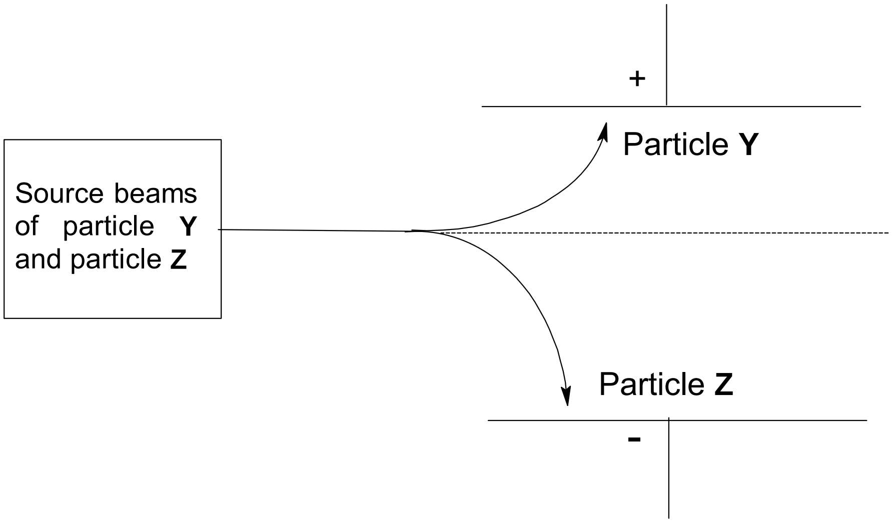
Pioneer Junior College
JC2 Preliminary Examination 2008
H1 Chemistry Paper 2
Suggested Answers

Section A

1 (a)

Particle	Electric charge	Mass number	Number of		
			Protons	Electrons	Neutrons
X	0	**32**	16	**16**	16
Y	1-	81	35	36	**46**
Z	**3+**	70	31	28	**39**

(b)

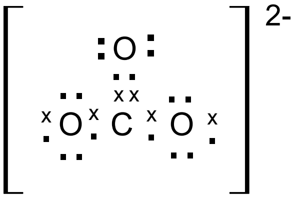


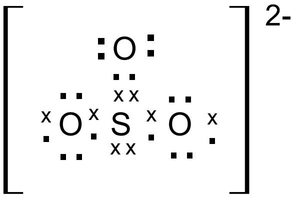
2 (a) Electrons repel each other and the electron pairs would arrange themselves as far apart as possible.

Or

lone pair-lone pair repulsion > bond pair - lone pair> bond pair - bond pair

(b)





For CO_3^{2-}, there are 3 bond pairs and 0 lone pair. By VSEPR, the shape is trigonal planar.

For SO_3^{2-}, there are 3 bond pairs and 1 lone pair. By VESPR, the shape is trigonal pyramidal.

3 **(a)** Phosphorus burns with a blue flame.

$P_4 + 5O_2 \rightarrow P_4O_{10}$

Magnesium burns readily in oxygen with a bright white flame, leaving a white residue of MgO.

$2Mg + O_2 \rightarrow 2MgO$

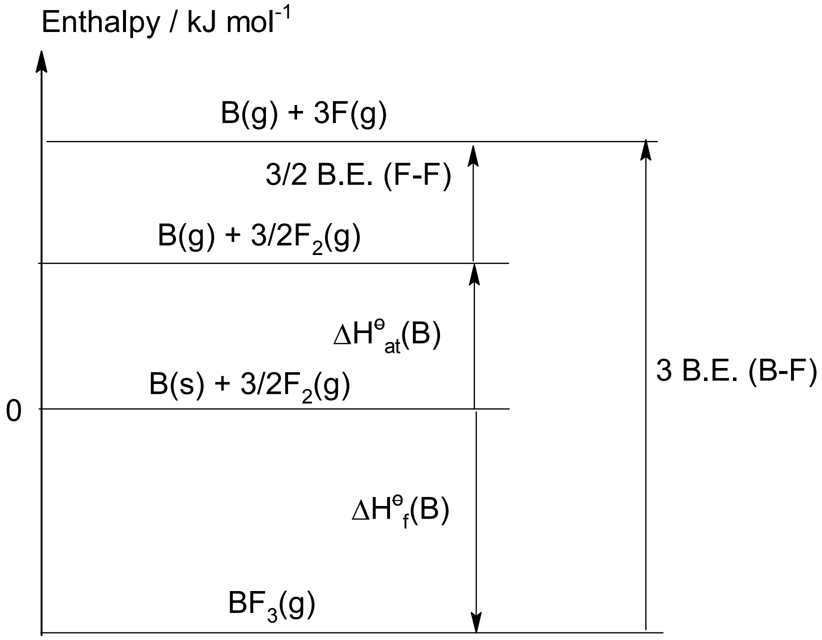
(b) Calcium has one more quantum shell of electrons than magnesium. Due to more effective shielding by inner shell electrons, the valence electrons are less attracted to the nucleus than magnesium and thus it would lose the electrons more readily to form ions.

