## 2018 Y6 H2 Chemistry Preliminary Examinations Paper 1 (Suggested Solutions)

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

## Q1(C)

Since the  $A_r$  of Fe is closest to 55.94, the most abundant isotope is  ${}^{56}Fe \Rightarrow \%$  abundance of  ${}^{56}Fe = 91.8$ % abundance of  ${}^{54}Fe \& {}^{58}Fe = 100 - 91.8 = \underline{8.2\%}$ Let the % abundance of  ${}^{54}Fe be x\%$ % abundance of  ${}^{58}Fe = 8.2 - x \% = z\%$ 

100

 $A_r$  of Fe =  $\frac{(53.94)(x) + (55.94)(91.8) + (8.2-x)(57.93)}{(57.93)}$ 

## = 55.849

% abundance of  ${}^{54}$ Fe = x = 6.37 % % abundance of  ${}^{58}$ Fe = 8.2 - x = 1.83 %

#### Q2(A)

$$\begin{split} &S_2Cl_x \text{ disproportionates completely in water to give} \\ &S:SO_2 = 3:1 = 6:2 \\ &\text{Writing and balancing half-equations:} \\ &[\textbf{R}] \ &3S_2Cl_x + (3x)e^- \longrightarrow \textbf{6}S + (3x)Cl^- \\ &[\textbf{O}] \ &S_2Cl_x + 4H_2O \longrightarrow \textbf{2}SO_2 + (8-x)e^- + 8H^+ + xCl^- \\ &electrons \ &loss = electrons \ &gain \\ &3x = 8-x \\ &x = 2 \end{split}$$

#### Q3(C)

Angle of deflection  $\propto \frac{\text{charge}}{\text{mass}}$ 

- A Angle of deflection  $\propto 1/(15 + 15) = 0.0333$
- **B** Angle of deflection  $\propto 3/(12 + 16 + 16) = 0.0682$
- **C** Angle of deflection  $\propto 2/(12+16) = 0.0714$  (greatest value)
- **D** Angle of deflection  $\propto 2/(16 + 18) = 0.0588$

## Q4(C)

Mass number of  $\mathbf{E} = 241 - 4 = 237$ Number of protons in  $\mathbf{E} = 95 - 2 = 93$ Number of neutrons in  $\mathbf{E} = 237 - 93 = 144$ 

# Q5(C)

- A Only **G** has an aldehyde functional group that can be oxidised by potassium dichromate (VI).
- B Both F and G exhibit intramolecular hydrogen bonding



- **C** Both **F** and **G** have 8  $\pi$  electrons (6 in benzene ring and 2 in C=O).
- D The carbon on the methyl side chain of F is sp<sup>3</sup> hybridised and tetrahedral in shape, hence F is not planar. G is planar as all the carbon atoms are sp<sup>2</sup> hybridised (trigonal planar) and the O atom has a bent shape.

#### Q6(A)

Manipulate the ideal gas equation, pV = nRT

**A**  

$$\frac{p}{T} = \frac{nR}{V} = nR\left(\frac{1}{V}\right)$$
  
Since  $\frac{p}{T} \propto \left(\frac{1}{V}\right)$ , **A** is correct

# В

 $\frac{V}{T} = \frac{nR}{P} = constant$ 

The graph should be a vertical straight line.

pV = 
$$\frac{m}{M}$$
RT, where n =  $\frac{m}{M}$   
p =  $\left(\frac{m}{V}\right)\frac{RT}{M}$   
Since  $\rho = \frac{m}{V}$ ,  
p =  $\rho \frac{RT}{M}$   
 $\rho = \left(\frac{M}{RT}\right)p$ 

Since  $\frac{M}{RT}$  is constant, gradient is constant and it should be a straight line through origin.

## **D** pV = nRT = (nR)T

The y-intercept should be 0, i.e. a straight line through origin, as temperature is measured in Kelvins.

#### Q7(B)

There are 2 propagation steps that lead to the formation of bromomethane, which explains the presence of 2 peaks (i.e. 2 transition states).

The 2 propagation steps are:

(a)  $CH_4 + Cl \bullet \longrightarrow \bullet CH_3 + HCl$  $\Delta H_a = [BE(C-H) - BE(H-Cl)] = 410 - 431 = -21 \text{ kJ mol}^{-1}$  (b)  $\bullet CH_3 + Cl_2 \longrightarrow CH_3Cl + Cl \bullet$  $\Delta H_b = [BE(Cl - Cl) - BE(C - Cl)] = 244 - 340 = -96 \text{ kJ mol}^{-1}$ 

 $\Delta H_{prop} = \Delta H_a + \Delta H_b = -117 \text{ kJ mol}^{-1}$ 

Hence, the propagation step is exothermic. The products formed are at a lower energy level than the reactants.

