

**Suggested ANSWERS for 2014 H1 Chemistry Preliminary Examination Paper 2****Section A**

1. (a) (i) Enthalpy change of hydrogenation of benzene  

$$= \Sigma(\Delta H_c(\text{reactants}) - \Delta H_c(\text{products}))$$

$$= -3268 + 3(-286) - (-3920)$$

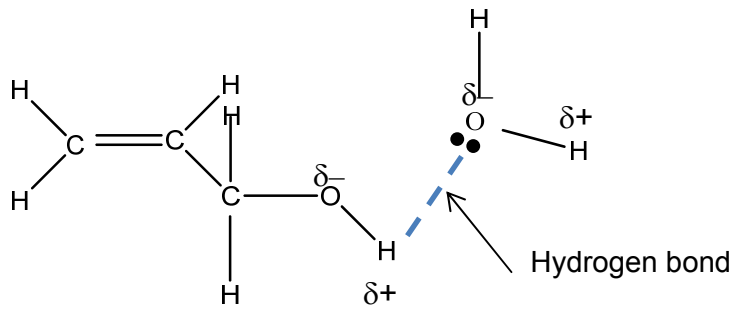
$$= -206 \text{ kJ mol}^{-1}$$
 [2]
- (ii) Enthalpy change of hydrogenation of benzene  

$$= \Sigma \text{B.E. (reactants)} - \Sigma \text{B.E. (products)}$$

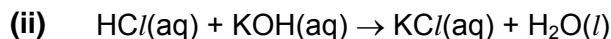
$$= 6\text{E}(\text{C}\equiv\text{C}) + 6\text{E}(\text{C}-\text{H}) + 3\text{E}(\text{H}-\text{H}) - 6\text{E}(\text{C}-\text{C}) - 12\text{E}(\text{C}-\text{H})$$

$$= 6\text{E}(\text{C}\equiv\text{C}) + 3\text{E}(\text{H}-\text{H}) - 6\text{E}(\text{C}-\text{C}) - 6\text{E}(\text{C}-\text{H})$$

$$= 6(520) + 3(436) - 6(350) - 6(410)$$

$$= -132 \text{ kJ mol}^{-1}$$
 [2]
- (iii) The bond energies quoted from the *Data Booklet* represent average bond energies derived from the full range of molecules containing the particular bond. [1]
1. (b) (i)  $\text{CH}_2(\text{Br})\text{CH}(\text{Br})\text{CHO}$  [1]
- (ii)  $\text{CH}_2=\text{CHCOOH}$  [1]
- (c) (i)  $\text{CH}_2=\text{CHCH}_2\text{Cl}$  [1]
- (ii) reduction  
 $\text{PCl}_5$   
 $\text{NaCN}$ , ethanol, heat [3]
- (iii)
- 
- [1]
- (iv) The large, non-polar benzene ring of cinnamyl alcohol hinders the formation of hydrogen bonds with water molecules. [1]

2. (a) (i) The *standard enthalpy change of neutralisation* of an acid with an alkali is the energy evolved when one mole of water is formed from the reaction of an acid and an alkali under standard conditions. [1]



Heat evolved by the neutralisation reaction

$$= (40.0 + 60.0) \times 4.2 \times 8.2 \times \frac{100}{80}$$

$$= 4305 \text{ J} / 4.305 \text{ kJ}$$

Amount of water formed

= Amount of KOH reacted (since KOH is the limiting reagent)

$$= \frac{60.0}{1000} \times 1.40$$

$$= 0.0840 \text{ mol}$$

Enthalpy change of neutralisation of HCl with KOH

$$= -\frac{4.305}{0.0840} = -51.3 \text{ kJ mol}^{-1} \quad [3]$$

- (iii)  $\text{CH}_3\text{COOH(aq)}$  is a weak acid that ionises partially in aqueous solution.

Since ionisation of  $\text{CH}_3\text{COOH(aq)}$  is an endothermic process, some heat released from the neutralisation is absorbed to further ionise the weak acid completely.

Therefore, the enthalpy change of neutralisation of  $\text{CH}_3\text{COOH}$  with KOH is less exothermic than that of HCl with KOH. [2]

- (b) (i) A catalyst speeds up the reaction by providing an alternative reaction path of lower activation energy than that of the uncatalysed reaction.