Or

As calcium has a larger atomic radius than magnesium, the valence electrons of calcium are further away from the nucleus. Thus, calcium will lose electrons more readily to form ions than magnesium.

4 **(a)** **(i)** Standard enthalpy change of formation of a compound is the heat change when one mole of compound is formed from its elements in their standard states under standard conditions of 298 K and 1 atm.

(ii)



(iii) By Hess' Law,

$3B.E.(B\text{-}F) = -(-1137) + (573) + 3/2(+158)$
$B.E.\ (B\text{-}F) = +649\ \text{kJ mol}^{-1}$

4 **(b)** **(i)** Number of moles of propan-1-ol burnt = 0.60 / [3(12.0) + 8(1.0) + 16.0)]
= 0.010 mol

(ii) Let the final temperature be T°C

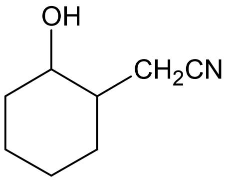
Amount of heat liberated from combustion = 0.010 x 2021
= 20.21 kJ

$$\frac{200 \times 4.18 \times (T - 21.0)}{1000} = 20.21$$

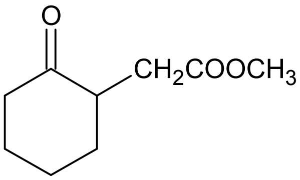
T = 45.1°C

(iii) Heat loss to surroundings or incomplete combustion of propan-1-ol resulting in less heat produced.

5 **(a)**



A



B

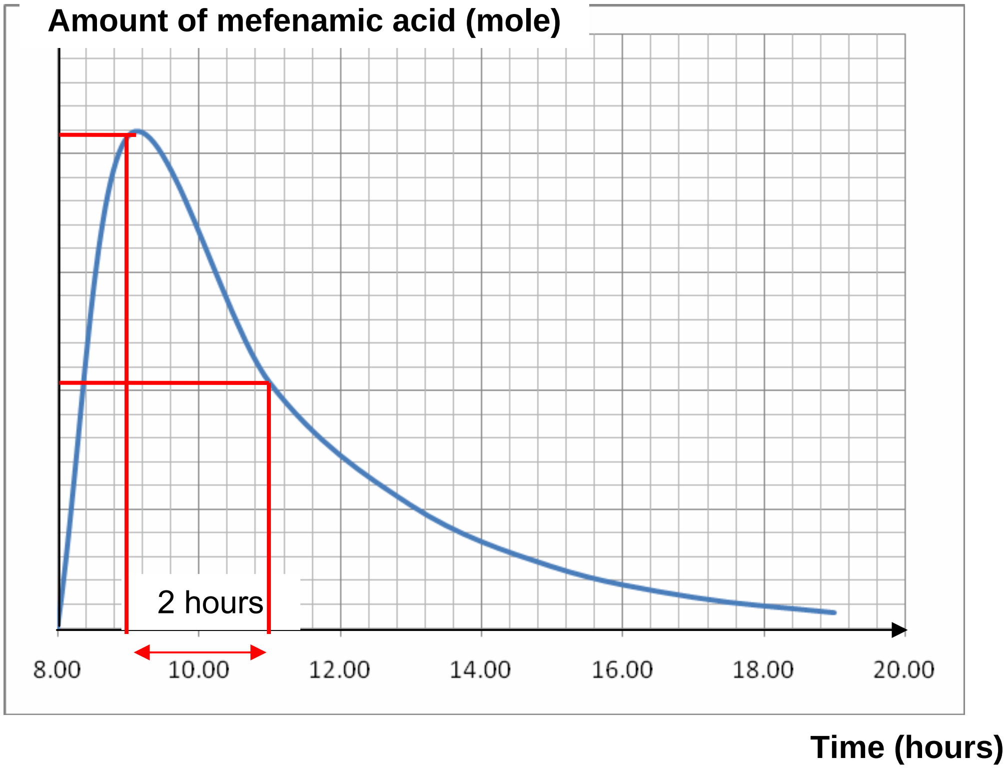
(b) Step 1: KCN, ethanol, heat
Step 2: HC*l*, heat
Step 3:$KMnO_4$, H_2SO_4 (aq), heat