# Q8(B)

- A The maximum attainable oxidation number of each element corresponds to the number of valence electron(s) in each atom of the element, i.e. all the valence electrons can be used for bonding.
- **B** MgO has a higher melting point than Na<sub>2</sub>O.

Recall that strength of ionic bonds  $\propto |\text{L.E.}| \propto \left| \frac{q_+ q_-}{r_+ + r_-} \right|$  .

The lattice energy of MgO will be more exothermic than  $Na_2O$  as  $Mg^{2+}$  has a higher charge and smaller cationic radius than  $Na^+$ .

- **C** The pH of the aqueous solutions of the chlorides decreases across the Period (refer to lecture notes on 'The Periodic Table (I)').
- **D** NaCl and MgCl<sub>2</sub> are ionic compounds while  $AlCl_3$ , SiCl<sub>4</sub> and PCl<sub>5</sub> are simple molecules.

## Q9(D)

- A *Cl*<sub>2</sub> molecule has less electrons than P<sub>4</sub> molecule. Hence *Cl*<sub>2</sub> has weaker instantaneous dipoleinduced dipole interactions and has a lower melting point.
- **B** Na has a lower melting point than Mg due to weaker metallic bonding in Na.

## Q10(C)

By inspection, rate =  $k[NO_2][SO_2]$ .

Since  $[SO_2] >> [NO_2]$  in all 3 experiments, this is a pseudo first-order reaction and rate = k [NO<sub>2</sub>], where k' = k[SO<sub>2</sub>].

$$t_{1/2} = \frac{\ln 2}{k'} = \frac{\ln 2}{k[SO_2]}$$

Since the  $[SO_2]$  in expt 1 and 2 are the same, the halflife should be the same at 48 s. Since  $[SO_2]$  in expt 3 is twice that in expt 1, the half-life would be halved to 24 s.

# Q11(A)

The time taken for the pink colour to fade also depends on "how pink" the solution was, i.e. [M], at the start of each experiment. So rate is directly proportional to [M]/t.

- 1 Comparing expt 1 & 2, when [**M**] doubled, the rate also doubled. ∴ order of rxn wrt **M** is 1.
- 2 Comparing expt 1 & 3, when [OH<sup>-</sup>] halved, the rate also halved. ∴ order of rxn wrt OH<sup>-</sup> is 1.
- 3 In expt 4, the volumes were all double that of expt 1, so the concentrations of all reactants in expt 4 were the same as expt 1. So the time taken should be 100 s.

# 12(C)

- A A catalyst will increase the rate of reaction but does not affect the composition of the mixture at equilibrium, i.e. [**S**] remain unchanged.
- **B**  $K_{p}$  changes with temperature.
- **C** Compression of reaction mixture causes the partial pressures of all gases to increase. Since there are fewer gas particles on the product side, the equilibrium position will shift right to produce more **S** and [**S**] will increase.  $K_0$  only changes with temperature.

The rates of the forward and backward reactions increase because the particles are closer to one another and the frequency of effective collisions increase.

D At constant volume, the partial pressures (and hence concentrations) of all species remain unchanged and the equilibrium position will not shift, , i.e. [S] remain unchanged.

# Q13(A)

From both graphs, the yield of  $NH_3$  decreases as the temperature increases. This means that as temperature increases, the backward reaction is favoured. Hence the backward reaction is endothermic and the forward reaction must be exothermic. (x < 0)

Comparing the two graphs at any given temperature,  $p_1$  gives a higher yield of NH<sub>3</sub> than  $p_2$ . Since there are fewer gas particles on the product side, an increase in pressure will favour the forward reaction which decreases the total pressure of the system. Hence,  $p_1 > p_2$ .

## Q14(D)

$$[OH^{-}] = \sqrt{C_0 \times K_b} = \sqrt{C_0 \times \frac{K_w}{K_a}} = \sqrt{0.2 \times \frac{1.0 \times 10^{-14}}{5.6 \times 10^{-10}}}$$
  
pH = 14 - pOH  
= 14 -  $\left( -\lg \sqrt{0.2 \times \frac{1.0 \times 10^{-14}}{5.6 \times 10^{-10}}} \right)$   
= 14 +  $\lg \sqrt{0.2 \times \frac{1.0 \times 10^{-14}}{5.6 \times 10^{-10}}}$ 

## Q15(B)

A buffer solution is produced when there is a weak acid/base and its conjugate base/acid in solution.

