## 2024 JC2 Preliminary Examination H2 Chemistry 9729 Paper 1 Worked Solution

mass of Fe in 0.32 g of Fe<sub>2</sub>O<sub>3</sub> =  $\frac{2 \times 55.8}{2 \times 55.8 + 3 \times 16.0} \times 0.32$  g = 0.2238 g % by mass of Fe in ore =  $\frac{0.2238}{0.6}$ = 37.3%

 $\Rightarrow \mathbf{B}$ 

1

2  $n_{y^{2+}} = \frac{25.0}{1000} \times 0.400 = 0.0100 \text{ mol}$ 

 $n_{\rm MnO_4^-} = \frac{40.00}{1000} \times 0.10 = 0.00400 \text{ mol}$ 

 $5Y^{2+} \equiv 2MnO_4^-$ 

 $MnO_4^-$  is an oxidising agent, per mole, it takes in 5 moles of electrons:  $MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$ 

 $5Y^{2+} \equiv 10e^{-}$ , each mole of  $Y^{2+}$  gives out 2 moles of electrons.

 $\Rightarrow$  Final oxidation of Y is +4.

 $\Rightarrow$  A

3

nuclide	$\frac{\text{charge, } q}{\text{mass, } m}$ ratio
<sup>24</sup> Mg <sup>+</sup>	$\frac{1}{24} = 0.0417$
<sup>48</sup> Ti <sup>3+</sup>	$\frac{3}{48} = 0.0625$
<sup>59</sup> Co <sup>2+</sup>	$\frac{2}{59} = 0.0339$
<sup>101</sup> Ru <sup>4+</sup>	$\frac{4}{101} = 0.0396$

Since <sup>48</sup>Ti<sup>3+</sup> has the largest  $\frac{q}{m}$  ratio

amongst the four nuclides, it will experience the greatest deflection.

 $\Rightarrow$  B

$$\Rightarrow$$
 D

5

Using 
$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2} \Rightarrow p_2 = p_1 \times \frac{V_1}{V_2} \times \frac{T_2}{T_1}$$
  
 $p_k = 40 \text{ kPa} \times \frac{100 \text{ cm}^3}{(100 + 400) \text{ cm}^3} \times \frac{(227 + 273)\text{ K}}{(227 + 273)\text{ K}}$   
 $= 8 \text{ kPa}$   
 $p_L = 20 \text{ kPa} \times \frac{400 \text{ cm}^3}{(100 + 400) \text{ cm}^3} \times \frac{(227 + 273)\text{ K}}{(127 + 273)\text{ K}}$   
 $= 20 \text{ kPa}$ 

final pressure of mixture = 
$$p_{k} + p_{L}$$
  
= 8 kPa + 2

- 1√: Lattice energy is the energy released when 1 mole of ionic compound, KC*l*(s), is formed from its constituent gaseous ions, K<sup>+</sup>(g) and C*l*(g). The lattice energy of potassium chloride is Δ*H*<sub>3</sub>.
  - 2\*: The enthalpy change of solution is the energy change when 1 mole of substance in its standard state, KCl(s), is completely dissolved in a solvent to give a solution of infinite dilution,  $K^*(aq)$  and Ct(aq). The enthalpy change of solution of potassium chloride is  $\Delta H_4$ .
  - 3√: Enthalpy change of formation is the energy change when 1 mole of a substance in its standard state, KC*l*(s), is formed from its constituent elements in their standard states, K(s) and C*l*<sub>2</sub>(g). The enthalpy change of formation of solid potassium chloride is ( $\Delta H_1 + \Delta H_2 + \Delta H_3$ ).

 $\Rightarrow$  B

- 7 **1**  $\checkmark$ :  $(\Delta G_1 + \Delta G_2)$  is  $\Delta G$  for dissolving of AgC*l*(s) in NH<sub>3</sub>(aq);  $(\Delta G_3 + \Delta G_4)$  is  $\Delta G$  for dissolving of AgBr(s) in NH<sub>3</sub>(aq). As solid AgC*l* is more soluble than solid AgBr in NH<sub>3</sub>(aq), the former must be more exergonic, *i.e.*  $\Delta G$  is more negative. Thus,  $(\Delta G_1 + \Delta G_2) < (\Delta G_3 + \Delta G_4)$ .
  - **2**√: Eqm 2 and 4 are identical, with C*t*<sup>-</sup> and Br<sup>-</sup> being spectator ions: Ag<sup>+</sup>(aq) + 2NH<sub>3</sub>(aq)  $\rightleftharpoons$  [Ag(NH<sub>3</sub>)<sub>2</sub>]<sup>+</sup>(aq) Hence,  $\Delta G_2 = \Delta G_4$ .
  - **3\***: From 2,  $\Delta G_2 = \Delta G_4$ .
  - **4**√: Since solid AgC*l* is more soluble than solid AgBr in water,  $\Delta G_1$  must be more exergonic, *i.e.* more negative, than  $\Delta G_3$ . Thus  $\Delta G_1 < \Delta G_3$ .

