2020 JC2 Prelim Exam
H2 Chemistry 9729
Paper 1 Worked Solution

1 angle of deflection $\propto \left|\frac{q}{m}\right|$

ion	$^{7}Li^{+}$	$^{9}Be^{2+}$	$^{16}O^{2-}$	$^{14}N^{3-}$
$\left\|\frac{q}{m}\right\|$	$\left\|\frac{+1}{7}\right\|$ = 0.143	$\left\|\frac{+2}{9}\right\|$ = 0.222	$\left\|\frac{-2}{16}\right\|$ = 0.125	$\left\|\frac{-3}{14}\right\|$ = 0.215

$\Rightarrow$ **B**

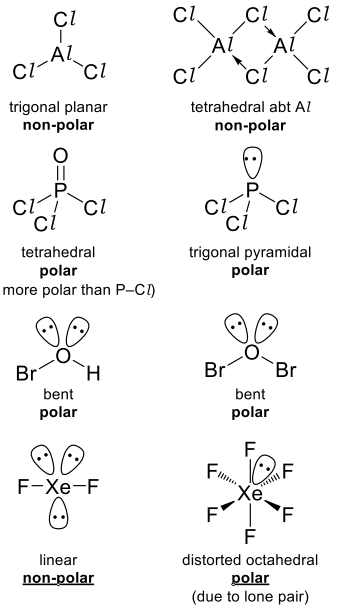
2 1× The electronic configuration of Cr is [Ar] $3d^5$ $4s^1$. The five d-electrons occupy each d-orbital singly.

2✓ The electronic configuration of Mn^{2+} is [Ar] $3d^5$. The five d-electrons occupy each d-orbital singly.

3✓ The electronic configuration of both Fe^{2+} and Co^{3+} are [Ar] $3d^6$.

$\Rightarrow$ **C**

3



$\Rightarrow$ **D**

4 1✓ Al_2O_3 is amphoteric.

2✓ Charge density of Al^{3+} is higher than Na^+, which gives it higher polarising power, hence imparting higher degree of covalent character to the Al–O bond.

3✓ $|\Delta H_{latt}| \propto \left|\frac{q^+ \times q^-}{r_+ + r_-}\right|$

Since $q_{Al^{3+}} > q_{Na^+}$ and $r_{Al^{3+}} < r_{Na^+}$

$\Rightarrow |\Delta H_{latt}(Al_2O_3)| > |\Delta H_{latt}(Na_2O)|$

$\Rightarrow \Delta H_{latt}$ of Al_2O_3 is more exothermic.

$\Rightarrow$ **A**

5 $pV = nRT \Rightarrow pV = \frac{m}{M}RT$

$$p = \frac{m}{V}\frac{RT}{M} = \left(\frac{RT}{M}\right)\rho$$

$$\text{gradient} = \frac{RT}{M}$$

$$\frac{3 \times 10^5 \text{ Pa}}{1.5 \times 1000 \text{ g m}^{-3}} = \frac{8.31 \times 500}{M}$$

$$M = 20.8 \text{ g mol}^{-1}$$

Neon has a molar mass closest to this.

$\Rightarrow$ **B**

6 $n_{Co_2(SO_4)_3} = \frac{20.3}{406} = 0.05$ mol

A✓ $n_{Co^{3+}} = 2n_{Co_2(SO_4)_3}$ and $n_{SO_4^{2-}} = 3n_{Co_2(SO_4)_3}$

$n_{ions} = n_{Co^{3+}} + n_{SO_4^{2-}} = 5n_{Co_2(SO_4)_3} = 0.25$ mol

no. of ions $= n_{ions} \times L = 1.5 \times 10^{23}$

B✓ $n_{Co^{3+}} = 2n_{Co_2(SO_4)_3} = 2 \times 0.05 = 0.1$ mol

C× mass % of Co $= \frac{2 \times 58.9}{406} \times 100\% = 29.3\%$

D✓ mass % of O $= \frac{4 \times 3 \times 16.0}{406} \times 100\% = 47.3\%$

$\Rightarrow$ **C**

7 $n_{BrO_4^-}$ reacted $= \frac{20.0}{1000} \times 0.02 = 0.0004$ mol

n_{NH_2OH} reacted $= \frac{80.0}{1000} \times 0.01 = 0.0008$ mol

$\Rightarrow BrO_4^- \equiv 2NH_2OH \equiv 6e^-$

$\Rightarrow$ Every 1 mol of NH_2OH lose 3 mol of e^-

O.N. of N in $NH_2OH = 3(-1) + 2 = -1$

O.N. of N in product $= -1 + 3 = +2$

$\Rightarrow$ Product is NO (O.N. of N = +2)

$\Rightarrow$ **A**

8 1✓ Both processes refers to the enthalpy change to form one mole of gaseous metal atoms from one mole of the metal in its standard state.