- 1 Excess of  $PO_4^{3-}$  reacts with limited H<sup>+</sup>, resulting in  $HPO_4^{2-}$  and  $PO_4^{3-}$  in solution. (Buffer)
- 2 Excess OH<sup>-</sup> reacts with limited CH<sub>3</sub>CO<sub>2</sub>H, resulting in CH<sub>3</sub>COO<sup>-</sup> and OH<sup>-</sup> in solution. (Not a buffer)
- 3 Excess HO<sub>2</sub>C–CO<sub>2</sub>H reacts with limited OH<sup>-</sup>, resulting in HO<sub>2</sub>C–CO<sub>2</sub><sup>-</sup> and HO<sub>2</sub>C–CO<sub>2</sub>H. (Buffer)

# Q16(A)

- A The ligand, edta, has a charge of 4–. Since overall charge is 2–, oxidation number of Fe = +2.
- **B** The ligand, CO, has a charge of 0. Since overall charge is 0, oxidation number of Fe = 0.
- **C** The ligand, phenoxide ion, has a charge of 1–. Since overall charge is 3–, oxidation number of Fe = +3.
- **D** The ligand, NCS, has a charge of 1–, while  $H_2O$  has a charge of 0. Since overall charge is 2+, oxidation number of Fe = +3.

# Q17(C)

 $[Cu(H_2O)_6]^{2+} + 4Cl^- \longrightarrow [CuCl_4]^{2-} + 6H_2O$ The number of d-electrons in copper remains the same because there is no change in oxidation state of copper. Since there is a colour change, the wavelength of light absorbed must be different and that must be due to a change in energy gap between the d-orbitals.

## Q18(D)

H<sub>2</sub>, Ni reduces alkene and carbonyl functional groups, but not carboxylic acid functional group.



The product contains 9 chiral centres and has 2<sup>9</sup> stereoisomers.



Options (1) and (3) are correct.

#### Q20(D)

**X** contains a secondary fluoroalkane. As the cleavage of the C-F bond requires a large amount of energy, it does not occur under the given condition and no ppt of AgF(s) is formed. [Also, AgF is very soluble in water.]

**Z** and **Y** contain a secondary iodoalkane and acyl bromide respectively. As the C=O carbon in **Y** is bonded to 2 highly electronegative atoms (O and Br), there is a larger  $\delta$ + charge on C and it is more susceptible to attack by nucleophiles and **Y** undergoes hydrolysis more easily than **Z**. Hence, the pale cream ppt of AgBr is formed the fastest.

The C–I carbon in **Z** is bonded to only 1 electronegative atom, I. Hence, there is a smaller  $\delta$ + charge on C and it is less susceptible to attack by nucleophiles as compared to the C=O carbon in **Y**.

## Q21(A)

1 Fehling's reagent react with <u>aliphatic</u> aldehydes to form a reddish brown ppt of Cu<sub>2</sub>O.  $\stackrel{0}{R-C-H} + 2Cu^{2+} + 50H^{-} \xrightarrow{warm} R - C - O^{-} + Cu_2O + 3H_2O$  $\xrightarrow{reddish-brown}_{precipitate}$ 

Aromatic aldehydes and ketones do not react with Fehling's solution. Hence, Fehling's reagent will form a reddish brown ppt with 3-phenylpropanal but not with 2-hydroxybenzaldehyde.

2 [Ag(NH<sub>3</sub>)<sub>2</sub>]<sup>+</sup> (also known as Tollens' reagent) reacts with both aromatic and aliphatic aldehydes.

$$\begin{array}{c} O \\ R - C - H + 2[Ag(NH_3)_2]^+ + 3OH^- \xrightarrow{warm} R - C - O^- + 2Ag + 4NH_3 + 2H_2O \\ silver mirror \end{array}$$

Hence, [Ag(NH<sub>3</sub>)<sub>2</sub>]<sup>+</sup> will form a silver mirror with both 3-phenylpropanal and 2-hydroxybenzaldehyde and cannot be used to distinguish between the two compounds.

3 SOC*l*<sub>2</sub> reacts with alcohol and carboxylic acid to form white fumes of HC*l* but not with phenol. Hence, SOC*l*<sub>2</sub> will not react with both 3-phenylpropanal and 2-hydroxybenzaldehyde, and cannot be used to distinguish between the two compounds.