## $\Rightarrow$ A

 8 A\*: Forward reaction of reaction 1 leads to the formation of Ag atoms, causing the photochromic glass to darken.

Reaction 2 and 3 together, is the backward reaction of reaction 1, catalysed by  $Cu^+$  and  $Cu^{2+}$ . This removes Ag atoms, causing the glass to becomes transparent again. Forward reaction of reaction 1 must be much faster than the backward reaction (reaction 2 + reaction 3) when intensity of UV light is high to ensure the glass darkens.

- **B** $\checkmark$ : The forward reaction of reaction 1 is only favoured when intensity of (high energy) UV light is high, showing that the forward reaction is endergonic, *i.e.*  $\Delta G > 0$  (non-spontaneous)
- C≭: When glass darkens in UV light, [Ag] increases while [Ag<sup>+</sup>] decreases, which will cause reaction 3 to be more spontaneous.
- D\*: The position of equilibrium of reaction 1 shifts to the right in strong UV light, leading to formation of Ag atoms which cause the photochromic glass to darken.

$$\Rightarrow \mathbf{B}$$

**9** The fraction of molecules with energy greater than or equal to a certain energy *E* is represented by the area under the graph beyond *E*. So, W+X+Y+Z = 1.

When a catalyst is added, the activation energy is lowered. Hence, the fraction of molecules with energy greater than or equal to activation energy for the catalysed reaction will be X+Y+Z.

 $\Rightarrow$  C

- 10 1≭: Rate is a kinetics property related to *E<sub>a</sub>*, while *K<sub>c</sub>* is a thermodynamics property related to ∆*G<sub>r</sub>*. They are independent of each other.
  - 2\*: The temperature of the solution does not change since boiling point of water is also at 373 K. Therefore, there is no change in the  $K_c$  value.
  - 3✓: The presence of a catalyst will not change the  $K_c$  value.

 $\Rightarrow$  A

- 11 A\*: As T increased, amount of A remaining at equilibrium increased. This shows that position of equilibrium shifts left, hence backward reaction is endothermic. Forward reaction is thus exothermic.
  - **B** $\checkmark$ : Position of equilibrium shifts left with increasing *T* to favour endothermic reaction. Thus  $K_p$  will decrease with increasing *T*.
  - **C\***: At 650 °C, amount of **A** remaining is 0.8 mol. Thus, 1.2 mol of **A** had decomposed. Percentage of **A** decomposed is  $\frac{1.2}{2.0} \times 100 = 60\%$ .
  - D\*: The amount of A used up is 1.2 mol and hence amount of C produced is 1.2 mol at equilibrium.

 $\Rightarrow$  B

**12**  $\left[ H^{+} \right] = 10^{-2} = 0.0100 \text{ mol } dm^{-3}$ 

$$[H^+] \text{ after mixing} = \frac{0.0100V + 0.0100V}{V + V + 2V}$$
  
= 0.00500 mol dm<sup>-3</sup>

$$pH = -lg[H^+] = -lg(0.00500) = 2.3$$

$$\Rightarrow$$
 C

13 For a weak acid, HA,

$$\begin{aligned} \mathcal{K}_{a} &= \frac{\left[\mathsf{H}^{+}\right]\left[\mathsf{A}^{-}\right]}{\left[\mathsf{H}\mathsf{A}\right]} \approx \frac{\left[\mathsf{H}^{+}\right]\left[\mathsf{salt}\right]}{\left[\mathsf{acid}\right]}\\ \text{Hence, } \left[\mathsf{H}^{+}\right] \approx \mathcal{K}_{a}\frac{\left[\mathsf{acid}\right]}{\left[\mathsf{salt}\right]} \end{aligned}$$

 $\Rightarrow$  C

**14**  $CaC_2O_4(s) \rightleftharpoons Ca^{2+} (aq) + C_2O_4^{2-}(aq) - \cdots (1)$ 

$$H_2C_2O_4(aq) \rightleftharpoons 2H^+(aq) + C_2O_4^{2-}(aq) - --- (2)$$

As pH increases,  $[H^+]$  decreases. Hence the position of eqm (2) shifts to the right, causing  $[C_2O_4^2^-]$  to increase. This will cause the position of equilibrium for eqm (1) to shift to the left, reducing the solubility of  $CaC_2O_4(s)$ .

