2022 JC 2 H2 Chemistry Prelim Paper 1 Worked Solutions

Qn	Ans	Solutions
1	D	Number of proton > electron => cation Number of proton > neutron => likely contain D (highlighted by question) <table><tr><td></td><td>No. of proton</td><td>No. of neutron</td><td>No. of electron</td></tr><tr><td>A. NO_2^+</td><td>7 + 2(8)</td><td>7 + 2(8)</td><td>7 +2(8) -1*</td></tr><tr><td>B. ND_2H</td><td>7 + 2(1)+ 1</td><td>7 + 2(1) + 0</td><td>7 + 2(1) + 1</td></tr><tr><td>C. NDH^-</td><td>7 + 1 + 1</td><td>7 + 1 + 0</td><td>7 + 1 + 1 +1*</td></tr><tr><td>D. ND_3H^+</td><td>7 + 3(1) + 1</td><td>7+3(1) + 0</td><td>7 + 3(1) + 1 -1*</td></tr></table>
2	A	A. $V^- \rightarrow V^{2-}$ $[Ar]\ 4s^23d^5$ B. $N \rightarrow N^-$ $1s^2\ 2s^2\ 2p^4$ C. $Se^+ \rightarrow Se$ $[Ar]\ 4s^23d^{10}4p^4$ D. $Ti \rightarrow Ti^-$ $[Ar]\ 4s^23d^3$
3	B	Significant increment from 5th to 6th I.E. Element M from period 3 and has 5 valence electrons. => Phosphorous Equation 2 is formation of PCl_3, Equation 3 is formation of PCl_5
4	D	Option A: The dipole moment on the HF molecule should be larger (HF dipole moment is larger and factoring in partial cancellation of 2 smaller OH dipole moments). Option B: As fluorine is more electronegative, the hydrogen bond formed between HF molecules will be stronger than the hydrogen bond formed between H_2O molecules. Option C: The change in id-id interactions is negligible. id-id interactions are not the predominant IMF for HF and H_2O molecules. Option D: H_2O forms more extensive hydrogen bonds than HF.
5	C	Option A: In BF_3, B shared its 3 valence electrons to form 3 covalent bonds with 3 F atoms. B is electron deficient. Option B: In CO, C shares its 2 valence electrons with 2 valence electrons on O (to maintain an octet electronic configuration for O). To achieve an octet electronic configuration for C, O will donate a lone pair of electrons to C and form a dative bond. Option C: In NO, N shares its 2 valence electrons with the 2 valence electrons on O (to maintain an octet electronic configuration for O). N is electron deficient. Option D: In SiO_2, which has a giant molecular structure, Si shares its 4 valence electrons with 4 oxygen atoms (which will further extends to obtain a macromolecule).

| Qn	Ans	Solutions
6	B	Deviation depends on IMF and size of particles. All 4 compounds has id-id, SO_3 has the highest M_r.
7	C	When an ideal gas is compressed from 20 atm to 80 atm with no further reaction, the volume is expected to change from 67.0 cm³ to 16.75 cm³ (instead of 15.5 cm³ as stated in the question). Option C is not a valid explanation since the dissociation of a gas would result in an observed gas volume of larger than 16.75 cm³ (instead of 15.5 cm³ as stated in the question).
8	A	From the information given, 20.0 cm³ of 0.20 mol dm⁻³ acid reacts exactly with 40 cm³ 0.10 mol dm⁻³ of base, indicating that reacting mole ratio of acid and base is 1:1. This would be inconsistent with option A since CH_3COOH and $Ba(OH)_2$ would react in a 2:1 ratio. Hence, option A is false, making A the answer.
9	A	ΔH must be negative for the overall process must be exothermic since heat must be generated by the reaction to enable the heating process. ΔS must be negative as indicated by the reaction equation as the reaction goes from reactants of (1 mol solid and 1 mol liquid) to products of 1 mol solid. ΔG must be negative since the process must be spontaneous as described by the question context.
10	C	For the decomposition of H_2O_2: $\Delta H = \frac{1}{2}[-572 - (-188)] = -192$ kJ mol⁻¹ $\Delta S = \frac{1}{2}[-0.325 - (-0.225)] = -0.050$ kJ mol⁻¹ K⁻¹ $\Delta G = \Delta H - T\Delta S = (-192) - (25 + 273)(-0.05) = -117.1$ kJ mol⁻¹
11	B	$Ca(s) + 2H_2O(l) \xrightarrow{x} Ca(OH)_2(aq) + H_2(g)$ $2H^+(aq) \quad a \searrow \quad b \nearrow 2H^+(aq)$ $Ca^{2+}(s) + 2H_2O(l) + H_2(g)$ a is twice the enthalpy change of neutralisation of calcium hydroxide (option 1) b is enthalpy change of reaction of calcium with acid (option 2)
12	A	Let the formula of hydrocarbon be C_xH_y. Molar ratio of carbon dioxide : hydrocarbon is 2 : 1 $\Rightarrow x = 2$ $C_xH_y(g) + (2 + \frac{y}{4}) O_2(g) \longrightarrow 2CO_2(g) + \frac{y}{2} H_2O(l)$ Since the remaining O_2 can burn up exactly 30 cm³ of the same hydrocarbon, this means that 100 cm³ of O_2 can burn 40 cm³ of the hydrocarbon.