#### Q22(A)

In increasing order of stability:



The more stable the anion (conjugate base), the stronger the acid. Hence, in increasing order of acid strength:



Since the stronger the acid, the weaker its conjugate base, the basicity decreases in the order:



Note: **G** is the most stable as the negative charge is delocalised between 2 highly electronegative oxygen atoms in the carboxylate group and has an electron withdrawing carbonyl group on the  $4^{th}$  position relative to the carboxylate group on the benzene ring, which increases the dispersal of the negative charge further. **H** is less stable than **G**, but is more stable than **F** and **E**, as the negative charge is delocalised between 2 highly electronegative oxygen atoms in the carboxylate group. However, **H** has an electron donating hydroxy group on the  $4^{th}$  position relative to the carboxylate group on the the carboxylate group.

negative charge compared to in **G**. **F** is more stable than **E** as the negative charge on the oxygen can be delocalised into the benzene ring. However in **E**, the negative charge is localised on the oxygen atom and intensified by the electron donating alkyl group.

benzene ring, which decreases the dispersal of the

#### Q23(B)



#### Q24(D)

Both -COOH and  $-NO_2$  groups are 3-directing and both  $-CH_3$  and -Br are 2,4-directing.







Option **D** will lead to the highest yield of the desired product.

#### Q25(D)

The type of reaction taking place is electrophilic addition, as shown below.



As  $H_2O$ : is also present to act as a nucleophile in the second (fast) step, the following two products can also be formed.



Compound in **D** will not be formed as this would require an attack by bromine to form a carbocation intermediate which contains a Br in the slow step. The only available bromine is in the form of  $Br^-$ , which is unable to act as an electrophile.

#### Q26(C)

The reaction takes place via the  $S_N1$  mechanism. In the  $S_N1$  mechanism (nucleophilic substitution with only 1 species in the rate determining step and is therefore a 2-step reaction), the C-X (X = halogen atom) bond breaks heterolytically, resulting in a carbocation intermediate, as shown in option **C**.

[Note: Although this is a secondary carbocation, the electrons from the benzene ring delocalise over the positively charged carbon, dispersing the positive charge and stabilising the carbocation.]

On the other hand, option **B** shows the transition state formed in the  $S_N2$  mechanism (2 species in the rate determining step and hence a one-step reaction). The NH<sub>3</sub> nucleophile and the halogen derivative react to form a transition state, where the C-Br bond is partially broken and the C-N bond is partially formed. A transition state is <u>not</u> a reaction intermediate. Option **A** is an intermediate formed in an electrophilic substitution reaction while option **D** is an intermediate formed in a free radical substitution reaction.

## Q27(B)

- 1 For one amide group and one ketone group to exist, there is a need for a C=C bond to be present in order for the compound to have the molecular formula  $C_4H_5O_2N$ . However, the compound does not decolourise Br<sub>2</sub> in CC*l*<sub>4</sub>.
- 2 For one ester group and one amine group to exist, there must be more hydrogen atoms present for the number of carbon atoms given in the formula  $C_4H_5O_2N$ . Also, an amine group is not neutral.
- 3 For one ester group and one nitrile group to exist, the following is a possible structure:

$$\bigcup_{nitrile} C \xrightarrow{+} CH_2 \xrightarrow{+} CO_2CH_3$$

## Q28(D)

In water:

Let solubilities of ZnCO<sub>3</sub> and Ag<sub>2</sub>CO<sub>3</sub> in water be x and y mol dm<sup>-3</sup> respectively.

 $ZnCO_3(s) \rightleftharpoons Zn^{2+}(aq) + CO_3^{2-}(aq)$ At equilibrium in the saturated solution,  $[Zn^{2+}] = [CO_3^{2-}] = x \mod dm^{-3}$  $K_{sp} = [Zn^{2+}][CO_3^{2-}]$ 1.46 x 10<sup>-10</sup> = x<sup>2</sup> x = 1.21 x 10<sup>-5</sup> mol dm<sup>-3</sup>

Ag<sub>2</sub>CO<sub>3</sub>(s)  $\rightleftharpoons$  2Ag<sup>+</sup>(aq) + CO<sub>3</sub><sup>2−</sup> (aq) At equilibrium in the saturated solution, [Ag<sup>2+</sup>] = 2y mol dm<sup>-3</sup> [CO<sub>3</sub><sup>2−</sup>] = y mol dm<sup>-3</sup>  $K_{sp} = [Ag^{2+}]^2[CO_3^{2-}]$ 8.46 × 10<sup>-12</sup> = (2y)<sup>2</sup>y y = 1.28 × 10<sup>-4</sup> mol dm<sup>-3</sup> (**B** is incorrect)

Since x < y, Ag<sub>2</sub>CO<sub>3</sub> is more soluble.

