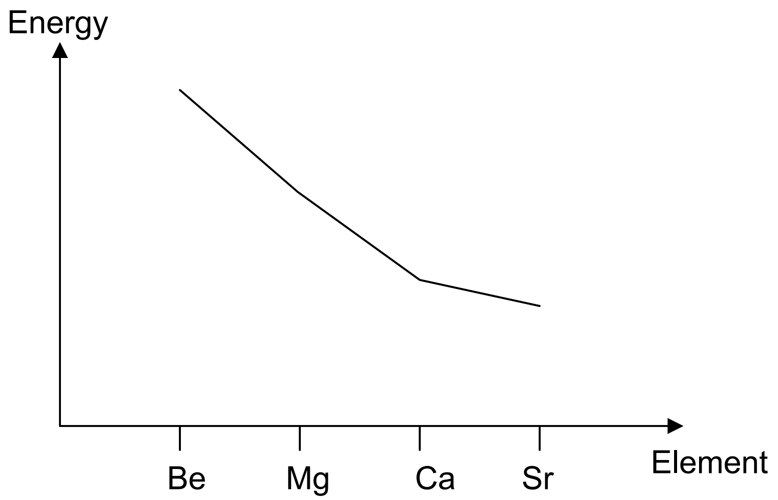
# Answers for MJC 2008 H1 Chem Prelim Paper 2

**1(a)** The graph below represents the first ionization energies from beryllium to strontium. Explain the general trend presented by the graph.

**[2]**



Down the group, from Be to Mg,

Nuclear charge increases as proton number increases.
Valence electrons are added to a next outer shell
⇒ valence electrons are further away from the nucleus.

Significant increase in shielding effect outweighs the increase in nuclear charge.

Effective nuclear charge decreases
Weaker electrostatic force of attraction between nucleus and valence electrons

⇒ Ionization energy decreases

**(b)** Write the electronic configurations of chromium ion, $Cr^{3+}$.

**[1]**

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

**(c)** Between $Cr^{3+}$ and $F^-$, state and explain which ion would be deflected the most when they are passed through an electric field?

**[2]**

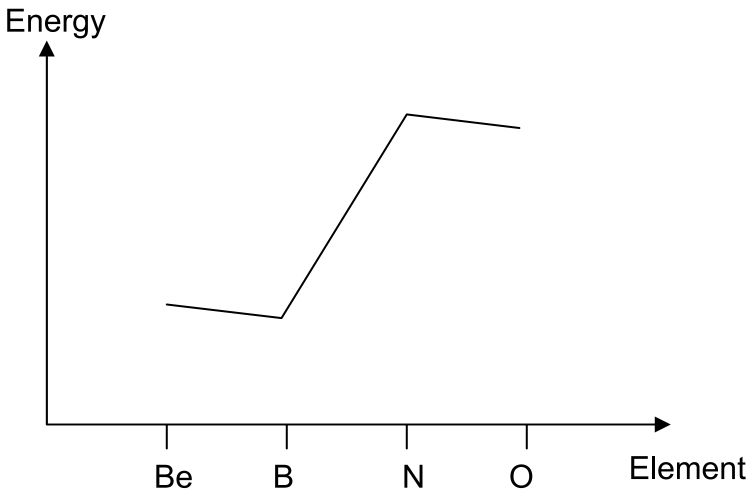
Extent of deflection $\propto \frac{\mathbf{q}}{\mathbf{m}}$

$\frac{q}{m}$ ratio for $Cr^{3+}$ $= \frac{\mathbf{3}}{\mathbf{52}} = 0.0577$

$\frac{q}{m}$ ratio for $F^-$ $= \frac{\mathbf{1}}{\mathbf{19}} = 0.0526$

Therefore $Cr^{3+}$ will deflect the most

**(d)** The first ionization energies of beryllium, boron, nitrogen and oxygen are presented in the graph below.



Explain the decrease in ionization energy from:

**(i)** Be to B

Be: $1s^2\ 2s^2$ B: $1s^22s^22p^1$

- The 2p electron in B is at a higher energy level than the 2s electron in Be
- Hence, less energy is required to remove the 2p electron from B compared to Be.

**(ii)** N to O

**[3]**

N: $1s^2\ 2s^2\ 2p^3$ O: $1s^2 2s^2 2p^4$

- There is inter-electron repulsion between the paired electrons in the 2p orbital of O.
- Hence, less energy is required to remove the 2p electron from O compared to N

**[Total: 8]**

**2** Certain enthalpy changes such as enthalpy change of formation cannot be found by direct experiment. Instead it can be found by applying Hess' Law to simple energy cycles.

**(a)** 500 $cm^3$ of water was heated in a calorimeter by burning a 1.30 g of butane, $C_4H_{10}$. The temperature rise of the water recorded was 30°C. Calculate the enthalpy change of combustion of butane.