(c) Step 1: substitution
Step 2: acid hydrolysis
Step 3: oxidation

6 **(a)** Molar mass of $C_{15}H_{15}NO_2$
= (12.0 x 15) + (1.0 x 15) + 14.0 + (16.0 x 2) = 241 g mol^{-1}

Amount of $C_{15}H_{15}NO_2$ in 2 capsules
= (50 x 10^{-3} x 2) / 241 = 0.000415 mol

(b)



Half-life ≈ 2 hours

(c) **(i)** Solubility of mefenamic acid = (20 x 10^{-3}) / 241
= 8.30 x 10^{-5} mol dm^{-3}

(ii) Although mefenamic acid contains carboxylic acid group and amine group that are capable of forming hydrogen bonds with water molecules, the presence of the two large hydrophobic aromatic rings interfere with the formation of hydrogen bonds results in its low solubility in water.

(d) NaOH(aq) / Na_2CO_3(aq) at room temperature

(e) Overdose = 740 mg kg^{-1}

Mass of mefenamic acid that result in an overdose in a 65 kg patient
= 740 x 65 = 48100 mg = 48.1 g

Since the bioavailability of mefenamic acid is given to be 90%,
maximum mass of mefenamic acid that can be ingested before an "overdose" occurs = 48.1 / 0.9 = 53.4 g

Section B

1 (a) (i) $[H^+] = 10^{-2.49} = 3.24 \times 10^{-3}$ mol dm^{-3}

(ii) 3-chloropropanoic acid is a weak acid because $[H^+] \ll$ [3-chloropropanoic acid], indicating it undergoes partial dissociation.

(iii)

$$K_a = \frac{[CH_2C\mathit{l}CH_2COO^-][H^+]}{[CH_2C\mathit{l}CH_2COOH]}$$

$$= \frac{(3.24\times10^{-3})^2}{(0.100-3.24\times10^{-3})} = 1.08 \times 10^{-4} \text{ mol dm}^{-3}$$

(b) (i) Concentration of NaOH $= \left(\frac{25.0}{1000}\times 0.100\right)\div\left(\frac{22.50}{1000}\right)$
$= 0.111$ mol dm^{-3}

(ii) Phenolphthalein is a suitable indicator because it works for a weak acid-strong base titration (i.e. the working range of the indicator coincides with the region of sharp pH changes at the end point). There is a distinct colour change from colourless to pink at the end point.

(c) (i) A *buffer solution* is one which resists changes in pH on dilution or on addition of small amount of acid or alkali.

(ii) On addition of small amount of OH$^-$,
$CH_2C\mathit{l}CH_2COOH + OH^- \rightarrow CH_2C\mathit{l}CH_2COO^- + H_2O$

$CH_2C\mathit{l}CH_2COOH$ will react with the OH$^-$ added. With no significant increase in [OH$^-$], pH is maintained at a near constant.

On addition of small amount of H$^+$,
$CH_2C\mathit{l}CH_2COO^- + H^+ \rightarrow CH_2C\mathit{l}CH_2COOH$

$CH_2C\mathit{l}CH_2COO^-$ will react with the H^+ added. With no significant increase in $[H^+]$, pH is maintained at a near constant.

(d) $$CH_2C\mathit{l}CH_2COOH \rightleftharpoons \underset{\text{less stable}}{CH_2C\mathit{l}CH_2COO^-} + H^+$$

$$CH_3CHC\mathit{l}COOH \rightleftharpoons \underset{\text{more stable}}{CH_3CHC\mathit{l}COO^-} + H^+$$

2-chloropropanoic acid will be a stronger acid because the electron-withdrawing C*l* is nearer to the carboxylate group. It helps to disperse the negative charge on the carboxylate anion more, thus stabilising the anion to a greater extent. As a result, 2-chloropropanoic acid tends to undergo dissociation to a greater extent, making it a stronger acid.

