## HCI (College) / 2009 C2 H1 Chemistry / Prelims Answers

Paper 1 – MCQ

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

Paper 2A - Structured

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1 (a) (i) Relative atomic mass, A_r = \frac{\text{average mass of one atom of an element}}{\frac{1}{12} \text{ x the mass of one atom of }^{12}\text{C}}
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(ii)  $A_r$  of Cu: (30.8/100)(65) + (69.2/100)(63) = 63.6

(iii)	lon	protons	neutrons	electrons		
	<sup>63</sup> Cu <sup>2+</sup>	29	34	27		

(b) (i) No of moles of excess  $HCl = 20 \times 0.5 \times 10^{-3}$ 

No of moles of NH<sub>3</sub> neutralized by HCl = (40-20)x0.5x10<sup>-3</sup> = 1.0x 10<sup>-2</sup>

No of moles of  $NH_4^+$  = mole of  $NH_3$  neutralized =  $1.0 \times 10^{-2}$ 

Mass of  $NH_4^+$  in 2g of salt A = 18(10<sup>-2</sup>) = 0.180 g

(ii) Mass of  $SO_4^{2-}$  ion in 2g of salt A = 2.33 x [( 32.1 +64)/ (137+96.1)] = 0.961 g

(iii) No of moles of A: 2.00 / 399.5 = 0.00501 mol

No of moles of  $NH_4^+$  = 0.0100 mol

No of moles of  $SO_4^{2-}$  = 0.960 / (32.1 + 16.0 x 4) = 0.0100 mol

No of mole of A:  $NH_4^+$  :  $SO_4^{2-}$ 1: 2 :2 [1]

Cu(NH<sub>4</sub>)<sub>2</sub>(SO<sub>4</sub>)<sub>2</sub>. 6H<sub>2</sub>O

2 (a)  $XCl_n \rightarrow XCl_{n-2} + Cl_2$   $\left(\frac{n-2}{n}\right) = \frac{(0.714/(108+35.5))}{(1.19/(108+35.5))} = \frac{3}{5}$ OR No. of moles of  $Cl^-$  for  $1^{st}$  sample  $= \frac{1.19}{108+35.5} = 8.29 \times 10^{-3}$  mol (1) No. of moles of  $Cl^-$  for  $2^{nd}$  sample  $= \frac{0.714}{108+35.5} = 4.98 \times 10^{-3}$  mol (2) (1) : (2) = 5 : 3 n = 5

Ar of X = 
$$\frac{0.5 - 0.294}{(8.29 \times 10^{-3}) \div 5} = 124.2$$

X is Sb

(b) (i) Both exist as giant ionic lattice held by strong electrostatic forces of attraction between oppositely charged ions.

$$LE \propto \left| \frac{q^+ q^-}{r^+ + r^-} \right|$$

q<sup>+</sup>, q<sup>-</sup> and r<sup>-</sup> are the same. r<sup>+</sup> of KC*I* is larger, hence numerical value of LE is lower. Less energy is required to break the weaker lattice structure.

- (ii) NaC*l* exists as giant ionic lattice held by strong electrostatic forces of attraction between oppositely charged ions.  $AlCl_3$  is a simple covalent molecule with weak dispersion forces between the molecules. Less energy is required to separate the molecules than the ions.
- (c) (i) The position of equilibrium shifts to the right. By Le Chatelier's principle, an increase in pressure favours the side of the reaction with less number of moles of gaseous molecules. This results in a decrease in pressure, thus re-establishing the equilibrium.
  - (ii) When temperature is increased, the position of equilibrium shifts to the left. Forward reaction is exothermic as it involves bond formation. By Le Chatelier's principle, the equilibrium will shift backward to remove the heat.



As shown by in the diagram, at a lower temperature, the proportion of molecules with kinetic energy  $\geq$  activation energy  $E_a$  decreases.

Frequency of effective collision decreases and thus reaction rate decreases.

- 3 (a) Average energy required when one mole of covalent bonds are broken in the gaseous state
  - (b) (i) enthalpy change for bond breaking = 4(410) + 350 + 740 + 5/2 (496) =  $3970 \text{ kJ mol}^{-1}$

enthalpy change for bond forming = 4(460) + 4(740)=  $4800 \text{ kJ mol}^{-1}$ 

enthalpy change of combustion =  $-830 \text{ kJ mol}^{-1}$ 

(ii) Bond energies quoted in tables represent average (mean) bond energies derived from a full range of molecules containing that particular bond. Hence results from calculations using average bond energies will show discrepancies when compared with results from experiments with specific molecules.