**[2]**

Heat absorbed, Q = $mc\Delta T$
= 500 x 4.18 x 30 J
= 62700 J

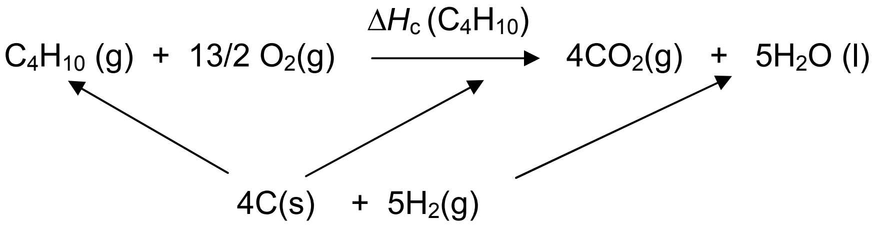
No of moles of butane burnt = 1.30/58
= $2.24 \times 10^{-2}$

Heat absorbed by water, Q = Heat released by combustion of butane, Q'

$$Q' = \Delta H_c\,(C_4H_{10}) \times n$$

$$\Delta H_c\,(C_4H_{10}) = -\frac{62700}{2.24 \times 10^{-2}} = \underline{\mathbf{-2799\ kJ\ mol^{-1}}}$$

**(b)** The energy cycle for the complete combustion of butane is shown below.



Using your answer in part (a) and the following enthalpy changes, calculate the enthalpy change of formation of butane.

$\Delta H_c\,(C) = -\,393.5\ \text{kJ mol}^{-1}$
$\Delta H_c\,(H_2) = -\,285.8\ \text{kJ mol}^{-1}$

**[1]**

By Hess's Law,

$$\Delta H_f\,(C_4H_{10}) = 4\Delta H_c\,(C) + 5\Delta H_c\,(H_2) - \Delta H_c\,(C_4H_{10})$$

$$= 4(-393.5) + 5(-285.8) - (-2799)$$

$$= \underline{\mathbf{-204\ kJ\ mol^{-1}}}$$

**(c)** Chlorofluorocarbons, CFCs, are small alkane molecules where a few of the hydrogen atoms have been replaced by chlorine atoms and fluorine atoms. The use of CFCs in daily life products have been banned in many countries because CFCs are environmentally hazardous.

**(i)** State one use of CFCs.

CFCs commonly used as refrigerants or aerosols

(ii) Why is CFCs an environmental concern?

[1]

CFCs causes the destruction/depletion of the ozone layer.

**[Total: 4]**

**3(a)** Explain what is meant by the *lattice energy* of an ionic compound.

**[1]**

The energy released when one mole of the ionic compound is formed from its constituent gaseous ions at 298K and 1 atm.

**(b)** Based on their lattice energies, explain why MgO is preferably used as refractory lining for furnaces rather than $MgCl_2$,

**[2]**

radius of anion, $r_-$ : $O^{2-} < Cl^-$
charge of anion, $r_-$ : $O^{2-} > Cl^-$

$| \Delta H_{latt} |$ : $MgO > MgCl_2$

$Mg^{2+}$ and $O^{2-}$ are held together by stronger electrostatic forces of attraction.

Hence MgO has a higher melting which makes it a better choice as a refractory lining.

**(c)** $MgCl_2$ is highly soluble in water and MgO is only sparingly soluble in water. Give an explanation for the observation.

**[2]**

Both $MgCl_2$ and MgO have giant ionic lattice structure. $MgCl_2$ is highly soluble because the formation of ion-dipole bonds release energy which causes the dissociation of ions from the lattice structure.

MgO is only sparingly soluble because of its highly exothermic lattice energy.

**(d)** $MgCl_2$ and MgO are added to separate aqueous solutions, each containing a few drops of phenolphthalein. Predict, with reasoning, the expected observations. Support your answers with any relevant equations.

**[3]**

For $MgCl_2$, the phenolphthalein solution will remain colourless as the $Mg^{2+}$ ions will polarised water to such an extent that hydrolysis occurs to give a slightly acidic solution (pH ≈ 6.5)

$MgCl_2\,(s) + aq \rightarrow [Mg(H_2O)_6]^{2+}\,(aq) + 2Cl^-\,(aq)$

$[Mg(H_2O)_6]^{2+}(aq) \rightleftharpoons [Mg(H_2O)_5(OH)]^+(aq) + H^+(aq)$

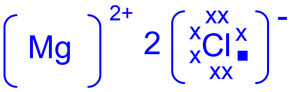
For MgO, the phenolphthalein solution will turn pink as MgO dissolves slightly in water to give a weakly alkaline solution (pH ≈ 9)

$MgO\,(s) + H_2O(l) \rightleftharpoons Mg^{2+}\,(aq) + 2OH^-(aq)$

**(e)** Unlike magnesium chloride, aluminium chloride is a covalent compound. In the gaseous state, $AlCl_3$ has an apparent $M_r$ of 267.0.

