these pits contain small amounts of cyanohydrins such as mandelonitrile and amygdalin, which slowly release hydrogen cyanide. An article mentioned that 100 g of crushed apple seeds can yield about 10 mg of HCN.

**(a)** What is the oxidation number of **(i)** Fe and **(ii)** Fe* in Prussian blue?

**(i) <u>+3</u>** **(ii) <u>+2</u>**

**(iii)** Find the percentage by mass of cyanide in Prussian blue.

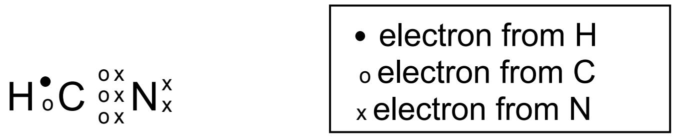
**Percentage by mass of cyanide in Prussian blue**

$$= \frac{26.0x6x3}{3[(26.0x6)+55.8]+(4x55.8)} \text{ x 100\%}$$

$$= \frac{468.0}{858.6} \text{ x 100\%}$$

**= <u>54.5%</u>**

**(iv)** Draw the dot-and-cross diagram for HCN and predict the shape of the molecule.



**Linear (2 bond pairs, 0 lone pairs on C).**

[3]

**(b)(i)** Assuming that the amount of HCN produced in US annually is the same, calculate the number of moles of HCN produced in US from 2000-2002.

**Total mass of HCN produced in 3 years = 732,552 x 3**

**= $2.20 \times 10^6$ tonnes**

**$M_r$ of HCN = 1.0 + 12.0 + 14.0 = 27.0**

**No. of moles of HCN =** $\frac{2.20 \times 10^6 \times 10^6}{27.0}$ **= $\underline{8.15 \times 10^{10} \text{ mol}}$**

**(ii)** What is the volume (in $dm^3$) of oxygen gas required via the Andrussov oxidation to form the amount of HCN mentioned in **(b)(i)** at r.t.p.?

**$3\ O_2 \equiv 2\ HCN$**

**No. of moles of $O_2$ = 3/2 x $8.15 \times 10^{10}$ = $1.22 \times 10^{11}$ mol**

**Volume of $O_2$ at r.t.p. = 24 x $1.22 \times 10^{11}$ = $\underline{2.93 \times 10^{12} \text{ dm}^3}$**

**(iii)** What is the role of platinum in the Andrussov oxidation?

**Pt is a <u>catalyst</u> which helps to <u>increase the rate of reaction</u>.**

[3]

**(c)** An apple has an average of 4 seeds and each seed weighs an average of 0.20 g. Find the mass of HCN that can be yielded from seeds of 10 apples.

**Mass of seeds from 10 apples = 10 x 4 x 0.20 = 8.00 g**

**Mass of HCN that can be produced from 10 apples**

$= \frac{8.00}{100} \times 10$ = **$\underline{0.800 \text{ mg}}$**

[1]

**(d) (i)** HCN gas is a highly poisonous gas that can cause permanent damage to the central nervous system. The toxic level of hydrogen cyanide gas in the air is about 0.001 mg dm$^{-3}$.

Express the toxic level of hydrogen cyanide gas in the air in terms of mol dm$^{-3}$.

**Toxic level of HCN =** $\frac{0.001 \text{x} 10^{-3}}{27.0}$

**= $\underline{3.70 \times 10^{-8}}$ $\underline{\text{mol dm}^{-3}}$**

**(ii)** How many molecules of HCN are present at this toxic level in 2 dm$^3$?

**No. of molecules of HCN at this toxic level**

**=** $\frac{0.001 \text{x} 10^{-3}}{27.0} \text{x} 6.02 \text{x} 10^{23} \text{x} 2$

**= $\underline{4.46 \times 10^{16}}$ $\underline{\text{molecules}}$**

**(iii)** When it rains, HCN dissolves in water to give an acid solution. If 2 dm$^3$ of air dissolves in 20 dm$^3$ of rainwater, find the concentration of H$^+$ in the acid solution using your answer in **d(i)**.