Reaction I: concentrated HNO<sub>3</sub>, concentrated H<sub>2</sub>SO<sub>4</sub>, any temperature ≤ 55 °C was accepted Reaction II: limited amount of Cl<sub>2</sub>, presence of UV light (accept: heat)
 Reaction III: NaOH or KOH in ethanol, heat under reflux or heat (accept: warm)
 Reaction IV: KOH(aq) or NaOH(aq), heat under reflux or heat (accept: warm)



## Paper 2B – Free Response

**5(ai)**  $\Delta H_{hyd}$  becomes less exothermic down the group (or from Ca<sup>2+</sup> to Sr<sup>2+</sup> to Ba<sup>2+</sup>).

Down the group, charge of the cations remains the same (+2) while the size of the cations increases;  $\therefore$  charge density of the cations decreases.

Thus, ion-dipole interactions formed between the cations and water molecules become weaker; less energy is released during hydration.



(bi) Ionic bonding between  $Ba^{2+}$  and  $C_2O_4^{2-}$  covalent bonding between C and O





Trigonal planar around C, 120°



pH of chlorides in water



(ii) MgCl<sub>2</sub> exists as a giant ionic lattice with strong electrostatic forces of attraction between oppositely charged Mg<sup>2+</sup> and C $\Gamma$  ions.

$$\begin{split} & \text{MgC}l_2(s) + 6\text{H}_2\text{O}(l) \rightarrow [\text{Mg}(\text{H}_2\text{O})_6]^{2^+}(aq) + 2\text{C}l^-(aq) \\ & [\text{Mg}(\text{H}_2\text{O})_6]^{2^+}(aq) + \text{H}_2\text{O}(l) \qquad [\text{Mg}(\text{H}_2\text{O})_5\text{OH}]^+(aq) + \text{H}_3\text{O}^+(aq) \end{split}$$

 $SiCl_4$  exists as simple covalent molecules with weak dispersion forces between its molecules.

 $SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(aq)$ 

(di)



(ii) Add aqueous bromine to both compounds.

For ethene, orange solution decolourises, while for butanedioic acid, orange solution remains.

OR

Add  $Na_2CO_3(aq)$  to both compounds. For butanedioic acid, effervescence of  $CO_2(g)$  observed, while for ethene, no gas observed.

6(ai) When a reversible reaction reaches a state of dynamic equilibrium, reaction continues to occur but the rates of the forward and backward reactions are equal.

(ii) 
$$K_c = \frac{[Cr_2O_7^{2^-}]}{[CrO_4^{2^-}]^2[H^+]^2}$$

- (iii) Initial  $[CrO_4^{2^-}] = \frac{8}{194.2} \div \frac{100}{1000} = 0.4119 \text{ mol } dm^{-3}$  $[CrO_4^{2^-}] \text{ at eqm} = \frac{1}{5}(0.4119) = 0.08239 \text{ mol } dm^{-3}$
- (iv)  $[Cr_2O_7^{2^-}]$  at eqm =  $\frac{4}{5}(0.4119) \div 2 = 0.1648 \text{ mol dm}^{-3}$  $[H^+] = 10^{-5.75} = 1.778 \text{ x } 10^{-6} \text{ mol dm}^{-3}$

Substituting into K<sub>c</sub>,  

$$K_{c} = \frac{[0.1648]}{[0.08239]^{2}[1.778 \times 10^{-6}]^{2}} = 7.67 \times 10^{12} \text{mol}^{-3} \text{dm}^{9}$$

**(bi)** 
$$6I^- + Cr_2O_7^{2-} + 14H^+ \rightarrow 3I_2 + 2Cr^{3+} + 7H_2O$$

(ii) 
$$2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-$$

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 $n(S_2O_3^{2^-})$  used =  $0.20 \times \frac{21.5}{1000}$  = 4.30 x 10<sup>-3</sup> mol  $n(I_2)$  formed = 4.30 x 10<sup>-3</sup> ÷ 2 = 2.15 x 10<sup>-3</sup> mol  $n(I^-)$  reacted with  $Cr_2O_7^{2^-}$  = 4.30 x 10<sup>-3</sup> mol