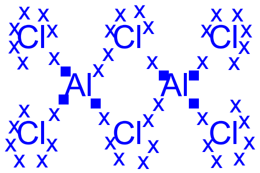
Draw a dot-and-cross diagram to illustrate the bonding of

**(i)** Magnesium chloride



**(ii)** Aluminium chloride in the gaseous state

**[2]**



**(f)** Unlike all other Group II oxides, beryllium oxide, BeO, is amphoteric in nature, like aluminium oxide, $Al_2O_3$. Suggest a reason for their similarity in chemical properties.

**[1]**

The similarity is due to the diagonal relationship. Al and Be have similar charge density.

**[Total: 11]**

**4(a)** Certain chlorides and oxides of period 3 elements dissolve in water.

Elements **K**, **L** and **M** are in Period 3. Chlorides of **K** and **L** dissolve in water to form a neutral solution (pH = 7) and an acidic solution (pH ≈ 3) respectively. Oxide of element **M** is found to be insoluble in water, whereas its chloride forms a strongly acidic solution (pH ≈ 2).

**(i)** Suggest the identity of elements **K** and **L** and with the aid of equations, explain the above observations as fully as you can.

**[5]**

Element K is Na.

$Na^+$ ion has low charge density. Hence, only hydration takes place with no hydrolysis, hence NaCl (aq) is neutral with pH 7.

$NaCl (s) + aq \rightarrow Na^+ (aq) + Cl^- (aq)$

Element L is A*l*.

$Al_2Cl_6$ undergoes both hydration and hydrolysis in water. $Al^{3+}$ has very high charge density. Hence, $Al^{3+}$ ion polarises its surrounding water molecules, weakening the O-H bond such that $H^+$ ions are released into solution. The solution is acidic (pH≈3).

$Al_2Cl_6(s) + 12H_2O(l) \rightarrow 2[Al(H_2O)_6]^{3+}(aq) + 6Cl^-(aq)$
$[Al(H_2O)_6]^{3+}(aq) \rightarrow [Al(H_2O)_5(OH)]^{2+}(aq) + H^+(aq)$

**(ii)** Identify element **M** and with the aid of an equation, explain why the chloride of **M** forms a strongly acidic solution.

**[2]**

Element M is Si.
$SiCl_4$ undergo complete hydrolysis in water to give strongly acidic solution (pH ≈ 2).

$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$

**[Total: 7]**

**5** Calcium hydroxide is a white solid which is only sparingly soluble in water. 1.85 g of $Ca(OH)_2$ will dissolve in 100 $cm^3$ of water. Ammonia is a pungent gas which is very soluble, 89.9 g of $NH_3$ dissolves in 100 $cm^3$ of water. The pH of saturated aqueous $Ca(OH)_2$ and $NH_3$ solution are 13.7 and 13.0 respectively.

Both compounds are useful for agricultural purposes. Calcium hydroxide can be used to control the pH level in soil while ammonia is reacted with nitric acid to produce ammonium nitrate for fertilizing uses.

In gardening, the pH level of the soil is very important. Soil pH is an important consideration for farmers and gardeners for several reasons, including the fact that many plants and soil life forms prefer either alkaline or acidic conditions. However, some diseases tend to thrive when the soil is too alkaline or acidic, and that the pH can affect the availability of nutrients in the soil.

Certain plants such as hydrangea will form flowers of different colours according to the pH of the soil. To encourage blue hydrangea flowers, the soil must have a pH of 5.2–5 and pH of 6.0–6.2 for pink blooms.

To raise the pH level of the soil, the gardener can adopt the liming method. The two common choice of lime is garden lime containing $CaCO_3$ and quicklime, CaO.

Quicklime is caustic and cannot be applied directly to the soil, instead it is spread around the land in heaps to absorb rain and form slaked lime ($Ca(OH)_2$), which is then spread on the soil. Their use is prohibited by the organic standards and while fast acting, the effect is short lived in comparison to the garden lime.