13	B	⇒ Molar ratio of hydrocarbon : O_2 = 40 : 100 = 1 : $\frac{5}{2}$
		⇒ $2 + \frac{y}{4} = 2.5$
		⇒ **y = 2**
		Formula of hydrocarbon is **C_2H_2**.
		Amount of SO_3^{2-} = $\frac{25.0}{1000}$ × 0.10 = 0.0025 mol
		Amount of electrons lost by 0.0025 mol of SO_3^{2-} = 2 × 0.0025 = 0.005 mol
		Amount of metallic salt = $\frac{50.0}{1000}$ × 0.10 = 0.005 mol
		Amount of electrons gained by 0.005 mol of metal ion = 0.005 mol
		Amount of electrons gained by 1 mol of metal ion = 1 mol
		Oxidation state of metal in product = +3 − 1 = **+2**
14	D	Since the concentration of acid in the solution remains constant, rate = $k'[CH_3CO_2CH_2CH_3]$ where $k' = k[H^+]$
		$t_{\frac{1}{2}} = \frac{\ln 2}{k'} = \frac{\ln 2}{k[H^+]}$
		Expt 1
		When [HCl] = [H⁺] = 0.2 mol dm⁻³,
		$t_{\frac{1}{2}}$ = 62 min
		Expt 2
		$t_{\frac{1}{2}}$ = 31 min (given in question)
		When [HCl] = [H⁺] = 0.1 mol dm⁻³ (halved),
		For $[CH_3CO_2CH_2CH_3]$ to fall from 0.2 mol dm⁻³ to 0.05 mol dm⁻³, it would take two $t_{\frac{1}{2}}$.
		Time taken = 2 × 62 = **124 min**
15	B	Option A: N_2O_2 is an intermediate since it is produced in the first step and consumed in the second step.
		Option B: Rate equation is rate = $k[NO]^2[H_2]$, hence the overall order of reaction is 3.
		Option C: Refer to the rate equation above. The order of reaction with respect to H_2 is 1.
		Option D: Refer to the rate equation above. The order of reaction with respect to NO is 2.
16	C	

	3Fe	+	4H₂O	⇌	Fe₃O₄	+	H₂
initial amt	3.0		2.0		0		0
change	$-\frac{3x}{4}$		− x		$+\frac{x}{4}$		$+\frac{x}{4}$

| 17 | B | Equilibrium amt |

3.0 − $\frac{3x}{4}$	2.0 − x	$+\frac{x}{4}$	$+\frac{x}{4}$

18	D		

salt	K_{sp} = IP
Ag₂S	6.8 × 10⁻⁵⁰= [Ag⁺(aq)]²(0.1) [Ag⁺(aq)] = 8.25 × 10⁻²⁵ mol dm⁻³
CuS	6.3 × 10⁻³⁶= [Cu²⁺(aq)](0.1) [Cu²⁺(aq)] = 6.3 × 10⁻³⁵ mol dm⁻³
SnS₂	1.0 × 10⁻⁷⁰= [Sn⁴⁺(aq)](0.1)² [Sn⁴⁺(aq)] = 1.0 × 10⁻⁶⁸ mol dm⁻³

The lower the pK_a value, the stronger the acid.

Strength of acid: $CH_3COOH < CH_2BrCOOH < CH_2FCOOH$

The three compounds given are carboxylic acids. The more stable the conjugate base, the stronger the carboxylic acid.

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

$CH_2BrCOOH \rightleftharpoons CH_2BrCOO^- + H^+$

$CH_2FCOOH \rightleftharpoons CH_2FCOO^- + H^+$

Stability of conjugate base: $CH_3COO^- < CH_2BrCOO^- < CH_2FCOO^-$

19	A	Statement 1: Correct, electronegative Br and F will draw electrons away from the O–H bond in COOH, resulting in the deprotonation of H from O–H bond to be easier for the halogenated carboxylic acids. Thus, the two halogenated carboxylic acids are more acidic than CH_3COOH. Also, the more electronegative F is more electronegative than Br thus CH_2FCOOH is more acidic than $CH_2BrCOOH$.
		Statement 2: Correct, electronegative Br and F will help to stabilise the negative charge on the COO⁻ hence resulting in these two halogenated carboxylic acids to be more acidic than CH_3COOH. Also, the more electronegative F will stabilise the conjugate base to a greater extent than Br thus CH_2FCOOH is more acidic than $CH_2BrCOOH$.
		Statement 3: Correct, the methyl group in CH_3COOH is electron donating and intensify the negative charge on CH_3COO^-, destabilising CH_3COO^- and hence making CH_3COOH the weakest acid amongst the three.
		Standard hydrogen electrode (S.H.E) consists of $H_2(g)$ at 1 bar bubbling over platinum electrode coated with finely divided platinum which is dipped into 1 mol dm⁻³ H⁺(aq) at 298 K.

6

		X is an aryl chloride which does not undergo hydrolysis. → mass of ppt = 0 for X ⇒ Contradiction in D. Rate of hydrolysis: Z > Y due to strength of C-Br bond weaker than C-Cl bond → amount of AgBr > amount of AgCl • Contradiction in A. → mass of AgBr > mass of AgCl • Contradiction in C.
22	C	Functional groups in compound P: ketone, carboxylic acid and terminal alkene H$_2$, Ni reduces ketone and alkene but not carboxylic acid LiAlH$_4$ in dry ether reduces carboxylic acid and ketone but not alkene.
23	A	Partial positive sp^2 hybridised carbon attracts lone pair of electrons, thus electrophilic. ↓ Carbonyl carbon shows heterolytic fission of π bond (Homolytic fission of bonds form free radicals) Only a single achiral organic product is formed, no racemic mixture.
24	D	Only the secondary alcohol in estradiol undergoes oxidation and turned hot orange acidified K$_2$Cr$_2$O$_7$ green. Only the ketone in daidzein undergoes condensation and give a yellow/orange ppt with 2,4-DNPH. Only the secondary alcohol in estradiol undergoes nucleophilic substitution and give a white fume with PCl$_5$. Both estradiol and daidzein has phenol function group that undergoes electrophilic substitution* and decolourised orange aqueous bromine. Alkene in daidzein undergoes electrophilic addition. *the positions of substitution is indicated by arrows in the figure below.