[Assume HCN dissociates completely in water]

**No. of moles of HCN in 2 dm$^3$ of air =** $3.70 \times 10^{-8} \times 2$

**= $\underline{7.40 \times 10^{-8}}$ $\underline{\text{mol}}$**

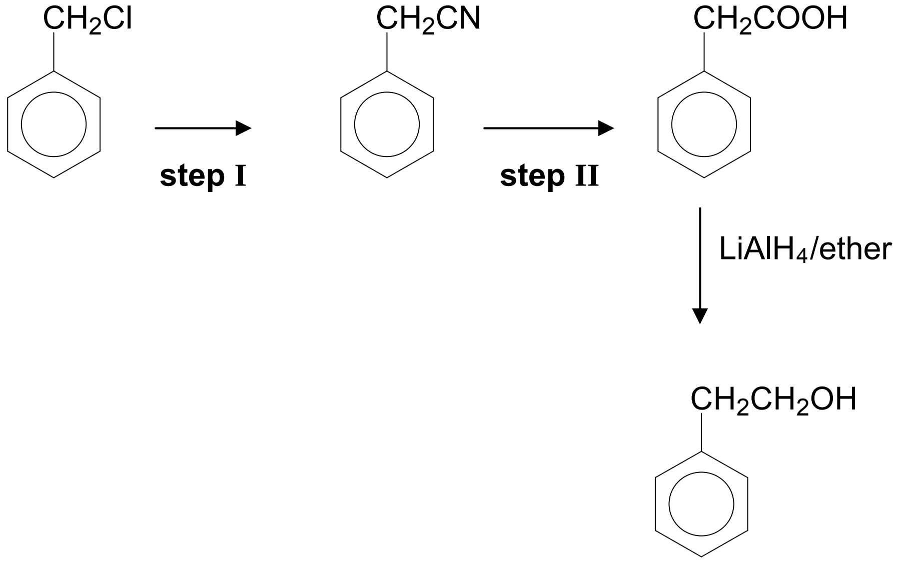
**$HCN (aq) \longrightarrow H^+ (aq) + CN^- (aq)$**

**$[H^+]$ =** $\frac{7.40 \times 10^{-8}}{20}$ **= $\underline{3.70 \times 10^{-9}}$ $\underline{\text{mol dm}^{-3}}$**

[3]

[Total: 10]

**4(a)** 2-Phenylethanol occurs naturally in the rose oil, much used in the perfume industry. It can be synthesized from chloromethylbenzene by the following series of reactions.



2-phenylethanol

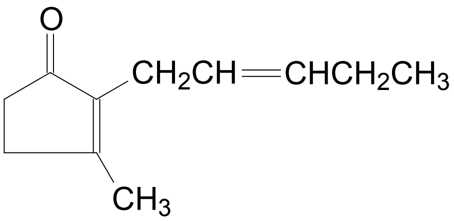
State the reagents, conditions and the type of reaction for steps **I** and **II**.

| Step | Reagent | Condition | Type of reaction |
|---|---|---|---|
| **I** | **KCN/ethanol** | **Reflux** | **Substitution** |
| **II** | **HCl(aq) or**<br>**$H_2O/H^+$(aq)** | **Heat** | **Hydrolysis** |

[3]

√ reagent, condition & type of reaction for each step 3 x 0.5m

**(b)** Jasmone is the other active ingredient in jasmine used in the perfume industry. It has the following structure:

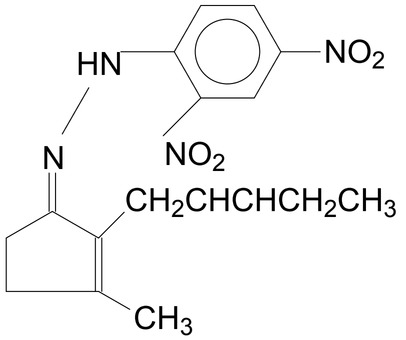
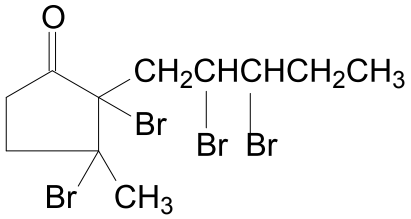