**(a)** Define the term pH.

**[1]**

$pH = -lg[H^+]$

**(b)** **(i)** Calculate the concentration in mol $dm^{-3}$ of

**I** saturated calcium hydroxide solution

$[Ca(OH)_2]_{\text{saturated solution}} = \underline{\mathbf{0.247\ moldm^{-3}}}$

**II** saturated ammonia solution

**[2]**

$[NH_3]_{\text{saturated solution}} = \underline{\mathbf{52.9\ moldm^{-3}}}$

**(ii)** Hence, explain whether calcium hydroxide is a strong or weak base.

**[2]**

$[Ca(OH)_2] \equiv 2[OH^-]_{Ca(OH)2}$

$[OH^-]_{Ca(OH)2} = 2 \times 0.247$
$= 0.494 \text{ moldm}^{-3}$

$[OH^-] = 10^{-0.3}$
$= 0.501 \text{ moldm}^{-3}$

Since $[OH^-] = [OH^-]_{Ca(OH)2}$
$\Rightarrow$ $Ca(OH)_2$ 100% dissociated.
$Ca(OH)_2$ is a strong base.

**(b)** A blue hydrangea is planted in a plot of soil. The pH of the soil is 5.1 and the volume of water in the soil is 500 $cm^3$.

**(i)** Calculate the minimum concentration of $H^+$ ions required for the blue hydrangea to change to pink color.

Minimum pH for pink hydrangea = 6.0

$[H^+]_{final} = 10^{-6.0}$
$= \underline{\mathbf{1.00 \times 10^{-6} \text{ moldm}^{-3}}}$

**(ii)** Calculate the minimum volume of $4\text{x}10^{-5}$ mol $dm^{-3}$ $Ca(OH)_2$ needed to change the color of the hydrangea to pink.
(*Ignore the contribution of $H^+$ and $OH^-$ ions from the auto-ionisation of water*)

**[3]**

Let the volume of hydroxide ions to be added be V.

$[H^+]_{initial} = 10^{-(5.1)}$
$= 7.943 \times 10^{-6} \text{ moldm}^{-3}$
$H^+ \equiv OH^-$

Initial number of moles of $H^+ = 7.943 \times 10^{-6} \times 0.5$
$= 3.972 \times 10^{-6}$

Number of moles of $OH^-$ required to react with $H^+ = 2 \times 4 \times 10^{-5} \times V$

Number of moles of $H^+$ unreacted $= 3.972 \times 10^{-6} - 8 \times 10^{-5} \times V$

$$[H^+]_{final} = \frac{[H^+]_{initial} - ([OH^-] \times V)}{0.5 + V}$$

$V = \underline{\mathbf{0.0429 \text{ dm}^3}}$

**(c)** Suggest why garden lime has a longer lasting effect than quicklime?

**[1]**

Garden lime has a longer lasting effect as the $CO_3^{2-}$ is a weak base and will only undergo partial dissociation to release $OH^-$ ions therefore the release of $OH^-$ ions will be over a period of time.

**(d)** A common advice given to aspiring gardeners is: “Never lime and fertilize at the same time”. Explain the rationale behind the advice.

**[1]**

Lime is basic ($CaCO_3$ and $Ca(OH)_2$) and fertilizers such as $NH_4NO_3$ are acidic. Therefore the lime and fertilizer will undergo neutralization reaction, thus rendering them useless.

**[Total: 10]**

## Section B (40 Marks)

*Answer **two** of the three questions in this section.*
*Begin each section on a fresh page.*

**6(a)** A commonly used laboratory procedure to test for the presence of manganese (II), $Mn^{2+}$ ions is to react them with a sodium salt, Na**R**O**ₙ**, where **R** is a period 6 element. A positive test for $Mn^{2+}$ is indicated by the formation of a dark purple colour due to the presence of $MnO_4^-$ ions in solution. It is found in an experiment that 30.00 $cm^3$ of 0.1 mol $dm^{-3}$ of $Mn^{2+}$ reacts with 15.00 $cm^3$ of 0.5 mol $dm^{-3}$ of $NaRO_n$. In the process, aqueous $R^{3+}$ ion is formed.

**(i)** Let **x** be the oxidation number of **R** in $NaRO_n$. Copy the half-equation as shown below onto your writing paper and complete the half-equation by filling in the blank.