Activation energy ( $E_a$ ) is the minimum amount of energy that reactants must possess before a reaction can occur. [2]

(ii) 
$$K_c = \frac{[\text{SO}_3]}{[\text{SO}_2][\text{O}_2]^{1/2}} \quad [1]$$



Initial conc/mol dm <sup>-3</sup>	2.0	$x$	–
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Eqm conc/mol dm <sup>-3</sup>	$2.0 - 1.6 = 0.4$	$x - \frac{1}{2}(1.6)$	1.6
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$$K_c = \frac{1.6}{(0.4)(x-0.8)^{1/2}} = 9.8$$

$$\text{Solving, } (x-0.8)^{1/2} = 0.408$$

$$(x-0.8) = 0.167$$

$$x = 0.967 \text{ mol dm}^{-3} \quad [2]$$

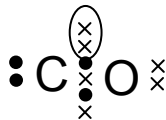
3. (a)  $\text{SF}_4$  is polar.

There is a resultant dipole moment in  $\text{SF}_4$  because in  $\text{SF}_4$ , there is a lone pair of electrons, which results in asymmetrical distribution of charge.

$\text{BeCl}_2$  is non-polar since all dipole moment cancel out.

[3]

- (b)



[1]

- (c) (i) CFCs form free radicals when exposed to UV radiation. These free radicals react with ozone in the atmosphere, depleting it.
- (ii) Fluoroalkanes do not react so easily since fluorine-carbon bond is much stronger than chlorine-carbon bond.

[1]

[1]

4. (a) (i) Volume of pure methanoic acid =  $6.0 \times 10^{-3} \times 0.5 \times \frac{100}{80}$   
 $= 3.75 \times 10^{-3} \text{ cm}^3$

[2]

- (ii) Number of ants to be distilled =  $\frac{1000}{3.75 \times 10^{-3}} = 2.7 \times 10^5$

[1]

- (iii) Amount of methanoic acid =  $\frac{6 \times 10^{-3} \times 0.5 \times 1.2}{46.0}$   
 $= 7.83 \times 10^{-5} \text{ mol}$

[1]

- (iv)  $\text{NaHCO}_3 \equiv \text{HCOOH}$   
 Mass of  $\text{NaHCO}_3$  required  
 $= 7.83 \times 10^{-5} \times (23.0 + 1.0 + 12.0 + 3(16.0)) \times 10^3$   
 $= 6.58 \text{ mg}$

[2]

- (b) (i)  $K_a = \frac{[\text{H}^+][\text{HCOO}^-]}{[\text{HCOOH}]}$

[1]

- (ii)  $[\text{H}^+] = 10^{-2.4} = 3.98 \times 10^{-3} \text{ mol dm}^{-3}$

[1]

- (iii)  $K_a = \frac{(3.98 \times 10^{-3})^2}{8.9 \times 10^{-2}} = 1.78 \times 10^{-4} \text{ mol dm}^{-3}$

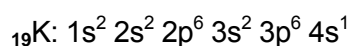
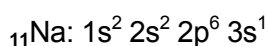
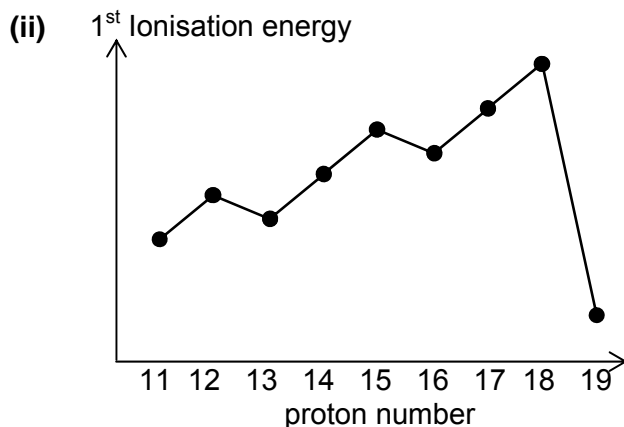
[1]

- (c)  $2\text{HCOOH} + \text{O}_2 \rightarrow 2\text{CO}_2 + 2\text{H}_2\text{O}$

[1]

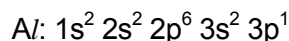
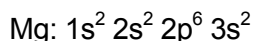
## Section B