**(i)** How many stereoisomers exist in Jasmone?

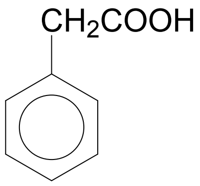
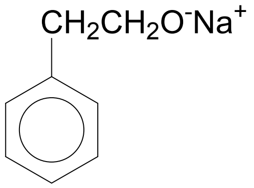
**2 cis-trans isomers**

**(ii)** Describe a positive test (state reagents, conditions, observations and draw structure of organic product with each compound) that would allow you to distinguish

**(I)** Jasmone from 2-phenylethanol

| Reagents and conditions | Observations | Structure of organic product |
|---|---|---|
| **2,4-dinitrophenylhydrazine/ room temperature** | **Jasmone gives orange precipitate but not 2-phenylethanol** |  |
| **OR** | | |
| **Bromine in $CCl_4$ / absence of light or/at room temperature** | **Jasmone decolourised reddish-brown bromine but not 2-phenylethanol** |  |

**(II)** 2-phenylethanol from Jasmone

| Reagents and conditions | Observations | Structure of organic product |
|---|---|---|
| **Acidified potassium dichromate/heat** | **2-phenylethanol will turn orange dichromate solution green but not Jasmone** |  |
| **OR** | **OR** | |
| **Sodium metal/room temperature** | **Effervescence for 2-phenylethanol but not Jasmone** |  |

[7]

[Total: 10]

## Section B

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

**5(a)** Ethanoic acid, $CH_3COOH$, is a typical weak acid. A solution of ethanoic acid was found to have a pH of 2.8.

**(i)** Explain the meaning of the term 'weak acid', including an equation in your answer.

**(ii)** Calculate the hydrogen ion concentration of this acid solution.

**(iii)** A titration was carried out between the ethanoic acid and 0.10 mol $dm^{-3}$ aqueous sodium hydroxide. State a suitable indicator that could be used to detect the end point and explain the reason for your choice.

[5]

**(i)** **Weak acid is one that does not dissociate completely to give $H^{+}$ ions/ ionizes partially to give $H^{+}$ ions**

$$CH_3COOH\ (aq) \rightleftharpoons CH_3COO^-\ (aq) + H^+\ (aq)$$

**(ii)** $[H^+] = 10^{-2.8} = 1.58 \times 10^{-3}$ **mol** $dm^{-3}$

**(iii)** **Phenolphthalein**

**At the end point, anion from salt $CH_3COONa$, hydrolyses in water as follows:**

$$CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$$

**Excess $OH^-$ ions renders the solution alkaline which falls within the working range of phenolphthalein.**

**[max:2]**

**(b)** When a solution of ethanoic acid reacts with magnesium metal, hydrogen gas is evolved. The volume of gas evolved for a particular experiment where magnesium was used in excess is given in the table:

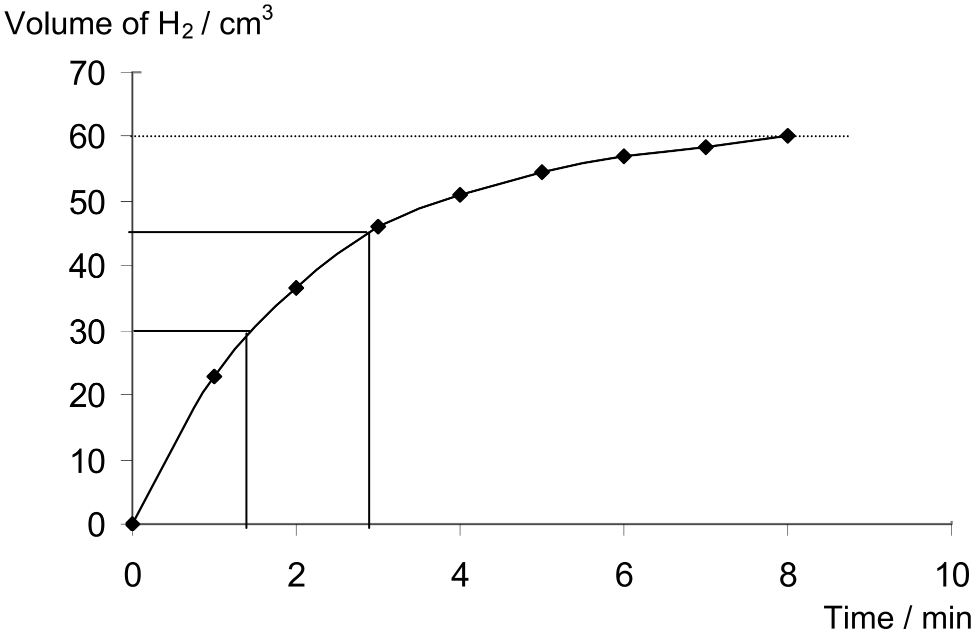
| Time/ min | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Total volume of gas/ $cm^3$ | 0 | 23.0 | 36.5 | 46.0 | 51.0 | 54.5 | 57.0 | 58.5 | 60.0 |

**(i)** Write an equation for the reaction between magnesium and ethanoic acid.

$$\mathbf{Mg + 2CH_3COOH \longrightarrow Mg(CH_3COO)_2 + H_2}$$

**(ii)** Plot the experimental results on graph paper.

From the graph, deduce with reasoning, the order of reaction with respect to ethanoic acid. Hence write a rate equation for the reaction.



**2 marks for graph – labeled axes , correct plot**

**Since half-life is constant at 1.5 minutes, reaction is first order wrt to acid. Must show 2 $t_{1/2}$ on graph**

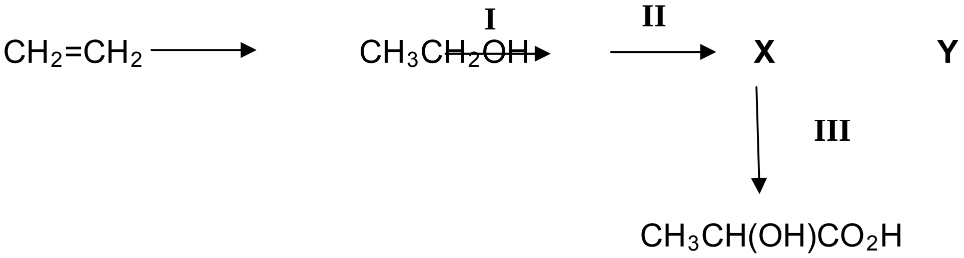
$$\mathbf{Rate = k\,[CH_3COOH]}$$

**(iii)** A separate experiment using powdered magnesium was used to react with the acid. Explain how this modification could affect the reaction rate.

[8]

**Powdered magnesium has greater surface area hence greater frequency of effective collisions between acid and metal hence rate increases.**

**(c)** The following reaction scheme was proposed to produce 2-hydroxy propanoic acid.



Suggest reagents and conditions for steps I to III.

Give the structures of the intermediates **X** and **Y**.

| Step | Reagents | Conditions |
|---|---|---|
| I | **$K_2Cr_2O_7$/ $H^+$** | **distil** |
| II | **HCN** | **Trace of NaCN or NaOH, room temperature** |
| III | **Aqueous $H_2SO_4$** | **heat** |