$$R^{x+} + \boxed{(x - 3)}\ e \rightarrow R^{3+}$$

**(ii)** Calculate the number of moles of $Mn^{2+}$ required to react with 1 mole of $NaRO_n$.

No. of moles of $NaRO_n$ in 15.00 $cm^3$ = $7.50 \times 10^{-3}$

No. of moles of $Mn^{2+}$ in 30.00 $cm^3$ = $3.00 \times 10^{-3}$

No. of moles of $Mn^{2+}$ that reacts with 1 mole of $NaRO_n$

$$= \frac{3 \times 10^{-3}}{7.5 \times 10^{-3}}$$

$= \underline{\mathbf{0.4}}$

**(iii)** Hence, deduce the oxidation number of **R** in $NaRO_n$ and the value of **n**.

Balancing electrons:
**(x - 3)** = 0.4 x 5
**x =** $\underline{\mathbf{+5}}$

To find **n**,
(+1) + (+5) + **n**(-2) = 0
**n** = $\underline{\mathbf{3}}$

**(iv)** The formula mass of Na**R**$O_n$ is 280.0. Determine the Ar of **R** and suggest the identity of **R**.

**[7]**

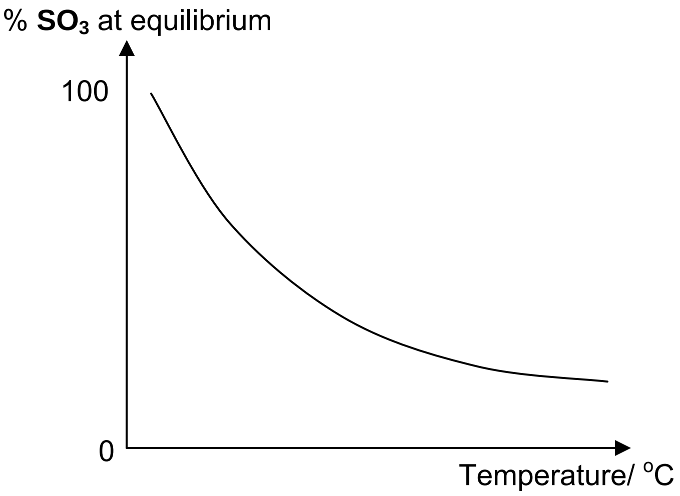
23 + (Ar of **R**) + 16 x 3 = 280
Ar of **R** = **209**

**R** is **Bi**

**(b)** For $MnO_4^-$ ions to act as an oxidizing agent, it has to be acidified with sulphuric acid. Sulphuric acid is manufactured by the Contact Process which involves the following reaction:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The percentage of $SO_3$ obtainable at equilibrium is plotted against the operating temperature.



**(i)** Explain whether the formation of $SO_3$ is an exothermic or endothermic process.

When temperature increased, % $SO_3$ at equilibrium decreases, which means backward reaction is favored.

By Le Chatelier's Principle, when temperature increases, the equilibrium position will shift to favor the endothermic reaction to absorb heat

⇒ Backward reaction is endothermic.

⇒ Forward reaction is exothermic

Therefore the **formation of $SO_3$ is exothermic**

**(ii)** Write an expression for the equilibrium constant, $K_c$.

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

**(iii)** Given that in a 3 $dm^3$ vessel, there are 0.2 moles of $SO_2$, 0.3 moles of $O_2$ and 4 moles of $SO_3$ at equilibrium. Calculate the $K_c$ value.

**[4]**

$K_C$ = **4000 $mol^{-1}dm^3$**

**(c)** **(i)** Describe the shapes and state the bond angles of $SO_2$ and $SO_3$. Explain their shapes in terms of the numbers and types of electron pairs they contain.

There are 3 bond pairs and 0 lone pairs about S in $SO_3$.
To minimize repulsion and maximize stability, the 3 electron pairs are directed to the corners of an equilateral triangle.
Shape of $SO_3$ is **trigonal planar** with bond angle of **$120^o$**.

There are 2 bond pairs and 1 lone pairs about S in $SO_2$.
To minimize repulsion and maximize stability, the 3 electron pairs are directed to the corners of an equilateral triangle.
Lone pair – Bond pair repulsion > Bond pair – Bond pair repulsion
Shape of $SO_2$ is **bend** with bond angle of **$118/119^o$**.

**(ii)** Indicate whether the $SO_2$ and $SO_3$ are polar or non-polar.

$SO_3$ is **non-polar**.
$SO_2$ is **polar**.

**(iii)** Sulphur dioxide ($SO_2$) and sulphur trioxide ($SO_3$) have different boiling points as shown in the table below.

| **Compound** | **Boiling Point / °C** |
|---|---|
| $SO_2$ | -10 |
| $SO_3$ | 45 |

With reference to the structure and bonding, explain why $SO_2$ and $SO_3$ have different boiling points.

**[7]**

$SO_2$ and $SO_3$ have simple molecular structures . Molecular size of $SO_3$ is larger than $SO_2$. The extent of distortion of electron cloud in $SO_3$ is greater than $SO_2$. More energy is required to break the more extensive and stronger van der Waals forces between $SO_3$ molecules. Hence, the boiling point of $SO_3$ is higher than $SO_2$.

**(d)** A few drops of sulphuric acid were added to a solution containing equal amounts of $H_2CO_3$ and $NaHCO_3$. With the aid of an equation, explain the change in pH of the solution.

[2]

When a small amount of $H_2SO_4$ is added,

$HCO_3^- + H^+ \rightarrow H_2CO_3$

$H^+$ is removed as $H_2CO_3$.
$[H^+]$ is slightly changed and pH of the solution remains fairly constant.