5. (a) (i) The *first ionisation energy* of an element is the energy required to remove one mole of electrons from one mole of gaseous atoms of the element. [1]



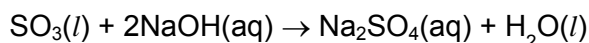
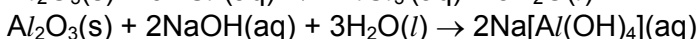
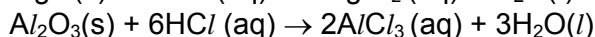
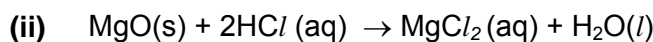
Na has one less quantum shell of electrons than K, resulting in a smaller atomic radius and smaller shielding effect by fewer inner shell electrons.

Hence 1<sup>st</sup> IE of Na is higher than that of K (despite its smaller nuclear charge).

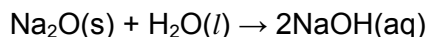


The 3p electron of Al is further away from the nucleus and has higher energy than the 3s electron of Mg. Less energy is required to remove the 3p electron from Al. Thus, 1<sup>st</sup> IE of Mg is higher than that of Al. [3]

- (b) (i) MgO, Al<sub>2</sub>O<sub>3</sub>, SO<sub>3</sub> [1]



- (c) Na<sub>2</sub>O has a giant ionic structure with strong ionic bonds between Na<sup>+</sup> and O<sup>2-</sup> ions. It reacts vigorously with water, to give an strongly alkaline solution with pH = 13-14.



P<sub>4</sub>O<sub>10</sub> has simple molecular structures with weak van der Waals' forces between molecules. P<sub>4</sub>O<sub>10</sub> reacts with water to give a strongly acidic solution with pH = 2.



- (d)  $\text{Ca}^{2+}\text{(g)} + \text{O}^{2-}\text{(g)} \rightarrow \text{CaO(s)}$

The cation in CaCl<sub>2</sub> and CaO is the same.

$$|L.E.|\propto \frac{q_+q_-}{r_+ + r_-}$$

The charge on O<sup>2-</sup> is doubled that of Cl<sup>-</sup>.

The ionic radius of O<sup>2-</sup> is smaller than that of Cl<sup>-</sup>. [2]

5. (e) (i) When temperature decreases, equilibrium position will shift to favour the exothermic reaction so as to release some of the heat. Since the colour fades i.e. less ozone is formed, we know that equilibrium position has shifted to the left. Hence, the forward reaction is endothermic. [2]

- (ii) Since  $2\text{S}_2\text{O}_3^{2-} \rightleftharpoons \text{I}_2$

$$\text{Amount of I}_2 = \frac{1}{2} \times \frac{15.0}{1000} \times 0.100 = 7.50 \times 10^{-4} \text{ mol} \quad [1]$$

- (iii) Since  $\text{O}_3 \rightleftharpoons \text{I}_2$

$$\text{Amount of O}_3 \text{ present} = 7.50 \times 10^{-4} \text{ mol}$$

$$\text{Volume of O}_3 \text{ present at s.t.p} = 7.50 \times 10^{-4} \times 22.4 = 0.0168 \text{ dm}^3$$

$$\% \text{ of O}_3 \text{ in gaseous mixture} = \frac{0.0168 \times 1000}{500} \times 100\% = 3.36\% \quad [2]$$

6. (a) (i) Both diamond and graphite have giant covalent structures.

A large amount of energy is required to break the strong covalent bonds between carbon atoms in diamond and graphite during melting.

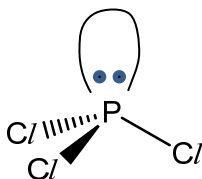
Hence, they have very high melting points. [1]

- (ii) Hardness

Diamond is hard while graphite is soft.

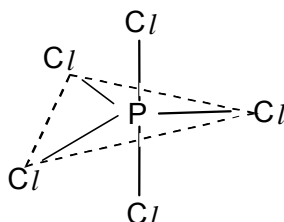
A larger amount of energy is needed to break the strong covalent bonds between C atoms in diamond, whereas in graphite, a smaller amount of energy is needed to overcome the weak intermolecular forces of attraction between layers of carbon atoms. [2]

- (b) (i)  $\text{PCl}_3$



Shape: trigonal pyramidal

- $\text{PCl}_5$



Shape: trigonal bipyramidal [3]

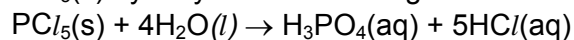
6. (b) (ii) Both  $\text{PCl}_5$  and  $\text{PCl}_3$  have simple molecular structures.