 $\Rightarrow$  D

- 15 A\*: Although nuclear charge increases, shielding effect is similar due to same number of inner shell electrons, hence, effective nuclear charge increased, leading to the general decrease in atomic radius across the period.
  - B\*: First ionisation energy generally increases due to increase in effective nuclear charge, however there is a decrease from Mg to Al (due to electron being removed from 3p

instead of 3s orbital), and from P to S (due to interelectronic repulsion between paired electrons).

- C✓: +1 in Na<sub>2</sub>O, +2 in MgO, +3 in Al<sub>2</sub>O<sub>3</sub>, +4 in SiO<sub>2</sub>, +5 in P<sub>4</sub>O<sub>10</sub>, +6 in SO<sub>3</sub>
- D≭: NaCl and MgCl₂ are ionic chlorides with higher melting points than the covalent AlCl₃, SiCl₄ and PCl₅.

 $\Rightarrow$  C

- **16** The solubility of a salt is related to  $\Delta G_{sol} = \Delta H_{sol} - T\Delta S_{sol}$ where  $\Delta H_{sol} = |L.E.| - |\Sigma \Delta H_{nyd}|$ 
  - **A\***: The charge density of  $Mg^{2+}$  is indeed higher such that  $Mg^{2+}$  is better at organising water molecules around it, which leads to a more negative  $\Delta S_{sol}$ . So, if  $\Delta S_{sol}$  is more negative, then  $\Delta G_{sol}$  is more positive for  $MgC_2O_4$ , which means that  $MgC_2O_4$  should be less soluble instead.
  - B✓: Mg<sup>2+</sup> has a higher charge density and forms stronger ion-dipole interaction and hence  $\Delta H_{hyd}$  is more negative. This potentially contributes to a more negative  $\Delta H_{sol}$ , which implies a more negative  $\Delta G_{sol}$  and greater solubility.
  - **C\***: While it is true that  $Mg^{2+}$  has a more negative L.E. due to  $Mg^{2+}$  having a smaller ionic radius than  $Ca^{2+}$ , a more negative L.E. leads to a more positive  $\Delta H_{sol}$  and hence lower  $\Delta G_{sol}$ .
  - **D\***: While this is true, electronegativity does not affect solubitlity.

 $\Rightarrow$  B

- 17 1√: As the atomic radius ↑es down the group, the valence orbitals used for bonding are larger and more diffused. This leads to less effective overlap of orbitals, resulting in X–X bond energy ↓ing down the group.
  - 2✓: The number of electrons ↑es down the group, resulting in ↑ polarisability of electron cloud and thus strength of the id-id interactions. Hence volatility ↓es (higher boiling point) down the group.
  - 3≭: E<sup>6</sup>(X<sub>2</sub>|X<sup>-</sup>) ↓es down the group, there is a ↓ in tendency for X<sub>2</sub> to be reduced. Oxidising power of Group 17 elements ↓es, *i.e.* they become weaker oxidising agents down the group.

 $\Rightarrow$  B

- 18 A\*: Compound R has 5 chiral centres, hence 2<sup>5</sup> = 32 stereoisomers.
  - **B\***: Compound **R** and **S** have exactly the same connectivity of atoms.
  - C✓: HO(CH<sub>2</sub>)<sub>13</sub>OH cannot rotate plane polarised light since it has a plane of symmetry.
  - Dx: Since the line structure of compound
     R does not possess any plane of symmetry and it has an odd number of chiral centres, none of its stereoisomers can exist as a meso compound.

⇒ C

- **19 A**★: C-F (485 kJ mol<sup>-1</sup>) is much stronger than C-Cl (340 kJ mol<sup>-1</sup>). Hence Cl• and •CClF<sub>2</sub> are the major free radicals instead.
  - B✓: Adding step 1 (×2) to step 2, we get  $2O_3 \rightarrow 3O_2$ , X• acts as a catalyst in the breakdown of  $O_3$  to  $O_2$ .

- C≭: Termination step involves the combination of two radicals, leading to the removal of tadical species.
- D\*: Being smaller in size, F• should be more reactive than Cl•.

⇒ B

20 The oxo reaction can be seen as the addition of -H and -CHO across the C=C:





- 21 A\*: Alkenes are stronger nucleophiles, since alkene can react with HBr at r.t., but not benzene.
  - B√: There is no cyclic ring of overlapping



the stable aromatic structure is destroyed, making this reaction highly unfavourable.

