## H2 Chemistry Prelim Exam Answers

## Paper 2 Answers

1 (a) (i) 
$$pV = nRT$$
  
 $[NOCl] = \frac{n}{V} = \frac{p}{RT}$   
 $= \frac{125 \times 101325}{8.31 \times (150 + 273)}$   
 $= 3603 \text{ mol m}^{-3}$   
 $= \frac{3603}{1000} \text{ mol dm}^{-3}$   
 $= 3.60 \text{ mol dm}^{-3}$ 

(ii) The pressure of NOC/ is very high, causing the volume of NOC/ gas particles to become more significant relative to the total volume of the gas.

There is significant intermolecular forces of attraction (i.e. permanent dipolepermanent dipole or instantaneous dipole-induced dipole interactions between NOC/ molecules) as it is polar/has a relatively large electron cloud size.



(ii) The graph is straight line passing through origin, rate increases linearly with  $(\rho_{NOCl})^2$ . The order of reaction with respect to  $\rho_{NOCl}$  is 2.

(iii) Rate = 
$$k(\rho_{NOCI})^2$$
 Units: N<sup>-1</sup> m<sup>2</sup> s<sup>-1</sup>





Increasing temperature will lead to

- an increase in the average kinetic energy of reactant molecules,
- more molecules will have energy greater or equal to Ea.
- frequency of effective collisions increases.
- rate of reaction increases,
- hence the rate constant increases (since rate = k[conc] and [conc] is unchanged).

(d)  $rate = k[Cl_2][NO]^2$ 

from its constituent gaseous ions under standard condition.

(ii) Ionic radius of  $Cl^{-}$  ion = 0.181 nm Ionic radius of  $I^{-}$  ion = 0.216 nm Ionic radius of  $Cl^{-}$  ion is smaller than the ionic radius of  $I^{-}$  ion.

Since  $Cl^-$  ion in AgCl and  $I^-$  ion in AgI have the same ionic charge, the theoretical lattice energy of AgCl is more exothermic than the theoretical lattice energy of AgI.

- (iii) Ag<sup>+</sup> has high charge density and hence high polarising power. It can distort the electron cloud of  $C\Gamma$  ion to result in sharing of electron density. This results in covalent character in the ionic bonds of AgC*l*.
- (iv) AgI has greater covalent character as I<sup>-</sup> has a larger and more polarisable electron cloud.

(b) (i) 
$$\Delta H_{latt}(\text{CaC}l) = \frac{107.9 \times 2 \times (+1) \times (-1)}{(0.133 + 0.181)} = -687 \text{ kJ mol}^{-1}$$
  
 $\Delta H_{latt}(\text{CaCl}_2) = \frac{107.9 \times 3 \times (+2) \times (-1)}{(0.099 + 0.181)} = -2310 \text{ kJ mol}^{-1}$ 





(iii)



From equation 4,  $2CaCl(s) \rightarrow 2Ca^{+}(g) + 2Cl^{-}(g) -2\Delta H_{eqn4}$ 

From equation 5, Ca<sup>+</sup>(g) + e<sup>-</sup>  $\rightarrow$  Ca(g)  $-\Delta H_{eqn5}$ 

 $y = \Delta H_{eqn2} + \Delta H_{eqn3} - 2\Delta H_{eqn4} - \Delta H_{eqn5} + \Delta H_{eqn6}$ = -178 + (-2310) + (-687 x -2) + (-590) + 1150 = -554 kJ mol<sup>-1</sup>

(c) (i)  $C\Gamma$  ion has a smaller ionic radius hence a higher charge density than  $\Gamma$  ions.  $C\Gamma$  ion forms a stronger ion-dipole interaction with H<sub>2</sub>O molecules.

The ion-dipole interaction formed between  $Ag^+$  and  $Cl^-$  ions with  $H_2O$  molecules is more exothermic than that formed between  $Ag^+$  and  $I^-$  ions with  $H_2O$  molecules. Hence, more energy is released to overcome the stronger ionic bonds in AgCl and hydrogen bonds between  $H_2O$  molecules.