2× $\Delta H_{sublimation} = \Delta H_{fusion} + \Delta H(l, \text{m.p.} \rightarrow \text{b.p.}) + \Delta H_{vapourisation}$

The energy required to raise the temperature of the molten metal from its melting point to its boiling point is not taken into account.

3× Xenon can be a solid at temperatures below its melting point.

$\Rightarrow$ **A**

9 $\Delta S_r^{\ominus} < 0$ since there is a decrease in the number of gaseous particles.

$\Delta G_r^{\ominus} = \Delta H_r^{\ominus} - T\Delta S_r^{\ominus} = -|\Delta H_r^{\ominus}| + T|\Delta S_r^{\ominus}|$

can be either positive or negative pending on T (which is always >0).

$\Delta G_r^{\ominus} = 0$, when $T = \frac{|\Delta H_r^{\ominus}|}{|\Delta S_r^{\ominus}|}$

$\Rightarrow$ **C**

10 Given that $\text{rate} = k[\mathbf{E}][\mathbf{F}]$.

A× Gradient of graph = instantaneous rate, should decrease as reaction proceeds, since **E** and **F** are being consumed.

B× [**G**] which is the product concentration should increase as reaction proceeds.

Since $[\mathbf{E}]_0 = [\mathbf{F}]_0$ and 1**E** ≡ 1**F**, therefore [**E**] = [**F**]. So the rate equation can be rewritten

$$\text{rate} = k[\mathbf{E}][\mathbf{F}] = k[\mathbf{E}]^2 = k[\mathbf{F}]^2.$$

Plot of [**E**][**F**] against t is the same as plot of $[\mathbf{E}]^2$ against t, for a second order reaction with rate equation $\text{rate} = k[\mathbf{E}]^2$. Since plot of [**E**] against t is a curve.

C× Plot of $[\mathbf{E}]^2$ against t will not be a straight line.

D✓ Plot of $[\mathbf{E}]^2$ against t is also a curve.

$\Rightarrow$ **D**

11 1× Step II is the rate-determining step. From Step II:

$$\text{rate} = k\left[H_3O_2^+\right][Br^-]$$
$$= k\left(K_c[H_2O_2]\left[H_3O^+\right]\right)[Br^-]$$
$$= k'[H_2O_2]\left[H_3O^+\right][Br^-]$$

where $k' = kK_c$

which corresponds to the experimentally-determined rate equation given.

Summing up step I to III gives

$$2H_2O_2 \rightarrow O_2 + 2H_2O$$

which is the equation for the decomposition of H_2O_2. H_3O^+ and Br^- are **not** consumed in the reaction.

2✓ Since H_3O^+ and Br^-, arising from the dissociation of HBr(aq), appear in the rate equation (*i.e.* speed up reaction), but are not consumed, HBr(aq) serves as a catalyst.

3✓ $\left[H_3O^+\right]$ and $[Br^-]$ remains constant. Hence, reaction is pseudo-zero order w.r.t. H_3O^+ and Br^-. The rate equation can be rewritten as $\text{rate} = k''[H_2O_2]$, where $k'' = k\left[H_3O^+\right][Br^-]$.

$\Rightarrow$ **C**

12 **A**✓ Adding a catalyst lowers the activation energy of both the forward and backward reaction, hence increasing the rate for both.

B✓ Decreasing volume of vessel causes the concentration/partial pressure of all species to increase. The equilibrium shifts to the left and when equation is re-established, the $[N_2]$, $[H_2]$ and $[NH_3]$ are all still higher than before the change and hence the rate of both forward and backward reactions are increased.

C✓ Increasing the temperature increases the rate of both the forward and backward reaction.

D× Removing gaseous NH_3 causes the equilibrium to shift to the left and hence the $[N_2]$, $[H_2]$ and $[NH_3]$ when equilibrium is re-established will be lower than before the change and hence, the rate of both forward and backward reaction will decrease.

$\Rightarrow$ **D**

13

	$N_2O_4(g)$	$\rightleftharpoons$	$2NO_2(g)$
initial partial pressure / atm	0.24		0
change in partial pressure / atm	$-x$		$+2x$
equilibrium partial pressure / atm	$0.24 - x$		$2x$

$p_{total} = 0.24 - x + 2x = 0.24 + x = 0.32$ atm

$\Rightarrow x = 0.08$ atm

eqm $p_{N_2O_4} = 0.24 - 0.08 = 0.16$ atm

$\Rightarrow$ **D**

14 An acidic/alkaline buffer is made up of a weak acid/base with its conjugate base/conjugate acid.

There is no conjugate acid-base pair in the mixture of potassium chloride and potassium ethanoate. Hence, the mixture is not a buffer.