C\*: The C=C in an alkene (610 kJ mol<sup>-1</sup>)

is stronger than the C==C in benzene (520 kJ mol $^{-1}$ ), which makes this statement false.

**D\***: The directing effect of substituents is not involved in the cyclopropane formation.

 $\Rightarrow$  B

22 The bond strength of the C–X bond determines the rate of hydrolysis. The stronger the C–X bond, the harder it is to undergo hydrolysis.

In addition, halogenoarenes are resistant to hydrolysis due to the lone pair of electrons on X delocalising into benzene ring which results in the partial double bond between C and X, strengthening the bond.

 $\Rightarrow$  A



24 2-methylpropan-1-ol and butan-1-ol are primary alcohols that can be oxidised, but they do not give a positive test with alkaline aqueous iodine. 2-methylpropan-2-ol is a tertiary alcohol that does not undergo oxidation. Only butan-2-ol can be oxidised and has the methyl alcohol group that gives a positive test with alkaline aqueous iodine.

- **25** 1√: C=C undergoes oxidative cleavage with KMnO₄/H<sup>+</sup>, decolourising it.
  - 2✓: 1 mol of –COCH<sub>3</sub> gives 1 mol of CHI<sub>3</sub> with alkaline iodine solution.
  - 3\*: 1 mol of X reacts with 3 mol of Br<sub>2</sub>(aq)

1 mol of 
$$Br_2(aq)$$
  
1 mol of  $Br_2(aq)$   
HO  
1 mol of  $Br_2(aq)$   
1 mol of  $Br_2(aq)$ 

 $\Rightarrow$  A

- **26 A\*:** HCHO will be distilled first before methanoic acid is formed.
  - B✓: HCO<sub>2</sub>H is formed as  $K_2Cr_2O_7$  is a milder oxidising agent than KMnO<sub>4</sub>. CH<sub>3</sub>OH + 2[O] → HCO<sub>2</sub>H + H<sub>2</sub>O
  - C, D\*: KMnO<sub>4</sub> is a stronger oxidising agent and further oxidises HCO<sub>2</sub>H: HCO<sub>2</sub>H + [O]  $\rightarrow$  H<sub>2</sub>CO<sub>3</sub>  $\rightarrow$  CO<sub>2</sub> + H<sub>2</sub>O

 $\Rightarrow$  B

$$\begin{array}{c} \mathbf{27} \quad \underbrace{CH_3CH_2CH_2O}_{\text{propyl}} \underbrace{O}_{\text{methanoate}} \\ \end{array} \\ \xrightarrow{O}_{\text{methanoate}} \\ \xrightarrow{O}_{\text{cH}_3CH_2CH_2OH} + HCO_2H \\ \Rightarrow \mathbf{C} \end{array}$$

**28** The  $pK_a$ 's are as follows:

$$pK_{a2} = 4.07$$
  
HO  
 $pK_{a3} = 9.47$   $PK_{a3}$   
 $PK_{a3} = 9.47$   $PK_{a3}$ 

pH 3.70 is closer to  $pK_{a2}$  than  $pK_{a1}$ , hence it has passed the first equivalence point, but before the second point of maximum buffer capacity. So the predominant form is where the most acidic proton is removed.

 $\Rightarrow$  C

- 29 1√: Since E<sup>⊕</sup>(Zn<sup>2+</sup>|Zn) is more negative, zinc will undergo oxidation and hence, it is the negative electrode.
  - 2✓: Since E<sup>9</sup>(Zn<sup>2+</sup>|Zn) is more negative, Zn is oxidised to Zn<sup>2+</sup> and electrons flow from the Zn<sup>2+</sup>|Zn half-cell (anode) to the Ag<sub>2</sub>O|Ag half-cell (cathode).
  - 3**≭**:  $\Delta G^{\Theta} = -2 \times 96500 \times (0.34 (-0.76))$ = -212.3 kJ mol<sup>-1</sup>

 $\Rightarrow$  B

30 0.10 mol of Cr(H<sub>2</sub>O)<sub>6</sub>Cl<sub>3</sub> gives 0.20 mol AgCl means there are 2 Ct per Cr<sup>3+</sup> not acting as ligand. Hence, the complex is [CrCl(H<sub>2</sub>O)<sub>5</sub>]<sup>2+</sup>(Ct)<sub>2</sub>.

 $\Rightarrow$  C

## Answer Key

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