5

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		By convention, the standard electrode potential for this reference hydrogen half-cell is taken to be 0.00 V. Statement 1: Correct because the hydrogen gas needs to be at 1 bar. Statement 2: Correct because the standard electrode potential of S.H.E is taken to be 0.00 V. Statement 3: Incorrect because at pH 1.0, [H$^+$] = 10$^{-1.0}$ = 0.100 mol dm^{-3}. This condition does not fulfil the requirement of [H$^+$] to be 1.00 mol dm^{-3}.
20	C	β-carotene undergoes oxidative cleavage with hot, acidified KMnO$_4$. Statement 1 is correct. • All sections of β-carotene labelled A formed an organic product. • All sections labelled B formed another organic product. • Final oxidised products from section labelled C are inorganic. Statement 2 is correct. • All organic products have a 'COCH$_3$ group that gives a positive iodoform test with warm aqueous alkaline iodine. Statement 3 is incorrect. • No stereoisomers or constitutional isomers present. • All products from the same section of β-carotene are identical.
21	B	Mass of ppt obtained is dependent on → Relative rate of hydrolysis to give free halide ions for precipitation → Type of halide precipitated: Molar mass of AgCl < AgBr
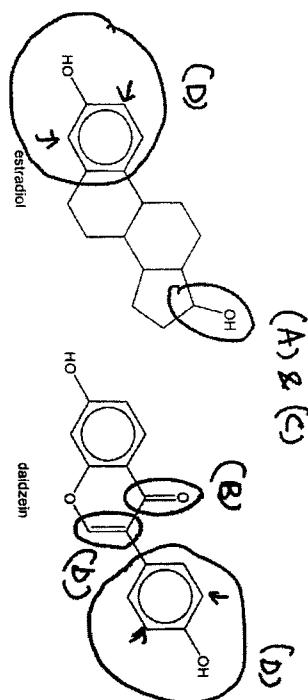
25	B	estradiol daidzein (A) & (C), (B), (D)
		$CH_3CH_2Cl + OH^- \rightarrow CH_3CH_2OH + Cl^-$
		CH_3CH_2Cl, a primary alkyl halide, favour Sn2 mechanism.
		transition state
		The only step is also the r.d.s. involving the heterolytic fission of the C`Cl bond.
26	B	$+ 2Br_2 \rightarrow \ldots + 2HBr$
		$+ Na_2CO_3 \rightarrow \ldots + CO_2 + H_2O$
		Products obtained after alkaline hydrolysis:
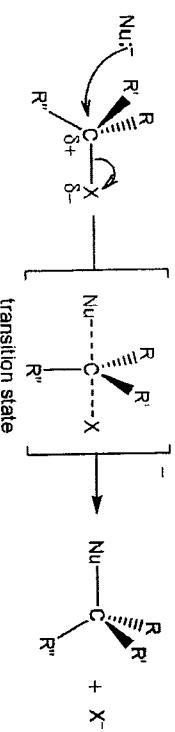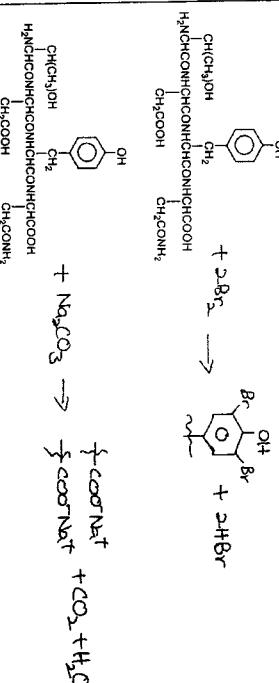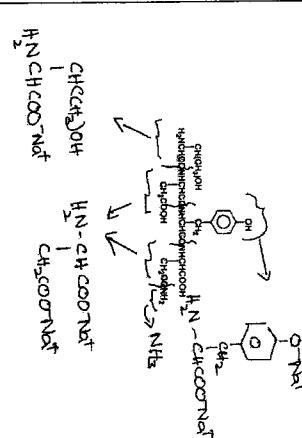
27	D	Reaction A: No heat is required for condensation reaction between amine and acyl chloride
		Reaction B: No heat is required for the hydrolysis of acyl chloride.
		Reaction C: Oxidation of primary alcohol to aldehyde requires heating with immediate distillation.
		Reaction D: alkaline hydrolysis of amide requires heating under reflux. Reflux will reduce the loss of solvent (H_2O) due to prolong heating.
28	D	phenyl 2-methylbutanoate
29	C	$Cu(NO_3)_2(aq) + 6H_2O(l) \rightarrow [Cu(H_2O)_6]^{2+}(aq) + 2NO_3^-(aq)$
		$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
		$[Cu(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s) + 6H_2O(l)$
		$Cu(OH)_2(s) + 4NH_3(aq) + 2H_2O(l) \rightleftharpoons [Cu(NH_3)_4(H_2O)_2]^{2+}(aq) + 2OH^-(aq)$
30	A	Iron functions as a heterogeneous catalyst in the Haber process, via
		1. the availability of energetically accessible vacant/ partially filled 3d orbitals which allow the ready exchange of electrons to and from reactant particles, thus facilitating the formation of weak bonds with the reactant particles (adsorption).
		2. the availability of 3d and 4s electrons for bond formation with reactant particles.
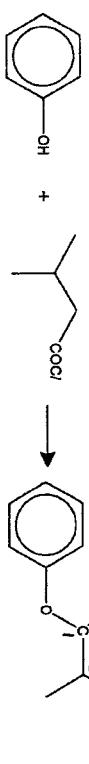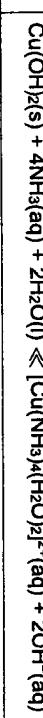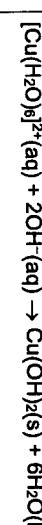
Suggestion Solutions for 2022 H2 Chemistry Prelim Paper 2