 $n(Cr_2O_7^{2^-})$  present in 25.0 cm<sup>3</sup> = 4.30 x 10<sup>-3</sup> ÷ 6 = 7.167 x 10<sup>-4</sup> mol

n(Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>) in the 100 cm<sup>3</sup> solution =  $7.167 \times 10^{-4} \times \frac{200}{25.0} = 5.733 \times 10^{-3}$  mol

 $[Cr_2O_7^{2^-}]$  in solution =  $\frac{5.733 \times 10^{-3}}{100/1000} = 0.0573 \text{ mol dm}^{-3}$ 

(ci) A undergoes oxidation with  $K_2Cr_2O_7$  to give B and C  $\Rightarrow$  A contains an alcohol group

B and C undergoes oxidative cleavage with hot conc.  $KMnO_4 \Rightarrow$  B and C contains an alkene group (double bond)

- B undergoes condensation reaction with 2,4-DNPH  $\Rightarrow$  B contains a ketone/aldehyde group
- A. CH3CH=CHCH2OH
- B. CH3CH=CHCHO

C: CH<sub>3</sub>CH=CHCO<sub>2</sub>H

(ii) Geometrical (cis-trans) isomerism



- (iii) Heat with distillation
- (di) Add an equal volume of 0.10 mol dm<sup>-3</sup> of sodium benzenesulfonate (C<sub>6</sub>H<sub>5</sub>SO<sub>3</sub>Na). OR Add 10 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> of NaOH(aq) to 20 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> of benzenesulfonic acid.

OR

Add 1.8 g of solid  $C_6H_5SO_3Na$  to 100 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> of benzenesulfonic acid. OR

Add 0.4 g of solid NaOH to 100 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> of benzenesulfonic acid.

(ii)  $C_6H_5SO_3H(aq) + OH^{-}(aq) \rightarrow C_6H_5SO_3^{-}(aq) + H_2O(l)$ 

The addition of small amounts of OH<sup>-</sup> ions are removed by the large reservoir of  $C_6H_5SO_3H$  and thus pH remains almost constant

**7(ai)** Energy required to remove 1 mole of electrons from 1 mole of gaseous atoms in the ground state to form 1 mole of singly charged gaseous cations.



Across the period, nuclear charge increases and shielding effect remains constant, thus effective nuclear charge increases and there's stronger attraction between the nucleus and the outermost electron. Hence, more energy needed to overcome the attraction.

B has a lower first I.E. than Be because the single 2p electron is effectively shielded by the 2s subshell and is further away from the nucleus, thus less energy is needed to remove the outermost electron.

O has a lower first I.E. than N because the electrons in the doubly-filled 2p orbital experiences interelectronic repulsion, thus less energy is needed to remove the electron.

Na has a lower first I.E. than Li because it has one more quantum shell than Li and thus weaker attraction between the nucleus and the outermost electron. Hence less energy needed to overcome the attraction.

(bi) Fe:  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$ Fe<sup>3+</sup>:  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$ Al:  $1s^2 2s^2 2p^6 3s^2 3p^1$ Al<sup>3+</sup>:  $1s^2 2s^2 2p^6$ 

- (ii)  $Fe^{3+}$  has one more quantum shell than  $Al^{3+}$  and the additional shielding by 2s and 2p electrons is effective, hence Fe<sup>3+</sup> has a larger ionic radius.
- (ci) Graphs for both experiments show straight line with constant gradient. Since rate of reaction  $\alpha$  gradient, rate is constant regardless of [OH<sup>-</sup>]  $\Rightarrow$  reaction is zero order with respect to NaOH

Initial rate for [RBr] = 0.20 mol dm<sup>-3</sup> is  $\frac{0.004}{6} = 6.67 \times 10^{-4} \text{ mol dm}^{-3} \text{ min}^{-1}$ Initial rate for [RBr] = 0.40 mol dm<sup>-3</sup> is  $\frac{0.008}{6} = 1.33 \times 10^{-3} \text{ mol dm}^{-3} \text{ min}^{-1}$ Since rate doubled when [RBr] doubled while [OH<sup>-</sup>] is constant  $\Rightarrow$  reaction is first order with respect to RBr

Rate = k[RBr]

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