**(6 x 0.5)**

**X** **$CH_3CHO$**

**Y** **$CH_3CH(OH)CN$**

If the experiment in **(b)** was repeated using 2-hydroxypropanoic acid,

**(i)** state the total volume of gas evolved from the reaction;

**Expected volume of hydrogen gas = 120 $cm^3$**

**(ii)** explain your answer.

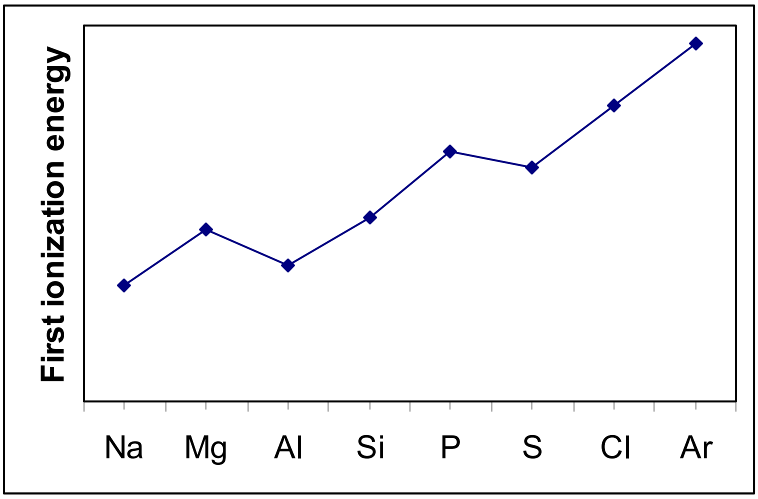
**<u>2 moles of OH groups</u> are present <u>per mole</u> of 2-hydroxypropanoic acid (<u>secondary alcohol and carboxylic acid groups</u>) which will react with 1 mole of Mg metal to produce 1 mole of hydrogen gas. Hence volume of gas evolved is <u>twice</u> that of the experiment in (b).**

[7]

[Total: 20]

**6(a)** Sketch a graph of the first ionization energies for sodium to argon and explain the relative values of the first ionization energies of magnesium and aluminium.

[2]



**1m for sketch, -½m for each mistake.**

**An s electron is being removed from Mg whereas a p electron is being removed from Al. Since an s electron has less energy than a p electron, more energy is required for its removal. [2]**

**(b)** A sample of magnesium oxide is contaminated with some aluminium oxide. By making use of the fact that Period 3 oxides have different acid-base properties, describe a simple method by which a pure sample of magnesium oxide can be obtained. Include an equation for any reaction that is utilized. [2]

**Add excess NaOH(aq).**
**Only aluminium oxide will dissolve to form a soluble complex:**
**$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$**
**The mixture is then filtered and the MgO residue is washed with distilled water. [2]**

**(c)** Another Period 3 oxide, sulfur trioxide dissolves in water to form sulfuric acid, $H_2SO_4$ which can be converted into peroxodisulfuric acid, $H_2S_2O_8$ via the two-step process below, with chlorosulfonic acid, $HSO_3Cl$, as an intermediate:

$$H_2SO_4 + HCl \rightarrow HSO_3Cl + H_2O$$
$$H_2O_2 + 2HSO_3Cl \rightarrow H_2S_2O_8 + 2HCl$$

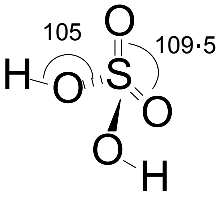
**(i)** The boiling point of $H_2SO_4$ is 290°C whereas that of $HSO_3Cl$ is 152°C. By comparing the structures of the two compounds, explain the difference in the boiling points.

**The molecular formulae suggest that the structure of chlorosulfonic acid is derived from that of sulfuric acid, with 1 –OH group being replaced by –Cl.**

**Hence the extent of hydrogen bonding is less between chlorosulfonic acid molecules which explains its lower boiling point. [2]**

**(ii)** Give the displayed formula of the $H_2SO_4$ molecule, showing the spatial arrangement and estimated bond angle around any one sulfur atom and one oxygen atom.