- (ii)  $\Delta G^{e}_{ppt} = 2.303 \text{ RT} \log K_{sp}$ = 2.303 × 8.31 × 298 × log (2.0 × 10<sup>-10</sup>) = -55310 J mol<sup>-1</sup> = -55.3 kJ mol<sup>-1</sup>
- (iii)  $\Delta G^{\Theta}_{ppt} = \Delta H^{\Theta}_{ppt} T\Delta S^{\Theta}_{ppt}$

 $\Delta S^{e}_{ppt} = -0.03591 \text{ kJ mol}^{-1} \text{ K}^{-1} \\ = -35.9 \text{ J mol}^{-1} \text{ K}^{-1}$ 

(iv)  $\Delta S_{ppt}^{\theta}$  is negative. Entropy of the system decreases as AgCl is precipitated.

There are less ways of arranging the ions in the solid than in the aqueous state, resulting in a more disordered system to a less disordered system.

(v)  $\Delta H^{\circ}_{ppt}$  is negative and  $\Delta S^{\circ}_{ppt}$  is negative. Hence  $-T\Delta S^{\circ}_{ppt}$  is positive. When temperature increased to 1000 K,  $-T\Delta S^{\circ}_{ppt}$  becomes more positive.

 $\Delta G^{e}_{ppt}$  will become more positive / less negative. Precipitation will be less spontaneous, hence solubility of AgC*l*(s) increases.

**3 (a) (i)** Concentrations of the different sugar in 100g of ice-cream are:

sucrose = 3g glucose = 7g lactose = 1.4g maltose = 8.5g

Taking the relative sweetness values from table sucrose =  $1 \times 3g = 3.000$  units of relative sweetness glucose =  $0.75 \times 7g = 5.250$  units of relative sweetness lactose =  $0.2 \times 1.4g = 0.2800$  units of relative sweetness maltose =  $0.5 \times 8.5g = 4.250$  units of relative sweetness

Overall relative sweetness of the 150g serving of ice-cream = 3.000 + 5.250 + 0.2800 + 4.250 = 12.78 = 12.8 units of relative

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Sugar	relative sweetness	price /kg	price per unit of relative sweetness
Glucose	0.75	\$8.63	\$11.51
Fructose	1.15	\$25.70	\$22.35
Lactose	0.2	\$15.49	\$77.45
Maltose	0.5	\$13.87	\$27.74

The price per unit of relative sweetness of lactose is the highest at \$77.45. To maintain the same level of relative sweetness, the manufacturer using more lactose will incur a much higher cost. Hence they would minimise use of lactose.

(iii) Volume of ice-cream after melting =  $150 \text{ g} / 0.5 \text{ g ml}^{-1} = 300 \text{ ml}$ 

Based on percentage mass given, 150g of ice-cream contains 4.5g of sucrose, 10.5g of glucose, 2.1g of lactose and 12.75g of maltose.

Total amount of sugar in the serving of ice-cream = 4.5g of sucrose + 10.5g of glucose + 2.1g of lactose + 12.75g of maltose = 29.85 g

Since sugar content = 29.85 g / 300 ml = 9.95 g / 100 mlThe assigned grade would be C.

- (ii) Glucose and fructose have simple molecular structure with hydrogen bonds between their molecules. A lot of energy is required to overcome the strong hydrogen bonds which results in a high boiling point and low volatility. Hence these molecules do not get vaporise and travel easily to get picked up by smell receptors of the human body.
- (iii) It is reducing in nature/ It caused reduction of Tollens' reagent/ It undergoes oxidation.
- (c) (i) Dynamic equilibrium occurs in a reversible system, where the rates of the forward and reverse reactions are the same. There is no net change in the concentration of the reactants and products.
  - (ii) percentage of the  $\alpha$ -glucose left =  $\frac{52.2 19.0}{113.4 19.0} = \frac{33.2}{94.4} = 0.3516 = 35.2\%$ percentage of the  $\beta$ -glucose formed = 100 - 35.16 = 64.84%

Assuming there was 1 mol of  $\alpha$ -glucose at the start,

$$\operatorname{Kc} = \frac{\left[\beta - glucose\right]}{\left[\alpha - glucose\right]} = \frac{\left(\frac{0.6484}{1}\right)}{\left(\frac{0.3516}{1}\right)} = 1.844 = 1.84$$

(iii) The new equilibrium mixture will contain more  $\alpha$ -glucose and less  $\beta$ -glucose.

When the temperature is increased, by Le Chatelier's Principle, the reverse endothermic reaction is favoured to reduce the added heat. Hence the position of equilibrium will shift to the left.