1 (a) The enthalpy change of solution of a substance is the enthalpy change when one mole of the substance is completely dissolved to give an infinitely dilute solution, so that no further enthalpy change takes place on adding more solvent. [1]

(b) (i) Assuming no heat loss to surroundings,

amount of NH_4NO_3 × 26000 = 50 × 4.18 × 5

amount of NH_4NO_3 = 0.04019 mol

minimum mass of NH_4NO_3 = 0.04019 × (2(14.0) + 4(1.0) + 3(16.0))

= 3.22 g   [1]

(ii)

temperature/°C

corrected ΔT

3.0

time/ min

(c) Energy / kJ mol⁻¹

$NH_4^+(g) + Cl^-(g)$ [✓]

$\Delta H_{hyd}(NH_4^+) + \Delta H_{hyd}(Cl^-)$ [✓]

$NH_4^+(aq) + Cl^-(aq)$ [✓]

$\Delta H_{soln}(NH_4Cl)$ [✓]

$NH_4Cl(s)$ [✓]

$LE(NH_4Cl)$ [✓]
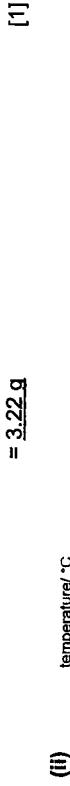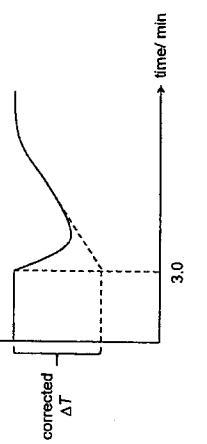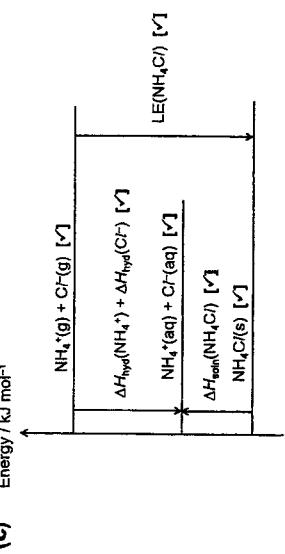
By Hess' Law,

$\Delta H_{soln}(NH_4Cl) = -(-705) + [(-307) + (-381)]$

= +17.0 kJ mol⁻¹   [2]

(d) Since Cl^- has a smaller ionic radius and higher charge density than Br^-, it forms stronger ion-dipole interactions with water molecules.

Thus, Cl^- has a larger magnitude of ΔH_{hyd} than Br^-.   [2]

[Total: 9]

[Turn over]

2

2 (a) It is a d-block element that is able to form one or more stable ions with a partially filled d subshell. [1]

(b) Both elements have giant metallic lattice structure and exhibit metallic bonding. In Co, both the 4s and 3d electrons can be contributed to form the sea of delocalised electrons as they are very close in energy. The resulting cobalt ion has a higher positive charge and a smaller ionic radius/ higher charge density. This results in stronger electrostatic forces of attraction between the metal cations and the sea of delocalised electrons in Co as compared to Ca, which only contributes 2 valence electrons per Ca atom to form Ca^{2+}. [2]

(c) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$ [1]

(ii) $O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$ $E = +0.40$ V

Overall equation:

$4[Co(NH_3)_6]^{2+} + O_2 + 2H_2O \longrightarrow 4[Co(NH_3)_6]^{3+} + 4OH^-$
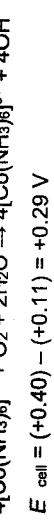
$E_{cell} = (+0.40) - (+0.11) = +0.29$ V

Since $E_{cell} > 0$, the reaction is feasible.

Hence, yellow-brown $[Co(NH_3)_6]^{2+}$ is oxidised by oxygen in air to produce red-brown $[Co(NH_3)_6]^{3+}$ [2]

(iii)

(iv)

Electron flow

V

Salt Bridge

Pt electrode

Pt electrode

$H_2(g)$ 25 °C, 1 Bar

1 mol dm⁻³ H^+(aq), 25 °C

1 mol dm⁻³ $[Co(NH_3)_6]^{2+}$(aq)
1 mol dm⁻³ $[Co(NH_3)_6]^{3+}$(aq)
25 °C

[3]
[1]

(d) (i) Amount of **D** reacted with EDTA $= \dfrac{18.75}{1000} \times 0.0400$

$= 7.500 \times 10^{-4}$ mol

Amount of **D** in 3.501 g sample $= \dfrac{500}{25.0} \times 7.500 \times 10^{-4}$

