## Answer Keys to H1 Prelims P2

1 (a) (i)

	Protons	Neutrons	Electrons
Relative Mass	1	1	1/2000
Charge	+1	0	-1
Location in atom	Nucleus	Nucleus	Orbitals

- (ii) Protons: 31; Neutrons: 38; Electrons: 31
- (b) (i) Isotopes are atoms of the same element with the same no. of protons and electrons but different no. of neutrons.

(ii) 
$$A_r \text{ of } Ga = (\frac{3}{5}x69) + (\frac{2}{5}x71)$$
  
= 69.8

- (iii) Both have the same charge of +3.  $^{69}$ Ga<sup>3+</sup> is deflected to a larger angle towards the negative plate as it is lighter in mass.
- 2 (a) (i) Bond energy of NO is the energy required to break one mole of covalent bonds between N and O in a gaseous NO molecule at standard conditions.
  - (ii)  $\Delta H_r = 4[3(+390)] + 5(+496) + 4(-607) + 6[2(-460)]$ = - 788 kJ mol<sup>-1</sup>
  - (b) (i)  $\Delta H_f^{\theta}$  of  $O_2(g)$  is zero as it is an element at standard state.
    - (ii)  $\Delta H_r = 4(+90) + 6(-285.8) 4(-46)$ = - 1170.8 kJ mol<sup>-1</sup>
    - (iii) The water in (aii) is in the gaseous phase while the water in (bii) is in the liquid phase. Bond energy value in (aii) is less exothermic as energy is required to vapourise the liquid water to gas.





Purple solution of  $KMnO_4$  decolourise, brown ppt of  $MnO_2$  formed.

(c) Geometric isomerism



4 (a) (i) 4 HCl(aq) + MnO<sub>2</sub>(s) 
$$\rightarrow$$
 MnCl<sub>2</sub>(s) + Cl<sub>2</sub>(g) + 2H<sub>2</sub>O(l)

(ii) No. of moles of 
$$MnO_2 = \frac{5}{86.9}$$
  
= 0.0575 mol

No. of moles of hydrochloric acid =  $6.0 \times 25 \times 10^{-3}$ = 0.15 mol

HCI is limiting reagent.

Volume of 
$$Cl_2 \frac{0.15}{4}x24 = 0.9 \text{ dm}^3$$

(iii) HCl is the reducing agent.

(b) (i) 50 ppm would endanger human health.  
In 1, 000, 000 dm<sup>3</sup> of air, there are 50 dm<sup>3</sup> of Cl<sub>2</sub>  
In 24 dm<sup>3</sup> of air, volume of Cl<sub>2</sub> = 
$$\frac{50}{10^6}$$
 x24  
= 1.2 x 10<sup>-3</sup> dm<sup>3</sup>  
No. of moles of Cl<sub>2</sub> =  $\frac{1.2x10^{-3}}{24}$   
= 5 x 10<sup>-5</sup> mol

(ii) 
$$4 \operatorname{Cl}_2(g) + \operatorname{S}_2\operatorname{O}_3^{2-}(\operatorname{aq}) + 5 \operatorname{H}_2\operatorname{O}(I) \rightarrow 8 \operatorname{Cl}^-(\operatorname{aq}) + 2 \operatorname{SO}_4^{2-}(\operatorname{aq}) + 10 \operatorname{H}^+(\operatorname{aq})$$

(iii)  
No. of moles of 
$$Cl_2 = \frac{500 \times 10^{-3}}{24}$$
  
= 0.0208 mol

No. of moles of 
$$S_2O_3^{2-} = \frac{0.0208}{4}$$
  
= 5.208 x 10<sup>-3</sup> mol  
 $[S_2O_3^{2-}] = \frac{5.208 \times 10^{-3}}{700} \times 1000$   
=7.44 x 10<sup>-3</sup> mol dm<sup>-3</sup>



lonic radius decreases from Na<sup>+</sup> to Si<sup>4+</sup> as no. of protons increase but the number of electrons are the same, hence, p/e ratio increases and the valence electrons are drawn nearer to the nucleus due to increasing attraction. The same explanation applies for  $P^{3-}$  to Cl<sup>-</sup>.