[5]



***Comments***
***displayed formula***
***bond angle and tetrahedral shape with wedge formula around S***
***bond angle and bent shape around any one O [3]***

**(d)** Aluminium oxide reacts with chlorine trifluoride, $ClF_3$, according to the following equation:

$4ClF_3(g) + 2Al_2O_3(s) \rightarrow 4AlF_3(s) + 2Cl_2(g) + 3O_2(g) \quad \Delta H_r^{\ominus} = -1420\ \text{kJ mol}^{-}$
1

**(i)** Write the equation which corresponds to the standard enthalpy change of formation of chlorine trifluoride.

$$\tfrac{1}{2}Cl_2(g) + 3/2F_2(g) \rightarrow ClF_3(g) \quad [1]$$

**(ii)** Some standard enthalpy changes are given below:

| | |
|---|---|
| Enthalpy change of formation of $AlF_3(s)$ | $-1350\ \text{kJ mol}^{-1}$ |
| Enthalpy change of combustion of $Al(s)$ | $-840\ \text{kJ mol}^{-1}$ |

Using the data given in the question, calculate the enthalpy change of formation of chlorine trifluoride.

$$\Delta H_f(Al_2O_3) = 2\ \Delta H_c(Al) = 2(-840) = -1680\ \text{kJ mol}^{-1}$$
$$\Delta H_r = \sum(\Delta H_f)_{products} - \sum(\Delta H_f)_{reactants}$$
$$-1420 = 4(-1350) - 4\ (\Delta H_f)_{ClF3} - 2(-1680)$$
$$(\Delta H_f)_{ClF3} = -155\ \text{kJ mol}^{-1} \quad [1½]$$

**(iii)** Using your answer in **d(ii)** and data from the *Data Booklet*, estimate the average bond energy of the C*l*-F bond.

**Consider ½ $Cl_2(g)$ + 3/2 $F_2(g)$ → $ClF_3(g)$**
**From the Data Booklet, B.E. of C*l*–C*l* = 244, F–F = 158**
**-155 = ∑( B.E.)$_{reactants}$ - ∑( B.E.)$_{products}$**
**= ½ (244) + 3/2(158) – 3 B.E.(C*l*–F)**
**B.E. (C*l*–F) = 171 kJ mol$^{-1}$ [1½]**

**(iv)** $BrF_3$ reacts with aluminium oxide in a way analogous to $ClF_3$. Assuming that the standard enthalpy change of this reaction is known, explain why a method similar to that used in **(iii)** will yield a less accurate value for the bond energy of the Br–F bond.

[5]

**$Br_2$ (OR $BrF_3$) are in the liquid state whereas bond energy values can only be used to calculate the enthalpy change of gaseous reactions. [1]**

**(e) (i)** Define the term *lattice energy.*

**Lattice energy is the heat evolved when one mole of an ionic solid is formed from its isolated gaseous ions from an infinite distance apart under standard conditions. [1]**

**(ii)** State and explain whether the oxide or fluoride ion is smaller.

**$F^-$ is a smaller ion.**
**Both $O^{2-}$ and $F^-$ are isoelectronic ions and hence shielding effect is similar for both ions. However, $F^-$ has a higher nuclear charge which causes its outermost electrons to experience a higher effective nuclear charge and be pulled closer to the nucleus. [2]**

**(iii)** Refractories are heat-resistant compounds used to line furnaces. Which compound, magnesium oxide or magnesium fluoride, is more suitable for use as a refractory? Explain your answer.

[6]

**The higher charge of $O^{2-}$ suggests that MgO has a higher LE while its bigger ionic size suggests otherwise.**
**The anionic charge is the more important factor.**

**OR**
**Lattice energy α $q_+q_- / (r_+ + r_-)$. However, the higher charge of $O^{2-}$ outweighs its larger ionic size.**

**Hence MgO has a higher melting point OR lattice energy and hence is more suited for use as a refractory. [3]**

[Total: 20]

**7 (a)** The table below shows the boiling points of some organic compounds.

| Name of compound | Molecular Formula | Boiling point /°C |
|---|---|---|
| Methane | $CH_4$ | -162 |
| Ethane | $C_2H_6$ | -88 |
| Propane | $C_3H_8$ | -42 |
| Butane | $C_4H_{10}$ | 0 |
| *Cis*-but-2-ene | $C_4H_8$ | 4 |
| *Trans*-but-2-ene | $C_4H_8$ | 1 |
| Propan-1-ol | $CH_3CH_2CH_2OH$ | 97 |
| Propanal | $CH_3CH_2CHO$ | 49 |
| Propanone | $CH_3COCH_3$ | 56 |