$= 0.01500$ mol

Molar mass of **D** $= \dfrac{3.501}{0.01500}$

$= 233.4$ g mol⁻¹   [2]
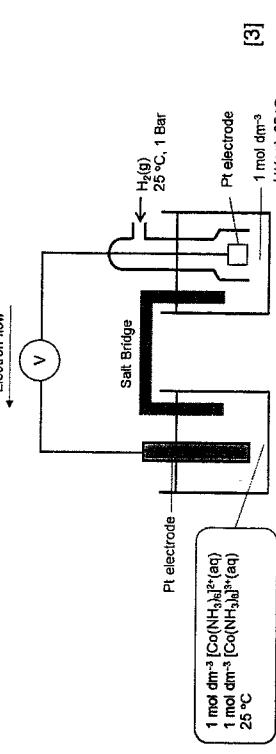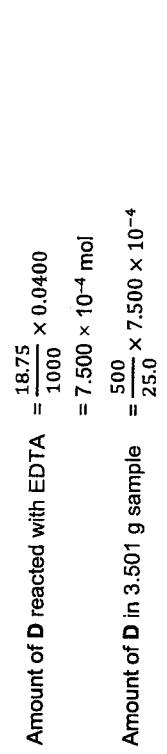
3

(ii) Amount of **D** reacted with AgNO₃ = $\dfrac{23.34}{233.4}$

= 0.1000 mol

Amount of AgCl₂ formed = $\dfrac{14.340}{(107)+(35.5)}$

= 0.1000 mol

Mole ratio of **D** : AgCl is 1 : 1   [1]

(iii) 17a + 35.5(3) = 233.4 − 58.9

Solving: a = 4

Cation: [Co(NH₃)₄Cl₂]⁺   [2]

(iv)

[2]

[Total: 17]

3 (a) (i) Enantiomerism

[2]

(ii) An electrophile is an <u>electron pair acceptor</u> and is <u>electron deficient</u>.   [1]

4

(iii)

[2]

(iv)

[1]

(b)

Eₐ(1): activation energy for first step
Eₐ(2): activation energy for second step

[2]
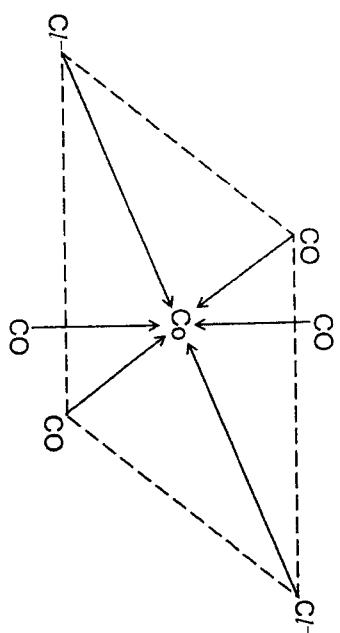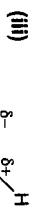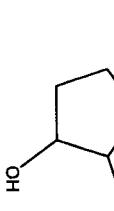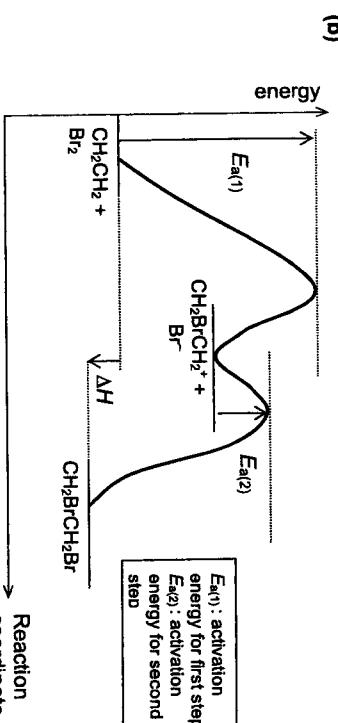
(c) All three substances have <u>simple molecular/ covalent structures. More energy is needed to overcome the stronger hydrogen bonds between CH₃OH</u> molecules than the weaker <u>instantaneous dipole-induced dipole (id-id) interactions between CH₃SH or CH₃SeH molecules. Thus CH₃OH</u> has the highest boiling point.

As <u>CH₃SeH has a larger number of electrons than CH₃SH, more energy is needed to over the stronger id-id interactions between CH₃SeH molecules</u> than the weaker id-id interactions between CH₃SH molecules. Thus CH₃SeH has a higher boiling point than CH₃SH.   [3]

(d) (i) ΔS is positive as there is an <u>increase in disorder as the amount of gas molecules increases from 0 mol to 3 mol</u>.   [1]

(ii) ΔG⦵ = ΔH⦵ − TΔS⦵

= +129 − (130 + 273)(0.332)

5

$= -4.80 \text{ kJ mol}^{-1}$

Since $\Delta G < 0$, reaction is <u>spontaneous</u> at 130°C. [2]

[Total: 14]

4 (a) (i)

$pV = nRT$

$pV = \dfrac{m}{M_r}RT$

$M_r = \dfrac{mRT}{pV}$

$M_r = \dfrac{(1.50)(8.31)(327 + 273)}{(1.60 \times 10^5)(250 \times 10^{-6})}$

$= 187.0$

$= \underline{\underline{187 \text{ (to 3 s.f.)}}}$ [1]

(ii) Let the mole fraction of $AlCl_3$ be x.