For the solution containing 0.02 mol dm<sup>-3</sup>  $Zn(NO_3)_2$  and 0.02 mol dm<sup>-3</sup>  $AgNO_3$ :

 $Ag_2CO_3(s) \Rightarrow 2Ag^+(aq) + CO_3^{2-}(aq)$ When  $Ag_2CO_3$  starts to precipitate,  $K_{sp}$  of  $Ag_2CO_3 = ionic \text{ product of } Ag_2CO_3$  $K_{sp} = [Ag^{2+}]^2[CO_3^{2-}] = (0.02)^2[CO_3^{2-}] = 8.46 \times 10^{-12}$  $[CO_3^{2-}] = 2.12 \times 10^{-8} \text{ mol dm}^{-3}$  (**D** is correct)

 $ZnCO_3(s) \rightleftharpoons Zn^{2+}(aq) + CO_3^{2-}(aq)$ When  $ZnCO_3$  starts to precipitate,  $K_{sp}$  of  $ZnCO_3$  = ionic product of  $ZnCO_3$  $K_{sp} = [Zn^{2+}][CO_3^{2-}] = (0.02) [CO_3^{2-}] = 1.46 \times 10^{-10}$  $[CO_3^{2-}] = 7.30 \times 10^{-9} \text{ mol dm}^{-3}$  Since a lower  $[CO_3^{2-}]$  is required for the precipitation of  $ZnCO_3$ ,  $ZnCO_3$  will precipitate first. (**A** is incorrect)

Both ZnCO<sub>3</sub> and Ag<sub>2</sub>CO<sub>3</sub> will be precipitated at the same time after ionic product of Ag<sub>2</sub>CO<sub>3</sub> exceeds that of its  $K_{sp.}$  (**C** is incorrect)

#### Q29(D)

 $4Al + 3O_2 \longrightarrow 2Al_2O_3$ Amount of O<sub>2</sub>  $= \frac{3}{2} \times \text{amount of } Al_2O_3$  $= \frac{3}{2} \times \frac{23.7}{102}$ 

At the anode:

 $2H_2O \longrightarrow O_2 + 4H^+ + 4e^-$ Amount of electrons, n<sub>e</sub>, that passed through in time t = 4 × amount of O\_2 = 4 ×  $\frac{3}{2} \times \frac{23.7}{102}$ Q = It = n<sub>e</sub>F t =  $\frac{n_eF}{1} = \frac{4 \times \frac{3}{2} \times \frac{23.7}{102} \times 96500}{1.4} = \frac{3 \times 23.7 \times 4 \times 96500}{2 \times 102 \times 1.4}$ 

#### Q30(A)

Based on the battery's polarity, reduction takes place at the platinum electrode while oxidation takes place at the alloy electrode.

- 1 Since  $X^{2+}$  was reduced to X at the platinum electrode and no H<sub>2</sub> gas was formed at the platinum electrode, it shows that  $X^{2+}$  is preferentially reduced as compared to water. Thus,  $E^{\oplus}(X^{2+}/X) > E^{\oplus}(H_2O/H_2).$
- 2 At the alloy electrode, **X** and **Y** are preferentially oxidised as compared to **Z**. So  $E^{\ominus}(\mathbf{Z}^{2+}/\mathbf{Z}) < E^{\ominus}(\mathbf{X}^{2+}/\mathbf{X})$  and  $E^{\ominus}(\mathbf{Z}^{2+}/\mathbf{Z}) < E^{\ominus}(\mathbf{Y}^{2+}/\mathbf{Y})$ . However, at the platinum electrode,  $\mathbf{X}^{2+}$  was reduced to **X** but  $\mathbf{Y}^{2+}$  was not reduced to **Y**. So  $E^{\ominus}(\mathbf{X}^{2+}/\mathbf{X}) > E^{\ominus}(\mathbf{Y}^{2+}/\mathbf{Y})$ . Overall:  $E^{\ominus}(\mathbf{Z}^{2+}/\mathbf{Z}) < E^{\ominus}(\mathbf{Y}^{2+}/\mathbf{Y}) < E^{\ominus}(\mathbf{X}^{2+}/\mathbf{X})$
- 3 If the polarity of the battery is reversed, then oxidation should take place at the platinum electrode. Hence, reduction of H<sub>2</sub>O to form H<sub>2</sub> will not occur at the platinum electrode.