**(i)** Explain the difference between the boiling points of *cis*-but-2-ene and *trans*-but-2-ene.

**The intermolecular forces between cis-but-2-ene are <u>permanent dipole-permanent dipole</u> forces of attraction which are <u>stronger</u> than the <u>dispersion</u> forces between trans-but-2-ene molecules and hence requires <u>more energy</u> to overcome. Thus cis-but-2-ene has <u>higher</u> b.p..**

**(ii)** Explain why the boiling point of propan-1-ol is higher than that of propanal and propanone.

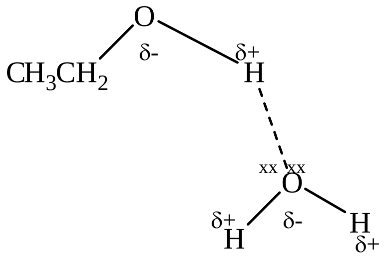
**Propan-1-ol has <u>higher</u> b.p. as their molecules can form <u>stronger</u> intermolecular <u>hydrogen bonding</u> which requires more energy to overcome, whereas propanal and propanone molecules can only form weaker intermolecular <u>permanent dipole-permanent dipole</u> forces of attraction.**

**(iii)** If the intermolecular bonding in propan-1-ol is the same as that in the alkanes, predict a value for its boiling point. Explain your answer.

**The intermolecular forces between alkane molecules are <u>weak dispersion forces</u> of attraction (induced dipole-induced dipole).**
**Dispersion forces are <u>affected by number of electrons in the molecule</u>. Since the <u>molecular formula of propan-1-ol and hence number of electrons is about the same as that of butane</u>, its boiling point will be <u>0°C</u>, if the type of intermolecular forces in propan-1-ol is also dispersion forces.**

**(iv)** As compared to the alkanes, alcohols are more soluble in water. Draw a diagram to show the interaction between propan-1-ol molecules and water molecules.

[7]



Dotted bond denotes **hydrogen bond**

**(b)** 0.10 mole of an organic compound **A**, $C_xH_yO_z$ gives 0.40 mole of carbon dioxide and 0.40 mole of water vapour upon complete combustion. 8.8 g of **A** when vapourised, was found to occupy 2.4 dm$^3$ at room temperature and pressure.

Compound **A** does **not** react with aqueous sodium hydroxide. However, it forms a pale yellow precipitate when warmed with alkaline aqueous iodine. **A** reacts with $SOCl_2$ and liberates gaseous products. A silver mirror is observed when **A** is warmed with Tollen's reagent.

Compound **B**, an isomer of **A**, is neutral to litmus. On treatment with hot aqueous sodium hydroxide, **B** yields **C**, $C_2H_3O_2Na$ and **D**, $C_2H_6O$.

**(i)** Determine the molecular formula of **A**.

$$C_xH_yO_z(l) + \left(x+\frac{y}{4}-\frac{z}{2}\right)O_2(g) \rightarrow xCO_2(g) + \frac{y}{2}H_2O(g)$$

**0.10 mol** **0.40 mol** **0.40 mol**

**Comparing mole ratio,**

**$x = 4, y = 8$**

**Molecular formula of E is $C_4H_8O_z$**

**No. of mol of A at r.t.p = $\frac{2.4}{24.0}$ = 0.100 mol**

**Molar mass of A = $\frac{8.8}{0.100}$ = 88.0 g mol$^{-1}$**

**$M_r$ of A = 88.0**

**To solve for the value of $z$:**

$$4(12) + 8(1) + z(16) = 88$$
$$z = 2$$

**Molecular formula of A is $C_4H_8O_2$**

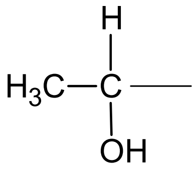
(ii) Deduce, with reasoning, the structures of **A**, **B**, **C** and **D**.
[Chemical equations are not required.]

