2022 JC2 Preliminary Examination
H2 Chemistry 9729
Paper 1 Worked Solution

1 $n_{H^+} = n_{OH^-} = \frac{25}{1000}\times 1.0\times 10^{-2} = 2.50\times 10^{-4}$ mol

1 Ca^{2+} ≡ 2 H^+

$n_{Ca^{2+}} = \frac{1}{2}n_{H^+} = 1.25\times 10^{-4}$ mol

$$[CaSO_4] = [Ca^{2+}] = \frac{n_{Ca^{2+}}}{V} = \frac{1.25\times 10^{-4}}{\frac{50}{1000}}$$
$$= 2.50\times 10^{-3}\ \text{mol dm}^{-3}$$

⇒ **A**

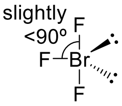
2 Large jump between 7th and 8th I.E.

⇒ 7 electrons in valence shell

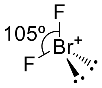
⇒ Group 17

⇒ **C**

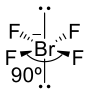
3



3 σ bond, 2 lone pairs
⇒ T-shaped (planar)



2 σ bond, 2 lone pairs
⇒ bent



4 σ bond, 2 lone pairs
⇒ square planar

⇒ **C**

4 $pV = nRT$

$pV = \frac{m}{M}RT$

Plot of *pV* against *T* will be a **straight line** that passes through the **origin (0 K)** with **gradient** $\frac{mR}{M}$.

Since *M*(**E**) < *M*(**F**), the gradient for **E** will be *steeper* than the gradient for **F**.

⇒ **A**

5 $\Delta G = \Delta H - T\Delta S$

1 ✗: $\Delta H > 0$, $\Delta S < 0$, $\Delta G > 0$ (non-spontaneous) at all *T*

2 ✗: $\Delta H < 0$, $\Delta S < 0$, $\Delta G > 0$ (non-spontaneous) when $T > \frac{\Delta H}{\Delta S}$

3 ✓: $\Delta H < 0$, $\Delta S > 0$, $\Delta G < 0$ (spontaneous) at all *T*

⇒ **D**

6 **A** ✓: 1 mol of H_2O is formed from the reaction of an acid and a base

B ✗: $\Delta H^{\ominus}_{\text{lattice energy}}(NaHCO_3(s))$ is for the reaction $Na^+(g) + HCO_3^-(g) \rightarrow NaHCO_3(s)$

C ✓: Being a strong acid, the HSO_4^- ion will fully dissociate in water to give $H^+(aq)$ and $SO_4^{2-}(aq)$

D ✓: $\Delta H^{\ominus}_{\text{formation}}$ involves forming $(NH_4)_2SO_4$ from the constituent elements, S, H_2, N_2 and O_2 in their standard states

⇒ **B**

7 1 ✓: From the slow step,
rate = $k[(CH_3)_2C^+(OH)][H_2O]$
= $k'[(CH_3)_2C(=O)][H_3O^+]$, $k' = kK_c$
At low pH, $[H_3O^+]$ is high and is essentially a constant.
rate = $k''[(CH_3)_2C(=O)]$

2 ✗: rate constant, $k = Ae^{-\frac{E_a}{RT}}$ depends only on the E_a and *T*.

3 ✓: I_2 is only involved in a fast step after the slow (rate determining) step. Hence rate of reaction is independent of $[I_2]$.

⇒ **D**

8 **A** ✗: Since there is no change in the number of gaseous particles upon reaction, the total pressure in the vessel remains constant. Hence the amount of reactants and products cannot be determined.

B ✗: Slow cooling allows the equilibrium to readjust to the new temperature. Hence, the K_c determined will be that at 20 ºC and not 500 ºC.

C ✓: Rapid cooling will slow down the reaction, allowing the amount of I_2 in the equilibrium mixture at 500 ºC, and hence K_c, to be determined.

D ✗: If the HI present is decomposed back to H_2 and I_2, the amount of reactants and product in the equilibrium mixture cannot be determined.

⇒ **C**

9 **A** ✗: Since $\Delta H < 0$, position of equilibrium lies more to the left with increasing *T*.

Hence $K_p = \frac{1}{p_{\mathbf{G}(g)}}$ ↓es with ↑ing *T*.

B ✗: $pV = nRT \Rightarrow p = \frac{n}{V}RT = CRT$

$$K_p = \frac{1}{p_{\mathbf{G}(g)}} = \frac{1}{[\mathbf{G}(g)]RT} = \frac{K_c}{RT}$$

C ✗: θ depends only on k_1, k_2 and $p_{\mathbf{G}}$. It is independent of the total surface area of the catalyst.

D ✓: At high $p_{\mathbf{G}}$, $1 + \frac{k_1}{k_2}p_{\mathbf{G}} \approx \frac{k_1}{k_2}p_{\mathbf{G}}$. Hence,

$\theta \approx 1$, which is independent of *T*.