$\Rightarrow$ **C**

15 Let the solubility be z mol dm^{-3}.

$[Al^{3+}] = z$ mol dm^{-3}; $[Y^-] = 3z$ mol dm^{-3}

$K_{sp} = K = [Al^{3+}][Y^-]^3 = (z)(3z)^3 = 3^3z^4$

$z = \left(\frac{K}{3^3}\right)^{\frac{1}{4}}$

⇒ **C**

16 Since Zn is being oxidised to Zn^{2+}

$E^{\ominus}_{oxidation} = E^{\ominus}(Zn^{2+}|Zn) = -0.76$ V

For the reduction by Zn to be spontaneous, $E^{\ominus}_{reduction} > -0.76$ V, so that $E^{\ominus}_{cell} > 0$.

$E^{\ominus}(VO_2^+|VO^{2+}) = +1.00$ V; $E^{\ominus}(VO^{2+}|V^{3+}) = +0.34$ V

$E^{\ominus}(V^{3+}|V^{2+}) = -0.26$ V; $E^{\ominus}(V^{2+}|V) = -1.20$ V

Therefore V^{2+} is the final product formed.

⇒ **A**

17 A× To form oxygen, water must be oxidised i.e. $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

B× Since $Cr_2O_7^{2-}$ is being reduced to chrome to chrome-plate the bumper, the bumper is the cathode.

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

Cathode: $Cr_2O_7^{2-} + 14H^+ + 12e^- \rightarrow 2Cr + 7H_2O$

$Cr_2O_7^{2-} \equiv 12e^- \equiv 2Cr \equiv 3O_2$

Hence, for every 52g (1 mol) of Cr, 1.5 mol of O_2 produced.

D✓ For every 52g (1 mol) of Cr, 6 mol of electrons are required.

$Q = It = nF$

$t = \frac{nF}{I} = \frac{6 \times 96500}{10} = 57900 \text{ s} \approx 16 \text{ h}$

⇒ **D**

18 1✓ $E^{\ominus}_{cell} = E^{\ominus}(Mn^{3+}|Mn^{2+}) - E^{\ominus}(MnO_2|Mn^{3+})$

$= +1.54 - (+0.95) = +0.54$ V > 0

2✓ $E^{\ominus}_{cell} = E^{\ominus}(Mn^{3+}|Mn^{2+}) - E^{\ominus}(Mn^{2+}|Mn)$

$= +1.54 - (-1.18) = +2.72$ V > 0

3× $E^{\ominus}_{cell} = E^{\ominus}(MnO_2|Mn^{2+}) - E^{\ominus}(Mn^{2+}|Mn)$

$= +0.95 - (-1.18) = +2.13$ V > 0

⇒ **B**

19 A× As effective nuclear charge increases across Period 3, electronegativity also increases.

B× Electrical conductivity increases across Groups 1 to 3 due to an increase in number of delocalised valence electrons contributed per atom.

C× The melting point decreases down Group 1 because metallic bonding weakens with decreasing charge density down the group.

D✓ Down the group, the first ionisation energy of the elements generally decreases as the valence electron is further away from the nucleus and hence less electrostatic attraction.

⇒ **D**

20 1✓ The 2nd IE of Group 2 elements is only about twice that of the 1st IE, while the 3rd IE is much higher than the 2nd IE. Hence the only oxidation number exhibited is +2, involving loss of 2 e^-.

2✓ As atomic radius increases down Group 2, tendency of the atoms to loss electrons (*i.e.* to be oxidised) increases, hence reducing strength increases.

3× $r_{Mg^{2+}} < r_{Ba^{2+}}$ ⇒ charge density of Mg^{2+} is higher than that of Ba^{2+}. Stronger ion-dipole interactions with water and hence more exothermic ΔH_{hyd} for Mg^{2+}.

⇒ **B**

21 A× H_2SO_4 is only reduced to either SO_2 or H_2S, but not oxidised.

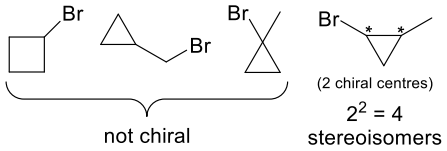
B× There is no transfer of H^+ in both equations shown.

C× Br^- is a weaker reducing agent than I^- as it can only reduce S to the +4 O.S. in SO_2, while I^- can reduce S to the −2 O.S. in H_2S.

D✓ Reducing power increases down Group 17, so Cl^- should be an even weaker reducing agent than Br^-.