$133.5x + (1 - x)(267) = 187$

$133.5x + 267 - 267x = 187$

$133.5x = 80$

$x = 0.59925$

$x = 0.6$ (to 1 d.p)

Mole fraction of $AlCl_3 = 0.6$

Mole fraction of Al_2Cl_6

$= 1 - 0.59925$

$= 0.40075$

$= 0.4$ (to 1 d.p) [1]

(iii) $P_{AlCl_3} = (0.6)(1.60 \times 10^5) = 96000 \; Pa$

$P_{Al_2Cl_6} = (0.4)(1.60 \times 10^5) = 64000 \; Pa$

$K_p = \dfrac{\left(P_{AlCl_3}\right)^2}{P_{Al_2Cl_6}}$

$K_p = \dfrac{(96000)^2}{64000}$

$= 144000 \; Pa$ [3]

[Turn over

6

(b) Since the reaction is <u>endothermic</u>, increasing the temperature will <u>favour the forward reaction/ shift the position of equilibrium to the right to absorb some of the extra heat.</u> Thus K_p will increase. [2]

(c) (i)

[1]

(ii) Elimination [1]

(e) (i)

[1]

(ii)

[3]

(iii) Nucleophilic substitution [1]

[Total: 14]

7

5 (a) (i)

(ii) Stage I
$HNO_3 + 2H_2SO_4 \rightleftharpoons NO_2^+ + 2HSO_4^- + H_3O^+$

Stage II

$+ NO_2^+ + HSO_4^- \longrightarrow$ [structure] $+ H_2SO_4$ [2]

[2]

(b) (i) Hydrolysis or acid-base [1]

(ii) Amount of Mg = 1.5 ÷ 24.3 = 6.17 × 10⁻² mol [1]

Amount of bromopropane = (5 × 1.35) ÷ 123 = 5.49 × 10⁻² mol [2]

Magnesium is in excess

(iii) Mg(s) + 2HCl(aq) → MgCl₂(aq) + H₂(g) [2]

(iv) Upper [2]

8

(v) Butanoic acid is more soluble in diethyl ether than water and will dissolve in the organic layer [1]. As diethyl ether is less dense than water, butanoic acid will be found in the upper layer.

1-bromobutane

Butanoic acid will undergo an acid-base reaction with NaOH to form the soluble salt, sodium butanoate, which will dissolve in the aqueous layer due to the formation of favourable ion-dipole interactions. 1-bromobutane will stay in the organic layer to be removed. [3]

(vii) Water [1]

(viii) Accept any range within 154-174 °C. [1]

(c) (i) $K_a = \dfrac{[H^+][X^-]}{[HX]}$

Since [H⁺] = [X⁻] and assuming that the degree of dissociation is small,

$10^{-4.82} \approx \dfrac{[H^+]^2}{0.20}$

[H⁺] = 1.74 × 10⁻³ mol dm⁻³

pH = –lg (1.74 × 10⁻³)

= 2.76 [2]

(d) (i) pH = 14.95 ÷ 2 = 7.48 [1]

(ii) H₂O(l) ⇌ H⁺(aq) + OH⁻(aq) K_w = 1.00 × 10⁻¹⁴ mol² dm⁻⁶

D₂O(l) ⇌ D⁺(aq) + OD⁻(aq) K_w = 1.12 × 10⁻¹⁵ mol² dm⁻⁶

The K_w value of D₂O is lower than the K_w value of H₂O. The position of equilibrium for D₂O lies more on the left/extent of ionisation of D₂O is lower than H₂O. Therefore the O-D bond is likely to be a stronger bond that is more difficult to break and dissociate. [2]

[Total: 21]

Suggested Solutions for H2 Chemistry Prelim Paper 3

1 (a) (i) $S(g) \rightarrow S^+(g) + e^-$ [1]

(ii) Less energy is required to remove the higher energy 3p electron from Al compared to the 3s electron from Mg. [1]

(b) (i) $CuCO_3 \rightarrow CuO + CO_2$ [1]

(ii) Ionic radius of Ca^{2+} = 0.099 nm

Ionic radius of Cu^{2+} = 0.073 nm

Decomposition temperature of $CuCO_3$ is expected to be lower.

Charge density of Cu^{2+} is greater than Ca^{2+} due to the smaller ionic radius of Cu^{2+}. Cu^{2+} ion is able to polarise (the electron cloud of) CO_3^{2-} ion to a larger extent, hence weakening the C‑O bond to a larger extent. [2]

(c) (i) $Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$

pH = 13 [1]

(ii) $SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(aq)$

pH = 2 [1]

(d) (i) Na(s) is an electrical conductor due to the presence of delocalised valence electrons which can migrate freely through the metallic structure when a potential difference is applied.

Na2O(s) does not conduct electricity because its ions are held in fixed positions in a giant lattice structure / it has no mobile ions. [2]

(ii)

$2Na^+$ $\left[\begin{matrix} \,^{xx}_{xx} O \,^{\times\times}_{\times\times} O \,^{\times\times}_{\times\times} \end{matrix} \right]^{2-}$ [2]

(iii) Na2O2 has a giant ionic lattice structure while H2O2 has a simple molecular/ covalent structure.

More energy is needed to overcome the stronger electrostatic forces of attraction between Na+ and O2^2− compared to the hydrogen bonds between H2O2 molecules.