⇒ **D**

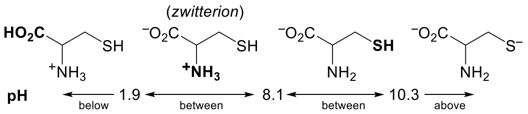
10 As HC*l* is titrated against Na_2CO_3, Na_2CO_3 is added from the burette into HC*l* in the conical flask, the pH increases with the volume of titrant. HC*l* will *completely* react with any Na_2CO_3 added

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$

Hence there will be only one end-point.

⇒ **A**

11 Considering the species present:



$$pI \approx \frac{1.9 + 8.1}{2} = 5.0 \text{ (zwitterion is neutral)}$$

⇒ **B**

12 **A** ✗: $[Ag^+] = 2\sqrt[3]{\frac{K_{sp}(Ag_2CO_3)}{4}} = 2.53\times 10^{-4}$

B ✗: $[Ag^+] = \sqrt{K_{sp}(AgCl)} = 1.34\times 10^{-5}$

C ✓: $[Ag^+] = \sqrt{K_{sp}(AgBr)} = 7.35\times 10^{-7}$

D ✗: $[Ag^+] = \sqrt{K_{sp}(AgIO_3)} = 1.79\times 10^{-4}$

⇒ **C**

13 Residue: SiO_2 (insoluble in H_2O & H_2SO_4)

Filtrate: acidic (gives H_2 with Zn) ⇒ HC*l*

⇒ **B**

14 Reducing power (chemical reactivity) of Group 2 metals ↑es down the group, since
⇒ atomic radius ↑es
⇒ ↓ attraction of nucleus for valence e^-s
⇒ easier to loss valence e^-s

Atomic radius increases as the number of electron shells ↑es, rendering valence electrons further from nucleus.

⇒ **D**

15 **A** ✗: Electronegativity ↓es with ↑ing size down Group 17, due to weaker attraction for shared pair of electrons.

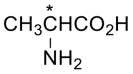
B ✗: Oxidising power (tendency to get reduced) ↓es with ↑ing size down Group 17, due to weaker attraction for incoming e^-.

C ✓: Polarisability of X^- ↑es with size down Group 17 as electrons are generally further from the nucleus.

D ✗: Oxidising power ↓es (**B**) down Group 17, hence $E^{\ominus}(X_2|X^-)$ becomes less positive (↓es).

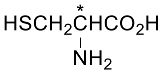
⇒ **C**

16 1 ✓:



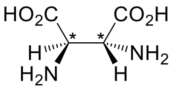
$CH_3\overset{*}{C}H(NH_2)CO_2H$ (1 chiral centre)

2 ✓:



$HSCH_2\overset{*}{C}H(NH_2)CO_2H$ (1 chiral centre)

3 ✓:



(2 chiral centres, no plane of symmetry)

⇒ **D**

17 **A** ✗: Homolytic fission also occurs in the second step where the X–O bond in X–O• is broken to give X•.

B ✗: Termination steps involves the removal of X• through reaction with another radical.

C ✓: X• serves as a catalyst to speed up the breakdown of O_3 into O_2.

D ✗: $CCl_2F_2 \rightarrow \bullet CClF_2 + \bullet Cl$ instead as the C–F bond is much stronger than the C–C*l* bond.

⇒ **C**

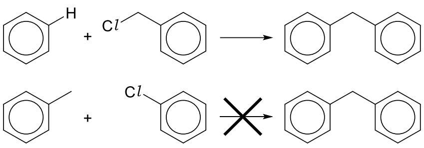
18 1 ✓: C=C in 2-methylbuta-1,3-diene reacts with $Br_2(aq)$

2 ✗: There are no chiral elements (centres) in 2-methylbuta-1,3-diene

3 ✗: The C=C–C=C π network is highly electron-rich and will repel approaching nucleophiles.

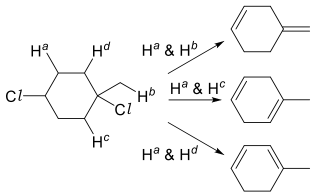
⇒ **A**

19 The two benzene rings can only be joined together via a *Friedel-Crafts alkylation* involving the aromatic hydrogen and a halogenoalkane:



⇒ **A**

20 Both C*l* undergoes elimination with *excess* ethanolic KOH:



⇒ **B**

21 Halogenoarenes do not undergo nucleophilic substitution with ethanolic $AgNO_3$.

A : 1 mol of AgC*l* (143.4 g)

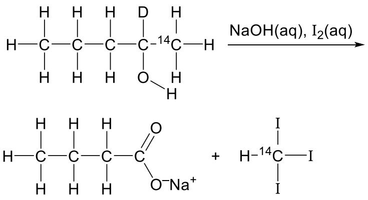
B : 1 mol of AgI (234.8 g)

C : 1 mol of AgC*l* + 1 mol of AgI (378.2 g)

D : 2 mol of AgBr (375.6 g)

⇒ **C**

22



⇒ **C**

23 **R** gives a red ppt with Fehling's solution
⇒ **R** is an aldehyde

Oxidation of **Q** give **R**, an aldehyde
⇒ **Q** is a 1º alcohol

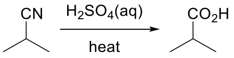
⇒ **B**

24 The carboxylic acid group reacts with alcohols (but not phenols) to give esters.

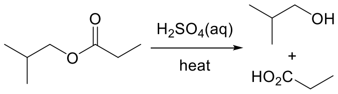
CH_3CHO and C_6H_5COCl both reacts with the amino group.