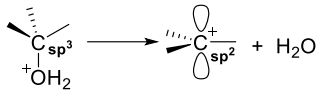
⇒ **D**

22



⇒ **B**

23 A×



B✓ $(CH_3)_3CO^+H_2$ (acid) loses a proton (H^+) to form $(CH_3)_3COH$ (conjugate base). Hence a conjugate acid–base pair.

C✓ Cancelling the common species:

$(CH_3)_3COH + HCl \xrightarrow{fast} (CH_3)_3\overset{+}{C}OH_2 + Cl^-$

$(CH_3)_3\overset{+}{C}OH_2 \xrightarrow{slow} (CH_3)_3\overset{+}{C} + H_2O$

$(CH_3)_3\overset{+}{C} + Cl^- \xrightarrow{fast} (CH_3)_3CCl$

Overall equation is

$(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$

D✓ The reaction involves the nucleophile Cl^- substituting OH^- in $(CH_3)_3COH$.

⇒ **A**

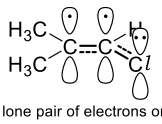
24 1✓ The alkyl group is not activating enough to allow the cumene to react with Br_2 without a catalyst.

2✓ Aluminium chloride reacts with C_3H_7Cl to form the electrophile, $C_3H_7^+$, and $AlCl_4^-$. Hence acting as a Lewis acid.

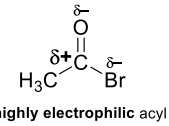
3× The electrophile is $(CH_3)_2CH^+$.

⇒ **B**

25



lone pair of electrons on Cl delocalised into C=C ⇒ **partial double bond character** in C–Cl bond ⇒ higher E_a for cleavage of stronger C–Cl bond ⇒ least reative towards nucleophile (H_2O)



highly electrophilic acyl carbon bonded to 2 electronegative atoms ⇒ highly susceptible to nucleophilic attack ⇒ most reactive towards nucleophile (H_2O)

$C_6H_5\overset{\delta+}{C}H_2-\overset{\delta-}{Cl} < CH_3CH_2\overset{\delta+}{C}H_2-\overset{\delta-}{I}$

C–Cl bond is stronger than C–I bond

⇒ higher E_a for cleavage of stronger C–Cl bond

⇒ $C_6H_5CH_2Cl$ hydrolyses slower than $CH_3CH_2CH_2I$

⇒ **C**

26 A× $CH_3CH_2OH \xrightarrow[heat]{KMnO_4} CH_3CO_2H$

B× $CH_3CH_2OH \xrightarrow[warm]{I_2,\ OH^-} CH_3CO_2^-$

C× $CH_3CH_2OH \xrightarrow[heat]{HBr} CH_3CH_2Br$

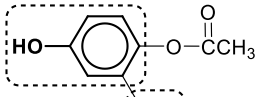
D✓ $CH_3CH_2OH \xrightarrow[r.t.]{Na} CH_3CH_2O^-Na^+$

⇒ **D**

27 phenol

A: decolourises orange $Br_2(aq)$;

C: purple complex with neutral $FeCl_3$



(aromatic) aldehyde **CHO**

B: orange $Cr_2O_7^{2-}$ reduced to green Cr^{3+}

D: does **not** react with Fehling's reagent

⇒ **D**

28 1✓ $CH_3CH(OH)CH_3 + 4I_2 + 6NaOH \rightarrow$

$CH_3CO_2^-Na^+ + CHI_3 + 5NaI + 5H_2O$

2✓ $CH_3CO_2CH_2CH_3 + NaOH \xrightarrow{hydrolysis}$

$CH_3CO_2^-Na^+ + HOCH_2CH_3$

3✓ $CH_3CN + NaOH + H_2O \xrightarrow{hydrolysis}$

$CH_3CO_2^-Na^+ + NH_3$

⇒ **A**

29 A× It reacts with anhydrous PBr_3 to give white fumes of HBr.

B× N_a is an aryl amine which is less basic than the alkyl amine N_b. Thus the conjugate acid of N_a is stronger than that of N_b, with a *lower* pK_a.

C✓ Both the secondary aryl amino group and the hydroxyl group are able to react with ethanoyl chloride.

D× 1 mol of hydroxychloroquine contains 1 mol of OH group which reacts with Na metal to give ½ mol of hydrogen gas.

⇒ **C**

30 Based on the masses of the different amino acids obtained upon hydrolysis,

aspartic acid : glutamine : proline

= 2 : 1 : 1

X is a tetrapeptide with 3 amide linkages

Hence, M_r of the polypeptide

= (2 × 133 + 146 + 115) - (3 × 18) = 473

⇒ **C**

Answer Key

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