Hence, Na2O2 has a higher melting point than H2O2 and is a solid at room temperature. [2]

(e) (i) $K_c = \dfrac{[Pb^{2+}][Cr^{2+}]^2}{[Cr^{3+}]^2}$ [1]

(ii) Equilibrium $[Pb^{2+}(aq)] = \frac{1}{2}(2.96 \times 10^{-4})$ [2]

= 1.48×10^{-4} mol dm^{-3}

$$K_c = \frac{(1.48 \times 10^{-4})(2.96 \times 10^{-4})^2}{(0.200)^2}$$

= 3.24×10^{-10} mol dm^{-3}

(iii) The concentration of all aqueous species/ ions will be lowered. Since there are more aqueous species/ ions on the right of the equation, the position of equilibrium shifts right. [2]

[Total: 17]

2 (a) (i)

iPhone (anode) · Pt or graphite (cathode) · H2SO4(aq)
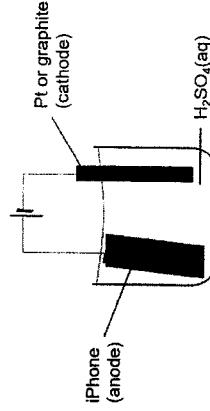
(ii) $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

$2Al(s) + 3/2O_2(g) \rightarrow Al_2O_3(s)$ [2]

(iii) Volume of Al_2O_3 = 96.2 × 0.03

= 2.886 cm^3

Mass of Al_2O_3 = 3.95 × 2.886

= 11.40 g

Amount of Al_2O_3 = $\dfrac{11.40}{2(27.0)+3(16.0)}$

= 0.1118 mol [2]

Amount of O2 = $0.1118 \times \dfrac{3}{2}$

= 0.1677 mol

Amount of electrons passed = 0.1677 × 4

= 0.6708 mol

Q = nF = It

0.6708 × 96500 = 2.0 × t

t = 3.24×10^4 s [3]

(b) Step 1: $2Fe^{3+}(aq) + 2I^-(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$ [2]

3

Step 2: $2Fe^{2+}(aq) + S_2O_8^{2-}(aq) \rightarrow 2Fe^{3+}(aq) + 2SO_4^{2-}(aq)$
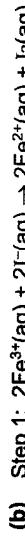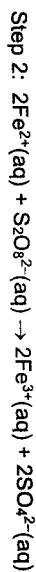
(c) (i) $BaSO_4$ [1]

(ii) Upon reaction with Br_2, the oxidation state of sulfur increases from +2 in $S_2O_3^{2-}$ to +6 in SO_4^{2-}.

Upon reaction with I_2, the oxidation state of sulfur increases from +2 in $S_2O_3^{2-}$ to +2.5 in $S_4O_6^{2-}$.

Therefore, <u>Br₂ is a stronger oxidising agent than I₂.</u> [2]

(d) P does not rotate plane-polarised light.
⇒ P <u>does not contain a chiral carbon.</u>

P is insoluble in both HCl(aq) and NaOH(aq)/ P <u>does not undergo acid-base reaction.</u>
⇒ P is <u>neutral.</u>

P undergoes <u>alkaline hydrolysis</u> with hot NaOH(aq).
⇒ P contains <u>ester and nitrile</u> groups.

1 mole of R undergoes <u>acid-base reaction</u> with 1 mole of Na_2CO_3(aq).
⇒ R contains <u>2</u> –COOH groups.

Q undergoes <u>oxidation</u> to give HCOOH and a pale yellow precipitate, CHI_3.
⇒ Q contains a <u>–CH(OH)CH₃ or –COCH₃ group.</u>

P undergoes <u>reduction</u> with LiAlH₄ to form Q and S.
⇒ Both Q and S contain a primary <u>–OH group.</u>
⇒ S contains a <u>–CH₂NH₂/ primary amine group.</u>

P R S Q
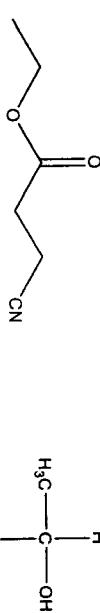
[8]

[Total: 20]

4

3 (a) (i) Primary amine, primary alcohol [1]

(ii) To act as a Lewis base, <u>the lone pair of electrons on N of TRIS is donated into the vacant orbital of H⁺/ proton from hydrochloric acid, resulting in the formation of a dative bond between N</u> of TRIS and H⁺. [2]

(b) (i) Initial [TRIS] = $\dfrac{121.14}{12.0\times4 +14.0+(16.0\times3)+11.0}$ = 1.001 mol dm⁻³

$K_b = \dfrac{10^{-14}}{8.32\times10^{-9}} = 1.202\times10^{-6}$ mol dm⁻³
$= \dfrac{[TRISH^+][OH^-]}{[TRIS]} = \dfrac{x^2}{1.001-x}$

Assuming x is very small,
$[OH^-] = x = \sqrt{(1.202\times10^{-6})(1.001)} = 1.097 \times 10^{-3}$ mol dm⁻³
$pOH = -lg(1.097 \times 10^{-3}) = 2.96$
$pH = 14 - pOH = 11.0$ [3]

(ii) $7.5 = -lg(8.32 \times 10^{-9}) + lg\left(\dfrac{[TRIS]}{[TRISH^+]}\right)$
$lg\left(\dfrac{[TRIS]}{[TRISH^+]}\right) = -0.580$
$\dfrac{[TRIS]}{[TRISH^+]} = 10^{-0.580} = 0.263$

Or
$K_a = 8.32 \times 10^{-9} = \dfrac{[TRIS](10^{-7.5})}{[TRISH^+]}$

Or
$K_b = 1.202 \times 10^{-6} = \dfrac{[TRISH^+](10^{6.5})}{[TRIS]}$
$\dfrac{[TRIS]}{[TRISH^+]} = 0.263$ [1]

(iii) $\dfrac{[TRIS]}{[TRISH^+]} = 0.263 = \dfrac{1.001-x}{x}$
$[TRISH^+] = x = 0.7926$ mol dm⁻³
Amount of HCl required = amount of TRISH⁺ in 1 dm³ = 0.7926 mol
Volume of HCl required = 0.7926/11.0 = 0.0721 dm³ [2]