There is a greater number of electrons per molecule of  $\text{PCl}_5$  compared to  $\text{PCl}_3$ .

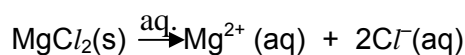
A larger amount of energy is needed to overcome the stronger van der Waals' forces between  $\text{PCl}_5$  molecules, than the weaker permanent dipole – permanent dipole interactions between  $\text{PCl}_3$  molecules. [2]

- (iii) Describe the reactions of  $\text{PCl}_5$  and  $\text{MgCl}_2$  with water, stating the pH of the resulting solutions. Write equations for all the reactions that occur.

$\text{PCl}_5(\text{s})$  hydrolyses in water to give an acidic solution of pH 2.



$\text{MgCl}_2(\text{s})$  dissolves in water to form a neutral solution aqueous  $\text{Mg}^{2+}$  and  $\text{Cl}^-$  ions.



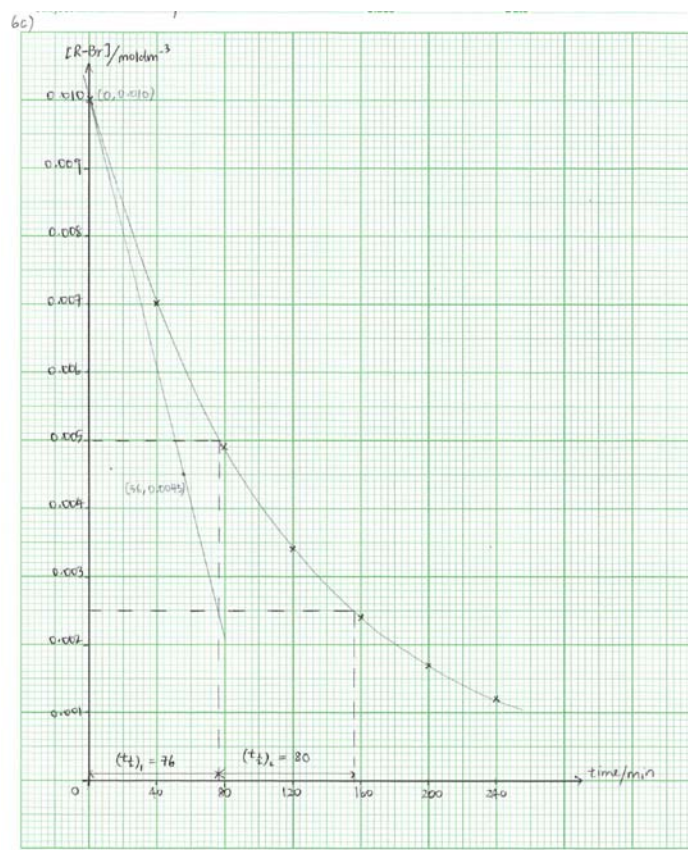
The resulting solution has a pH of 7. [3]

- (c) (i) See graph attached

$$(t_{1/2})_1 = 76 \text{ min}, \quad (t_{1/2})_2 = 80 \text{ min}$$

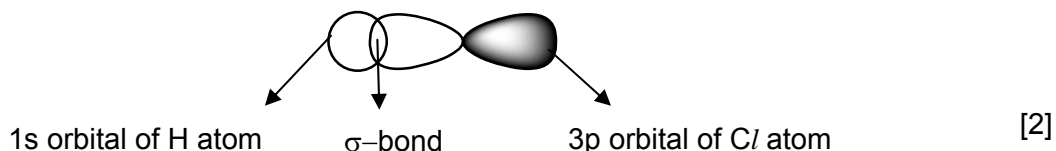
$$t_{1/2} = \frac{76 + 80}{2} = 78 \text{ min}$$

From the graph, successive half-lives are approximately constant and equal to 78 min, the order of reaction with respect to  $[\text{R-Br}]$  is one. [3]