(iv) The final measured optical rotation remains at +52.2° but it will be achieved faster.

The acid acts as catalyst for the conversion, lowering the activation energy of both the forward and reverse reactions to the **same extent**, therefore, increasing the rate of the forward and reverse reactions to the same extent, allowing dynamic equilibrium to be reached faster.

Addition of a catalyst has no effect on position of equilibrium, composition of equilibrium mixture remains unchanged and so the measured optical rotation remains the same.

(d) (i)



(ii) Point X. At isoelectric point, sum of the charges of the species in the solution is zero. Thus, the species present, HOOCCH<sub>2</sub>CH(NH<sup>3+</sup>)COO<sup>−</sup>, will not move when an electric field is applied.

(iii)



- 4 (a) (i) Ethanol:  $K_{a} = 1.26 \times 10^{-16} \Rightarrow K_{b} = \frac{1 \times 10^{-14}}{1.26 \times 10^{-16}} \Rightarrow pK_{b} = -\lg \frac{1 \times 10^{-14}}{1.26 \times 10^{-16}} = -1.90$ Phenol:  $K_{a} = 1.12 \times 10^{-10} \Rightarrow K_{b} = \frac{1 \times 10^{-14}}{1.12 \times 10^{-10}} \Rightarrow pK_{b} = -\lg \frac{1 \times 10^{-14}}{1.12 \times 10^{-10}} = 4.05$ 
  - (ii) For ethoxide, due to the presence of electron donating ethyl group, the electron density around oxygen atom is increased and lone pair of electrons is more available for donation.

For phenoxide, the p orbital of electrons of oxygen atom overlaps with the  $\pi$  electron cloud of benzene ring, lone pair of electrons on oxygen atom delocalised into the benzene ring and hence less available for donation. Thus phenoxide is less basic than ethoxide.

- (iii) O-H bond is polar while C-H bond is non polar.
- (b) (i) Nucleophilic addition
  - (ii)



(iii) Stage 1 ethanal: <u>Bronsted acid</u>

ethoxide: Bronsted base

*Stage 2* Enolate B: <u>Lewis base</u>

2-methyl-4-hexen-3-one: Lewis acid

(iv) Acidity depends on stability of conjugate base (enolate **B**).

The p orbital of electrons of the negatively charged carbon atom overlaps with the  $\pi$  electron cloud of C=O bond, lone pair of electrons on carbon atom delocalised into the C=O bond and disperse the negative charge. [1] This stabilises the conjugate base enolate **B**.

(v) Presence of an electron withdrawing –NH<sub>2</sub> group due to the highly electronegative nitrogen atom, the negative charge on the conjugate base (or enolate) is more dispersed. Hence stabilising the conjugate base.

The conjugate base (or enolate) of 3-aminoethanal is able to form intramolecular hydrogen bonding which stabilises the conjugate base.





(vii) The highly electronegative oxygen atom of carbonyl functional group polarises the alkene carbon. The p orbital of alkene carbons overlap with  $\pi$  electron cloud of C=O bond, the enolate B is able to attack the  $\delta$ + alkene carbon and causes a delocalisation of electrons to the oxygen atom.

2-methyl-4-hexen-3-one is unable to undergo nucleophilic addition at the carbonyl carbon due to the steric hindrance arising from the two bulkyl methyl groups that are next to the carbonyl group. Hence, the nucleophile, enolate **B** is unable to attack the carbonyl carbon.

(viii) A does not show any optical activity.

In stage 2, enolate **B** attacks the trigonal planar alkene from either the top or bottom of the plane with equal probability, producing equal amounts of two enantiomers. Each enantiomer rotates plane-polarised light in the opposite direction by the same magnitude hence the rotating powers of the enantiomers cancel out, making the product mixture optically inactive.

- (c) (i) All the atoms in **F** have an octet configuration but the carbocation carbon in **G** does not (or **G** is electron deficient).
  - (ii) In order to form C=O bond in **F**, the presence of unhybridised p orbital in the oxygen atom allows it to overlap with p orbital of carbocation forming a  $\pi$  bonding and delocalise lone pair of electrons, hence it has to be sp<sup>2</sup> hybridised.

## (iii)

• Nucleophilic Substitution (S<sub>N</sub>1)



(iv) No effect. For  $S_N1$  reaction, rate = k[H]. Any change in the nucleophile has no effect on rate of reaction.