**[Total: 20]**

**7(a)** Ethyl propanoate, an ester, is found naturally in apple juice, grapefruit peel and strawberries. Ethyl propanoate can be hydrolysed by aqueous NaOH.

$$C_2H_5OCOCH_2CH_3 + OH^- \rightarrow C_2H_5OH + {}^-OCOCH_2CH_3$$

The initial rate of the hydrolysis reaction between the ester and NaOH was measured in a series of experiments at a constant temperature. The results are obtained below:

| **Experiment** | **Initial conc. of NaOH / mol dm$^{-3}$** | **Initial conc. of ester / mol dm$^{-3}$** | **Initial rate / mol dm$^{-3}$ s$^{-1}$** |
|---|---|---|---|
| 1 | 0.020 | 0.010 | $1.80 \times 10^{-3}$ |
| 2 | 0.020 | 0.015 | $2.70 \times 10^{-3}$ |
| 3 | 0.030 | 0.015 | $4.05 \times 10^{-3}$ |
| 4 | 0.060 | 0.020 | – |

**(i)** Use the data in the table to deduce the order of reaction with respect to the ester and the order of reaction with respect to $OH^-$.

Comparing expt 1 and 2,
when [ester] increased by 1.5 times while keeping [$OH^-$] constant, initial rate increased by 1.5 times. Hence, order of reaction wrt [ester] is **1**.

Comparing expt 2 and 3,
when [$OH^-$] increased by 1.5 times while keeping [ester] constant, initial rate increased by 1.5 times. Hence, order of reaction wrt [$OH^-$] is **1**.

**(ii)** Calculate the initial rate of reaction for Experiment **4** and the rate constant, **k**.

**[5]**

Using expts 1 and 4,

$x = (3 \times 2 \times 1.80 \times 10^{-3})$
$= \underline{\mathbf{1.08 \times 10^{-2}\ mol\ dm^{-3}\ s^{-1}}}$

Using expt 1

$1.8 \times 10^{-3} = \mathbf{k}(0.02)(0.01)$
$\mathbf{k} = \underline{\mathbf{9\ mol^{-1}\ dm^{3}\ s^{-1}}}$

**(b)** Hydrolysis of the ester can also be carried out with water. However, this method is so slow that it is never used.

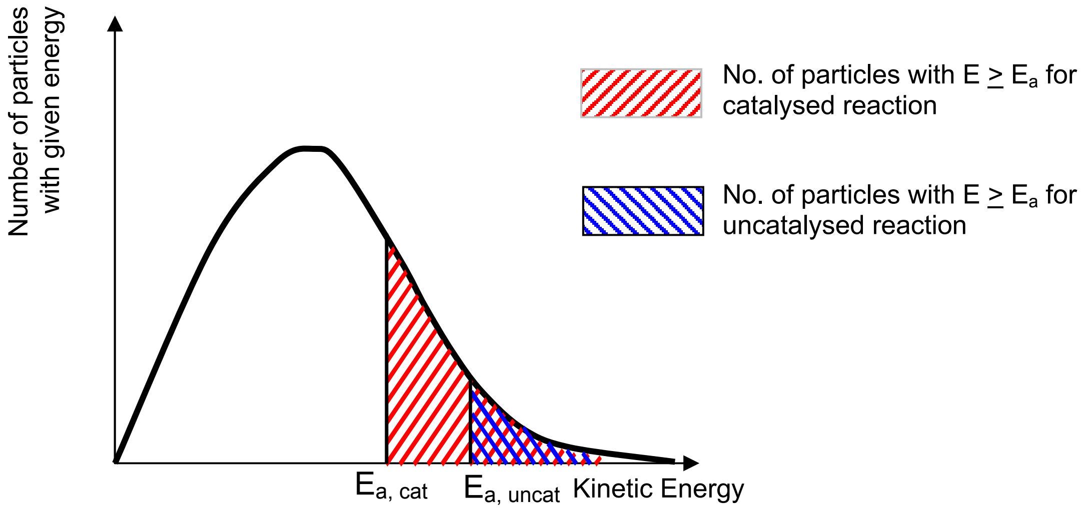
**(i)** Suggest a reason to explain why the hydrolysis is slow using water.

**[1]**

Water has a low concentration of $OH^-$

**(ii)** Ester hydrolysis can be catalyzed by dilute HCl. With the aid of a Maxwell-Boltzmann curve, explain the effect of catalyst on the rate of reaction.