(e) **(i)**

$$CH_3CH_2CH_2C\mathit{l} \xrightarrow{\mathbf{1}} CH_3CH{=}CH_2 \xrightarrow{\mathbf{2}} CH_3CH(OH)CH_2OH \xrightarrow{\mathbf{3}} CH_3COCHO$$

Step 1: KOH in ethanol, heat
Step 2: $KMnO_4$ in NaOH(aq), room temperature
Step 3: $K_2Cr_2O_7$ in dilute H_2SO_4, distil

(ii)

$$C_6H_5CH_2CH_2OH \xrightarrow{\mathbf{1}} C_6H_5CH{=}CH_2 \xrightarrow{\mathbf{2}} C_6H_5CH(Br)CH_3 \xrightarrow{\mathbf{3}} C_6H_5CH(NH_2)CH_3$$

Step 1: concentrated H_2SO_4, 170ºC
Step 2: HBr(g)
Step 3: excess NH_3 in ethanol, heat in sealed tube

2 **(a)** **A** is sodium.

Sodium chloride has a <u>giant ionic lattice structure with strong ionic bonds / electrostatic attractions between the sodium and chloride ions</u>. A large amount of energy is required to overcome the ionic bonds, thus it has a high melting point. Sodium chloride dissolves in water, without undergoing hydrolysis, thus giving a solution of pH 7.

$NaC\mathit{l}(s) + aq \rightarrow Na+(aq) + C\mathit{l}^-(aq)$

2.0 x 10^{-3} mol of chloride of **B** $\equiv \dfrac{1.435}{108+35.5}$ mol of AgC*l*

2.0 x 10^{-3} mol of chloride of **B** $\equiv$ 0.0100 mol of AgC*l* $\equiv$ 0.0100 mol of Cl^-

1 mol of chloride **B** $\equiv$ 5 mol of Cl^-

B is phosphorus.

$PCl_5 + 4H_2O \longrightarrow H_3PO_4 + 5HCl$

Phosphorus pentachloride has <u>a simple molecular structure with weak van der Waals' forces of attraction (induced dipole – induced dipole attractions) between its molecules</u>. As a relatively small amount of energy is required to overcome the intermolecular forces of attractions, it has a relatively low melting point of 180ºC. <u>Phosphorus pentachloride hydrolyses in water</u>, giving hydrochloric acid which reacts with silver nitrate to form a white precipitate of silver chloride.

(b) **(i)** $K_c = \dfrac{[SO_2Cl_2]}{[SO_2][Cl_2]}$

At 3 minutes, K_c = (0.02) / (0.05 x 0.08)
= 5.00 $mol^{-1}\ dm^3$

At 9 minutes, K_c = (0.04) / (0.08 x 0.06)
= 8.33 $mol^{-1}\ dm^3$

(ii) By Le Chatelier's Principle, a decrease in temperature favours an exothermic reaction. When temperature is decreased, the value of K_c increases, indicating that the forward reaction is favoured. Hence forward reaction is exothermic.

(iii) At 4th minute, <u>$[SO_2]$ is increased</u>. Hence equilibrium shifts to the <u>right</u> to <u>remove some of the added SO_2</u>. Hence $[SO_2Cl_2]$ and $[SO_2]$ increase while $[Cl_2]$ decreases.

(iv) A decrease in volume results in increase in pressure for the system. Hence equilibrium shifts to the <u>right</u> to <u>reduce the total no. of moles of gas</u> but of <u>K_c remains constant</u>.

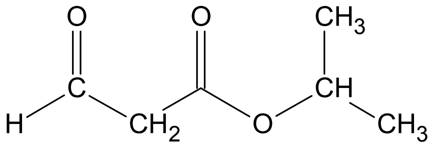
(c) **C** undergoes <u>condensation</u> reaction with 2,4-dinitrophenylhydrazine to give orange precipitate, indicating the presence of carbonyl group in **C**.

C undergoes <u>acid hydrolysis</u> to give **D** and **E**, suggesting that C contains an ester group.

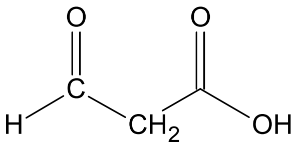
E gives <u>yellow precipitate of CHI_3</u> with alkaline aqueous iodine. E contains either CH_3CO- or $CH_3CH(OH)$- group.

F undergoes <u>acid-base reaction</u> with sodium carbonate to give carbon dioxide and a sodium salt **G**. Thus, **F** contains a carboxylic acid group

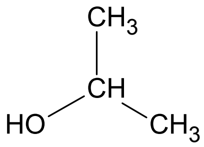
One mole of **F** reacts with one mole of sodium carbonate. **F** is a diacid.