[10]

**A does not undergo neutralisation with aqueous NaOH**
**⇒ A is not acidic (phenol & carboxylic acid absent)**

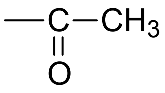
**A undergoes oxidative cleavage when warmed with alkaline aqueous $I_2$**
**⇒ pale yellow ppt is $CHI_3$**

**⇒ A contains the structural unit**



$\mathrm{H_3C-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle OH}{|}}{C}}-}$

**or**



$\mathrm{-\underset{\underset{\displaystyle O}{\|}}{C}-CH_3}$

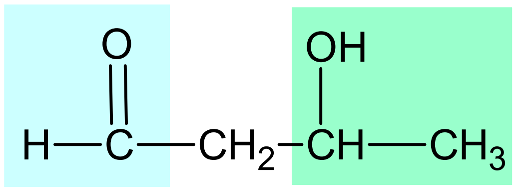
**A undergoes substitution with $SOCl_2$.**
**⇒ A is an alcohol**

**A undergoes oxidation with Tollens' reagent.**
**⇒ A is an aldehyde**

**B has the same molecular formula $C_4H_8O_2$ as A and is neutral to litmus.**
**⇒ B is an ester**

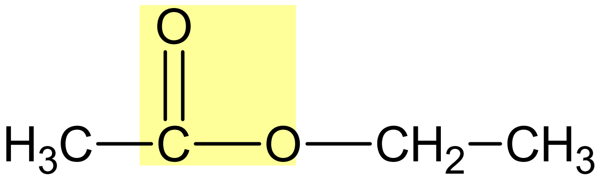
**B undergoes basic hydrolysis to form G and H.**
**⇒ B is an ester**
**⇒ C is a carboxylate salt (sodium ethanoate)**
**⇒ D is an alcohol (ethanol)**

**A**



$\mathrm{H-\overset{\overset{\displaystyle O}{\|}}{C}-CH_2-\overset{\overset{\displaystyle OH}{|}}{CH}-CH_3}$

**B**



$\mathrm{H_3C-\overset{\overset{\displaystyle O}{\|}}{C}-O-CH_2-CH_3}$

**C**

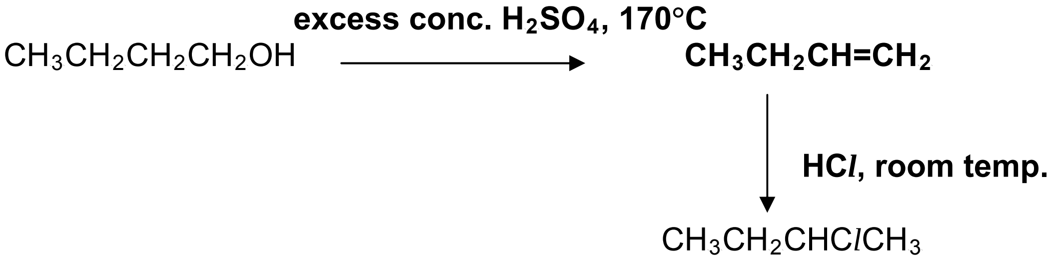
$CH_3CO_2^-Na^+$

**D**

$CH_3CH_2OH$

**(c)** Suggest reagents and conditions for converting butan-1-ol to 2-chlorobutane. Draw the structure of the intermediate product.

[3]



[Total: 20]

**Answers for H1 Chemistry Prelim Paper 2009**

| | | | | | |
|---|---|---|---|---|---|
| **1 C** | **6 B** | **11 C** | **16 A** | **21 D** | **26 B** |
| **2 A** | **7 A** | **12 B** | **17 D** | **22 B** | **27 D** |
| **3 A** | **8 B** | **13 D** | **18 B** | **23 C** | **28 C** |
| **4 B** | **9 D** | **14 B** | **19 D** | **24 A** | **29 A** |
| **5 C** | **10 C** | **15 C** | **20 D** | **25 C** | **30 A** |