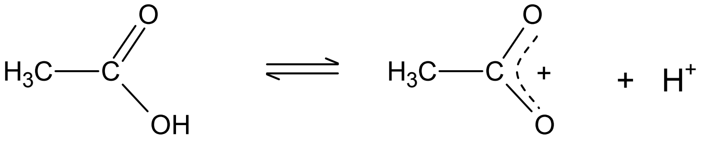
**[4]**



When the catalyst dilute HCl is added, the activation energy, $E_a$ is lowered via an alternative reaction pathway and the number of particles with E ≥ $E_a$ is increases. Number of effective collisions per unit time increases. Since rate of reaction is proportional to number of effective collisions per unit time, hence rate of reaction increases.

**(c)** With reference to the structure of ethanoic acid, explain why sodium hydroxide will only react with ethanoic acid and not ethanol.

**[2]**



- Ethanoic acid is a stronger acid than ethanol
- The negative charge is delocalised over two oxygen atoms in the carboxylate anion, hence stabilising the carboxylate anion relative to acid.
- There is a greater tendency for the carboxylic acid to ionise compare to alcohol.

**(d)** Compound **P**, $C_6H_{10}O_3$, is a sweet smelling solid. When **P** is heated with dilute HCl, 2 isomeric compounds **Q** and **R** with the molecular formula of $C_3H_6O_2$ are formed. Compound **Q** is able to dissolve in $CaCO_3$ (aq) but not compound **R**. Compound **R** gives an orange precipitate with 2,4-dinitrophenylhdrazine but does not show any observable change with a mixture of ammonia and silver nitrate. Compound **R** gives a yellow precipitate with hot alkaline iodine. On reaction with $PCl_5$, **R** gives dense white fumes.

Deduce the identities for the compounds **P**, **Q** and **R** and explain the chemistry of the reactions involved.

**[8]**
**[Total: 20]**

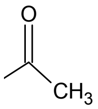
P, a sweet smelling compound undergoes acid hydrolysis with hot dilute HCl to give Q and R.
⇒ P is an ester
⇒Q and P are either alcohol or carboxylic acid

Q undergoes acid-carbonate/neutralization with $CaCO_3$ but not R
⇒ Q is a carboxylic acid
⇒ R is an alcohol

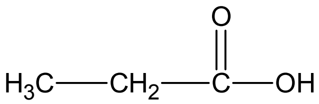
R undergoes condensation with 2, 4-dinitrophenylhydrazine to give yellow ppt of hydrazone
⇒ R is a carbonyl

R does not undergo oxidation with a mixture of ammonia and silver nitrate/Tollen's reagent.
⇒ R is a ketone

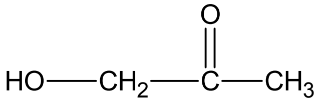
R undergoes oxidation with hot alkaline iodine/Iodoform test to give yellow ppt of $CHI_3$

⇒ R contains the  structure

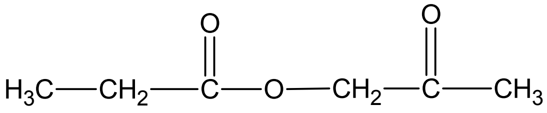
R undergoes nucleophilic substitution with $PCl_5$ to give white fumes of HCl
⇒ R is an alcohol

**Q:** 

$H_3C—CH_2—\overset{\overset{O}{\|}}{C}—OH$

**R:** 

$HO—CH_2—\overset{\overset{O}{\|}}{C}—CH_3$

**P:** 

$H_3C—CH_2—\overset{\overset{O}{\|}}{C}—O—CH_2—\overset{\overset{O}{\|}}{C}—CH_3$

**8(a)** Methylacetylene is an alkyne with the chemical formula $CH_3C{\equiv}CH$. 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:

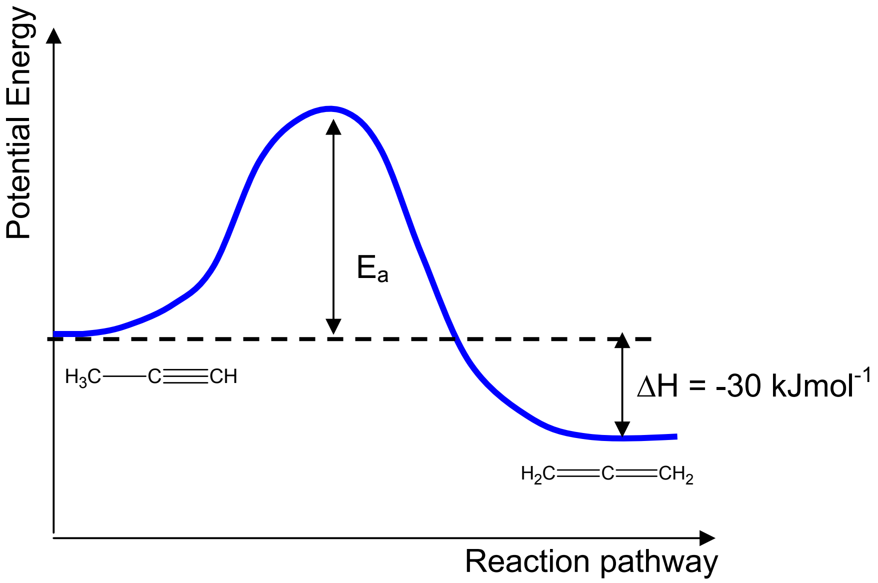
$$H_3C{-}C{\equiv}CH\ (g) \quad \boldsymbol{f} \quad H_2C{=}\underset{1}{C}{=}\underset{2}{C}H_2\ (g)$$