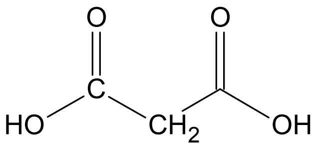
C



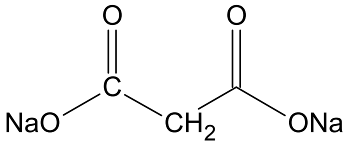
D



E



F



G

3 **(a)** **(i)** Reagent and condition: NaOH(aq), I_2(aq), heat

Yellow precipitate of CHI_3 observed for $CH_3COOCH_2CH_3$, no observable change for $CH_3CH_2COOCH_3$.

(ii) Reagent and condition: 2,4-dinitrophenylhydrazine

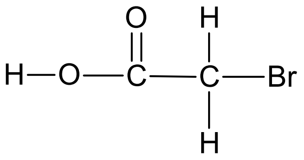
Orange precipitate observed for $CH_3COCH_2CH_3$. No precipitate observed for $CH_3CH_2CO_2H$.

Alternatively,

Reagent and condition: $Na_2CO_3(aq)$

Effervescence observed for $CH_3CH_2CO_2H$. Gas evolved gives a white precipitate with limewater. No gas evolved for $CH_3COCH_2CH_3$.

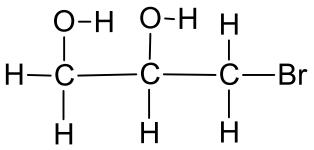
(b) **(i)** Purple $KMnO_4$ decolourises.



$$\mathrm{H{-}O{-}\overset{\overset{\displaystyle O}{\|}}{C}{-}\underset{\underset{\displaystyle H}{|}}{\overset{\overset{\displaystyle H}{|}}{C}}{-}Br}$$

Note: For displayed formulae, all bonds must be shown.

(ii) Purple $KMnO_4$ turns green and a brown precipitate of MnO_2 is obtained eventually .



$$\mathrm{H{-}\underset{\underset{\displaystyle H}{|}}{\overset{\overset{\displaystyle O{-}H}{|}}{C}}{-}\underset{\underset{\displaystyle H}{|}}{\overset{\overset{\displaystyle O{-}H}{|}}{C}}{-}\underset{\underset{\displaystyle H}{|}}{\overset{\overset{\displaystyle H}{|}}{C}}{-}Br}$$

(c) **(i)** Let rate = $k[CH_2{=}CHCH_2Br]^m[NaOH]^n$

Using results of experiments 1 and 3,

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

$m = 1$

Order of reaction with respect to $CH_2{=}CHCH_2Br$ = 1

Using results of experiments 1 and 2

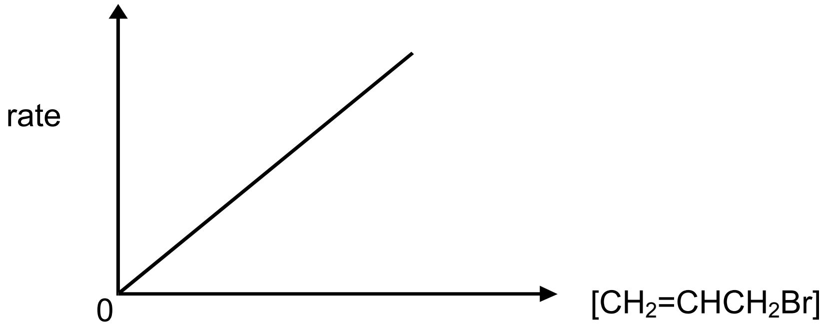
$$\frac{2.00}{1.00} = \frac{k(0.20)^1(0.20)^n}{k(0.10)^1(0.10)^n}$$

$n = 0$

Order of reaction with respect to NaOH = 0

(ii) Rate = $k[CH_2{=}CHCH_2Br]$

(iii)



(iv) Since reaction is first order with respect to $CH_2=CHCH_2Br$, the half-life is constant. It takes 2 half-lives for 75% of $CH_2=CHCH_2Br$ to be used up. Thus, half-life of the reaction is 5 minutes.

Time take for 87.5% of $CH_2=CHCH_2Br$ to be used up = 5 x 3
= 15 min

(v) The presence of the π bond adjacent to the C-Br bond reduces the dipole (δ+) on the C, making less reactive. The interaction of the lone pair of electrons on Br with the p orbitals of the π bond results in the strengthening of the C-Br bond, reducing its reactivity too.

(d) A catalyst is a substance which increases the rate of a chemical reaction provides an alternative reaction pathway with a lower activation energy. This results an increase in the number of particles with energy ≥ E_a. The number of frequency of effective collisions increases, resulting in an increased rate of reaction.