The anions are bigger than the cations as they have one extra quantum shell hence the distance of the valence electrons from the nucleus will be greater.

(ii) MgO,  $AI_2O_3$  and  $SO_2/SO_3$ .

MgO(s)+ 2 HCl (aq)  $\rightarrow$   $MgCl_2(aq)$  +  $H_2O(l)$ 

 $AI_2O_3$  (s)+ 6 HCl (aq) → 2 AlCl<sub>3</sub>(aq) + 3 H<sub>2</sub>O(l)  $AI_2O_3$  (s)+ NaOH (aq) → NaAl(OH)<sub>4</sub>(aq)

 (iii) SO<sub>2</sub>/SO<sub>3</sub>; MgO; Al<sub>2</sub>O<sub>3</sub> SO<sub>2</sub>/SO<sub>3</sub> exists as simple covalent molecules with weak Vander Waals forces holding the molecules together in fixed positions. These forces are weaker than the ionic bonds holding the ions in the MgO and Al<sub>2</sub>O<sub>3</sub> giant ionic lattice, thus requiring less energy to break.

The ionic bonds between  $Mg^{2+}$  and  $O^{2-}$  are weaker than the ionic bonds between  $Al^{3+}$  and  $O^{2-}$  as  $Al^{3+}$  has higher charge density than  $Mg^{2+}$ , hence require more energy to break.

(b) (i) For  $IO_3^-$ , use expt 2 and 3, when  $V_{IO_3^-}$  increase 2x, initial rate increase 2x. Thus, 1<sup>st</sup> order wrt  $IO_3^-$ .

For I<sup>-</sup>, use expt 2 and 4, when  $V_{I^-}$  increase 2x, initial rate increase 2x. Thus, 1<sup>st</sup> order wrt I<sup>-</sup>.

For H<sup>+</sup>, use expt 1 and 2, but half all volumes in expt 1. When  $V_{H^+}$  increase 2x, initial rate increase 4x. Thus, 2nd order wrt H<sup>+</sup>.

 $=> R = k[H^+]^2[I^-][IO_3^-]$ 

- (ii) The total volume of the solutions is kept constant so the volume of reactants are proportional to the concentration of the reactants. Varying amounts of water was added to each solution until the final volume is 1000 cm<sup>3</sup> for all experiments.
- (iii) When temperature increases, kinetic energy of the molecules increases, thus there will be a greater fraction of molecules with energy colliding with energy more than activation energy, thus, more effective collisions.

Fraction of molecules



- 6 (a) Reaction is still ongoing, but rate of forward equals rate of reverse reaction, thus, concentration of the reactants and products are constant.
  - (b) Concentrated H<sub>2</sub>SO<sub>4</sub> removes water, hence equilibrium shifts right to produce more ethyl propanoate.

(c) (i) 
$$K_c = \frac{[ethyl \, propanoate][water]}{[B][C]}$$

(ii)		acid <b>B</b>	alcohol <b>C</b>	ethyl propanoate	water
	Initial conc	х	x	-	-
	<u>E</u> quilibrium <i>conc</i>	x - 0.40	x – 0.40	0.40	0.40

$$K_{c} = \frac{(0.4)^{2}}{(x - 0.4)^{2}} = 3.5$$
$$\sqrt{\frac{(0.4)^{2}}{(x - 0.4)^{2}}} = \sqrt{3.5}$$
$$\frac{0.4}{x - 0.4} = 1.871$$
$$x = 0.614$$

Equilibrium concentrations of **B** and **C** = 0.214 mol dm<sup>-3</sup>

(iii) Forward reaction is endothermic. As temperature increases, equilibrium shift right to remove some of the added heat. K<sub>c</sub> increase as product increase and reactant decrease.