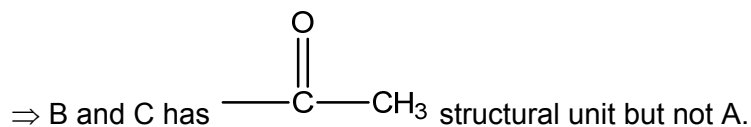


6. (c) (ii) Gradient of tangent =  $\frac{0.0045 - 0.010}{56 - 0} = -9.82 \times 10^{-5} \text{ mol dm}^{-3} \text{ min}^{-1}$
- Initial rate =  $9.82 \times 10^{-5} \text{ mol dm}^{-3} \text{ min}^{-1}$  [2]
- (iii) When [R-Br] remains constant and [NaOH] increases to 1.67 times of its original value, the rate increases to 1.68 times of its original value.
- Hence, the order of reaction with respect to [NaOH] is one. [2]
- (iv) rate =  $k[\text{R-Br}][\text{NaOH}]$
- $3.2 \times 10^{-4} = k(0.0100)(0.500)$
- $k = 0.0640 \text{ mol}^{-1} \text{ dm}^{-3} \text{ min}^{-1}$  [2]

7. (a) (i) A Brønsted-Lowry acid is a proton donor.
- A conjugate acid-base pair refers to a pair of acid and base whose formulae differs by one proton. [2]
- (ii)  $\text{H}_2\text{PO}_4^-$  is the acid and  $\text{HPO}_4^{2-}$  is its conjugate base.
- $\text{OH}^-$  is the base and  $\text{H}_2\text{O}$  is its conjugate acid. [1]
- (b) A buffer is a solution that resists changes in pH when small amounts of acid or base is added to it. An acidic buffer is made up of a mixture of a weak acid and its salt.
- In blood, we have the  $\text{H}_2\text{CO}_3/\text{HCO}_3^-$  buffer.
- When a small amount of acid is added, the large amount of  $\text{HCO}_3^-$  present will remove the acid added.
- When a small amount of base is added, the large amount of  $\text{H}_2\text{CO}_3$  present will remove the base added.
- Hence, pH of the blood is maintained. [3]
- (c) The H-Cl bond is a sigma bond formed by the head-on overlap of the 1s orbital of the hydrogen atom and the 3p orbital of the Cl atom.

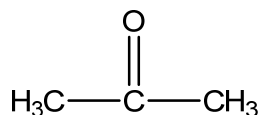
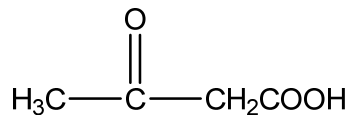
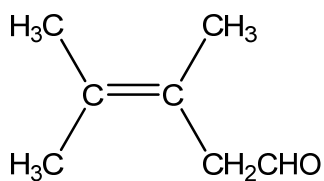
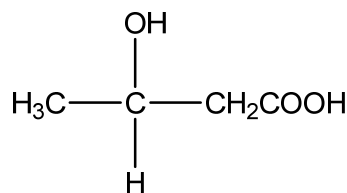


7. (d) (i)
1. A undergoes oxidation with hot, concentrated  $\text{MnO}_4^-$  to give B and C.  
 $\Rightarrow$  A has an alkene group.
  2. A, B and C undergo condensation reaction with 2,4-DNPH,  
 $\Rightarrow$  A, B and C are aldehydes or ketones.
  3. A undergoes oxidation with Fehling's solution but B and C do not.  
 $\Rightarrow$  A is an aliphatic aldehyde but B and C are not.
  4. B and C undergo positive iodoform test with alkaline aqueous iodine but A does not.

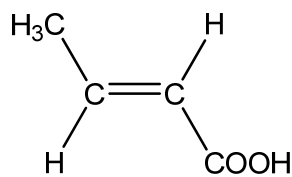
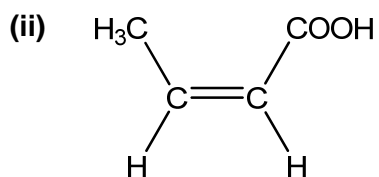


5. C undergoes acid-carbonate reaction to give  $\text{CO}_2$ .  
 $\Rightarrow$  C is a carboxylic acid.
6. Reduction of C by  $\text{NaBH}_4$  suggests that the ketone group in C is reduced, not the carboxylic acid group.  
 $\Rightarrow$  D is a secondary alcohol.

7. (d) (ii) The structures are:

**B****C****A****D**

[9]



geometrical isomerism

[3]