⇒ **C**

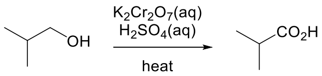
25 **A** ✓:



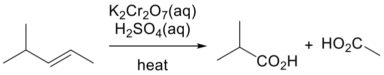
B ✗:



C ✓:



D ✓:



⇒ **B**

26 **A** ✗: The form of asparagine in aqueous solution depends on the pH of the solution. It exists solely in the form of the zwitterion at the isoelectric point.

B ✓: The side chain, $-CH_2CONH_2$, being an *amide* is neutral.

C ✗: Hot dilute H_2SO_4 hydrolyses the amide side chain to give NH_4^+ (aq) and not NH_3(g)

D ✗: All the 26 amino acids are crystalline solids at room temperature due to strong ionic bonding between the zwitterions.

⇒ **B**

27 **[O]:** $Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$ $\quad E^\ominus = +0.77$ V

[R]: $O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$ $\quad E^\ominus = +1.23$ V

$$\begin{aligned} E^\ominus_{\text{cell}} &= E^\ominus_{\text{reduction}} - E^\ominus_{\text{oxidation}} \\ &= E^\ominus\left(O_2|H_2O\right) - E^\ominus\left(Fe^{3+}|Fe^{2+}\right) \\ &= +1.23 - (+0.77) = +0.46 \text{ V} \end{aligned}$$

$$E_{\text{cell}} = E_{\text{reduction}} - E_{\text{oxidation}} = E(\mathbf{T}) - E(\mathbf{S})$$

1 ✗: $[Fe^{2+}]$ and $[Fe^{3+}]$ ↓es by the same extent. Eqm is not affected. $E(\mathbf{S}) = E^\ominus\left(Fe^{3+}|Fe^{2+}\right)$. No change to E_{cell}.

2 ✓: CN^- forms complex with Fe^{3+} and Fe^{2+}. New eqm established

$$[Fe(CN)_6]^{3-} + e^- \rightleftharpoons [Fe(CN)_6]^{4-}$$

with $E^\ominus = +0.36$ V.

$E(\mathbf{S}) < E^\ominus\left(Fe^{3+}|Fe^{2+}\right)$. Hence E_{cell} ↑es (more positive)

3 ✗: $[H^+]$ ↓es. Eqm shifts left.

$E(\mathbf{T}) < E^\ominus\left(O_2|H_2O\right)$ Hence E_{cell} ↓es (less positive)

⇒ **D**

28 Cathode: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

Anode: $\quad 2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

$$Q = It = 15.0 \times (5 \times 60) = 4500 \text{ C}$$

$$n_{e^-} = \frac{Q}{F} = \frac{4500}{96500} = 0.04663 \text{ mol}$$

$$\begin{aligned} n_{\text{gas}} &= n_{O_2} + n_{H_2} = \frac{1}{4}n_{e^-} + \frac{1}{2}n_{e^-} = \frac{3}{4}n_{e^-} \\ &= \frac{3}{4} \times 0.04663 = 0.03497 \text{ mol} \end{aligned}$$

⇒ **C**

29 $\text{density} = \dfrac{\text{mass}}{\text{volume}} \approx \dfrac{\text{mass of an atom}}{\text{volume of an atom}} \propto \dfrac{A_r}{r^3}$

1 ✓: A_r ↑es across the Period 4 TM, while r remain relatively constant, hence density ↑es

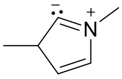
2 ✓: Number of nucleons (protons and neutrons) ↑es ⇒ mass of atom ↑es, hence density ↑es

3 ✗: ↑ in number of outer shell electrons has negligible effect on mass of the atom $\left(m_e \approx \dfrac{1}{1833} m_p \text{ or } m_n\right)$

⇒ **B**

30 Within the tetradentate ligand, the two N atoms with 3 bonds (and 1 lone pair) are neutral, but the two nitrogen with only 2 bonds (and 2 lone pairs) are negatively charged. Hence the tetradentate ligand has a –2 charge.

The remaining two ligands, CH_3OH and



, are neutral. Hence for an overall charge of +1 for the complex cation, Co must be in the +3 oxidation state.

⇒ **C**

Answer Key

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