## (d) (i) B is propanoic acid, C is ethanol.

(ii) Compound D is chloroethane as ethanol undergo substitution reaction with PCl<sub>5</sub> to give chloroethane and white fumes of HCl.
 Compound D undergoes elimination with alcoholic KOH to give compound E which is ethene. Ethene undergoes addition reaction with bromine to give 1,2-dibromoethane hence decolourises Br<sub>2</sub>.

(iii)  $CH_3CH_2COOH + 4 [H] \rightarrow CH_3CH_2CH_2OH + H_2O$ LiAlH<sub>4</sub>, dry ether

> CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>OH + [O] → CH<sub>3</sub>CH<sub>2</sub>CHO + H<sub>2</sub>O K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>, H<sub>2</sub>SO<sub>4</sub>, heat with immediate distillation

(e) (i) Buffer





General increase in ionization energies as proton no. increases while screening effect is constant due to the same number of inner quantum shells. Hence, the valence electrons are more attracted to nucleus, requiring more energy to remove.

First ionization energy of AI less than Mg as the most loosely held electron of AI is removed from the 3p orbital which is at a higher energy than the electrons in the 3s orbital of Mg.

First ionization energy of S less than P as the paired electron of S in the same 3p orbital experience mutual electronic repulsion hence require more energy to remove than the unpaired electrons in the 3p orbitals of P.

(b) (i) NaCl, AlCl<sub>3</sub>, PCl<sub>3</sub> and PCl<sub>5</sub>

NaCl + aq  $\rightarrow$  Na<sup>+</sup> + Cl<sup>-</sup> NaCl dissolve in water to form a neutral solution pH = 7

AICl<sub>3</sub> hydrolyses in water to form an acidic solution of pH = 3

 $\begin{array}{l} \mathsf{PCI}_3 + 3 \ \mathsf{H}_2\mathsf{O} \rightarrow 3 \ \mathsf{HCI} + \mathsf{H}_3\mathsf{PO}_3 \\ \mathsf{PCI}_5 + 4 \ \mathsf{H}_2\mathsf{O} \rightarrow 5 \ \mathsf{HCI} + \mathsf{H}_3\mathsf{PO}_4 \end{array}$ 

 $PCI_3$  /  $PCI_5$  hydrolyse in water to form an acidic solution of pH =2.

(c) (i) Empirical formula is  $C_4H_9CI$ n(48 + 9 + 35.5) = 92.5 n = 1

**F** is C<sub>4</sub>H<sub>9</sub>Cl

(ii) **F** undergoes nucleophilic substitution with NaOH to give compound **G**. Since **G** reacts with alkaline iodine, **G** is a methyl alcohol with  $\begin{array}{c} H \\ R - C \\ - OH \\ C \\ H_3 \end{array}$  structure. Since **G** 

$$\begin{array}{cccccccc} \textbf{G} \ \text{is:} & \textbf{CH}_3 \textbf{CH}_2 & \begin{matrix} \textbf{H} \\ \begin{matrix} \textbf{L} \\ \textbf{CH}_3 \end{matrix} & \begin{matrix} \textbf{F} \ \text{is} & \textbf{CH}_3 \textbf{CH}_2 \end{matrix} & \begin{matrix} \textbf{H} \\ \begin{matrix} \textbf{L} \\ \textbf{CH}_3 \end{matrix} & \begin{matrix} \textbf{CH}_3 \textbf{CH}_2 \end{matrix} \\ \begin{matrix} \textbf{CH}_3 \end{matrix} \\ \end{matrix}$$

**G** is oxidized to **H** by KMnO<sub>4</sub>, **H** is 
$$CH_3CH_2$$
—C=O  
 $H_3CH_3$ 

 $CH_{3}CH_{2}CHClCH_{3} + NaOH \rightarrow CH_{3}CH_{2}CH(OH)CH_{3} + NaCl CH_{3}CH_{2}CH(OH)CH_{3} + [O] \rightarrow CH_{3}CH_{2}COCH_{3} + H_{2}O$ 

(iii) Reaction rate is faster since C-Br bond is weaker (280 kJ mol<sup>-1</sup>) than the C-Cl bond (340 kJ mol<sup>-1</sup>), thus easier to break.