**(i)** Use the bond energies given in the *Data Booklet* to calculate the standard enthalpy change for the conversion of methylacetylene to propadiene.

$\Delta H_{rxn}$ = [BE(C≡C) + BE(C-C) + 4 x BE(C-H)] – 2 x BE(C=C) + 4 x BE(C-H)
= $\underline{\mathbf{-\ 30\ kJmol^{-1}}}$

**(ii)** Sketch and label an energy profile diagram for the reaction showing all relevant energy changes.

**[4]**



**(b)** **(i)** State the hybridisation, shape and number of sigma and pi bonds about $C_1$ and $C_2$ of propadiene.

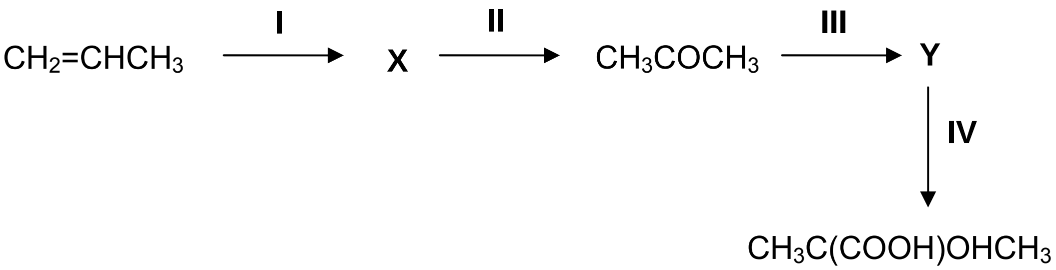
| **Reaction** | **Hybridisation** | **Shape** | **No. of sigma and pi bonds** |
|---|---|---|---|
| **$C_1$** | sp | Linear | σ bond – 2<br>π bond – 2 |
| **$C_2$** | $sp^2$ | Trigonal planar | σ bond – 3<br>π bond – 1 |

**(ii)** Suggest whether propandiene is a planar or non-planar molecule.

**[4]**

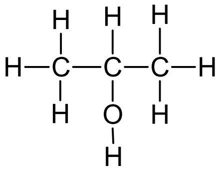
Non-planar

**(c)** Propene is a major commodity in the petrochemical industry. It is used as an intermediate in the production of various chemicals. Below is reaction scheme of propene.

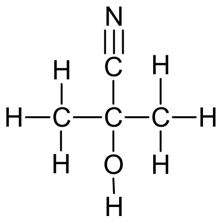


**(i)** Draw the displayed formulae of **X** and **Y**.

**X:**



**Y:**



**(ii)** State the reagents and conditions of reactions **I** – **IV**

**[6]**

| Reaction | Reagents | Conditions |
|---|---|---|
| **I** | Steam, conc $H_3PO_4$ | 300$^{o}$C, 65 atm |
| **II** | dil $H_2SO_{4(aq)}$,<br>$KMnO_4$ | Heat |
| **III** | HCN, trace amount of NaOH | Cold |
| **IV** | Dilute HCl | Heat |

**(d)** Predict with explanation whether $CH_3CH_2OH$ or $CH_3OCH_3$ has a higher boiling point.

**[3]**

$CH_3CH_2OH$ and $CH_3OCH_3$ have simple molecular structures.
$CH_3CH_2OH$ has hydrogen bonding between $CH_3CH_2OH$ molecules which requires more energy to overcome than the weak Van der Waals interaction between $CH_3OCH_3$ molecules.
$CH_3CH_2OH$ has a higher boiling point.

**(e)** Suggest a 2-steps chemical tests to distinguish between $CH_3COOH$ and $CH_3CH_2COOH$.

**[3]**

Test

To $2cm^3$ of each compound in separate test tubes, add $LiAlH_4$ in dry ether at rtp.
Followed by the addition of $NaOH_{(aq)}$ and $I_2$ and heat the mixture.

Observations

The test tube containing $CH_3COOH$ will have form a yellow ppt.
The test tube containing $CH_3CH_2COOH$ will not form the yellow ppt.

**[Total: 20]**