5

Or

Alternative for finding [TRISH$^+$]:

$$\frac{[TRIS]}{[TRISH^+]} = \frac{0.263}{1}$$

$$TRIS \quad + \quad H^+ \quad \rightarrow \quad TRISH^+$$

Eqm [] $\quad \dfrac{0.263}{1.263} \times 1.001 \qquad \dfrac{1}{1.263} \times 1.001$

$$[TRISH^+] = \frac{1}{1.263} \times 1.001 = 0.7926 \text{ mol dm}^{-3}$$

(c) (i)

A B [2]
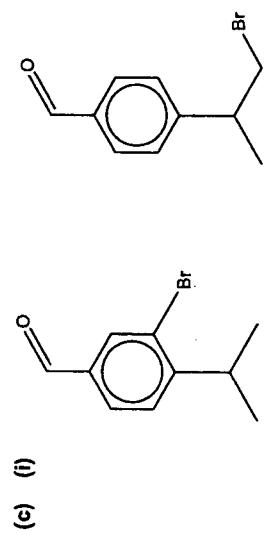
(ii) Formation of cream ppt of AgBr shows that compound **B** undergoes nucleophilic substitution with NaOH(aq) to release bromide ion for precipitation by AgNO$_3$.

Compound **B** is an alkyl bromide/ halide. [2]

(iii) Step 1: CH$_3$CHClCH$_3$, anhydrous AlCl$_3$

Step 2: acidified K$_2$Cr$_2$O$_7$, heat with immediate distillation [2]

(iv) Warm with Tollens' reagent.

Silver mirror/ black/ grey ppt formed with cuminaldehyde but no silver mirror/ black/ grey ppt formed with compound **D**.

Or

I$_2$ in NaOH(aq), warm.

Pale yellow ppt formed with compound **D** but no ppt formed with cuminaldehyde.

Or

acidified/H$_2$SO$_4$(aq), K$_2$Cr$_2$O$_7$(aq), heat

Orange acidified K$_2$Cr$_2$O$_7$(aq) turned green with cuminaldehyde, but remained orange with **D**. [2]

6

(d) (i) Transition metals have partially filled 3d orbitals.

In the presence of ligand field, the 3d orbitals are split into 2 sets of non-degenerate orbitals with small difference in energies.

Visible light of the electromagnetic spectrum is absorbed for the transfer of an electron from a lower energy d-orbital to an unfilled/ partially filled d orbital of higher energy.

The colour of complex observed corresponds to the complement of the absorbed colours. [3]

(ii) Complex is violet-red. Since yellow-green light is absorbed for d-d transition, the complementary colour violet-red will be observed. [1]

(iii) (M^{4+}) 1s^{2}2s^{2}2p^{6}3s^{2}3p^6

M   1s^{2}2s^{2}2p^{6}3s^{2}3p^{6}3d^{2}4s^2 [1]

(iv) Either of the following:

• In an octahedral ligand field of F$^-$, the energy gap between the non-degenerate 3d orbitals becomes very large.

• Radiation/ light absorbed for d-d transition is not from visible light range. [1]

[Total: 23]

4 (a) (i) The C-C bond in propanone is formed from the overlap between sp^2 and sp^3 hybridised carbons while the C-C bond in propane is formed from the overlap between sp^3 hybridised carbons.

sp^2 hybridised orbitals have greater s character/ lower p character, are shorter/ smaller and closer to the nucleus, making the C-C bond shorter than expected. [2]

(ii)

[2]

(iii)


[2]

7

(iv)

S (one of the 2)
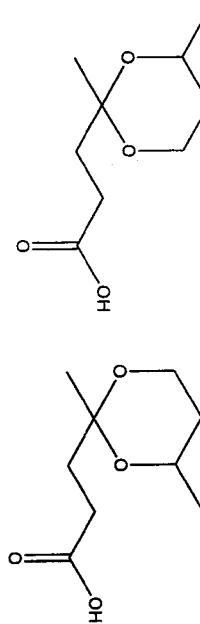
T (one of the 2)

U (one of the 4)

[3]

[Turn over
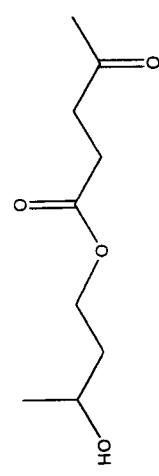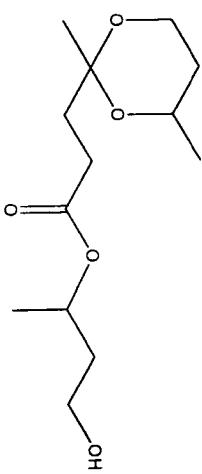
8
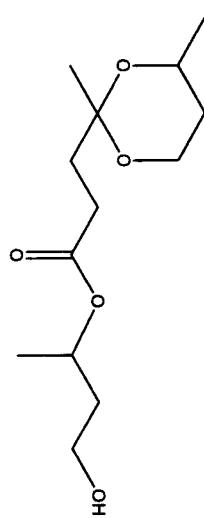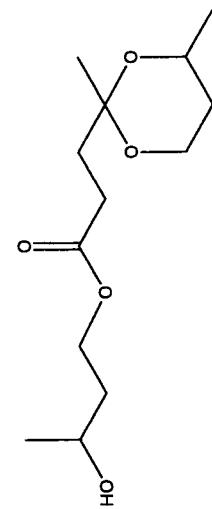
(b) (i) Cold alkaline KMnO₄ [1]

(ii)

or
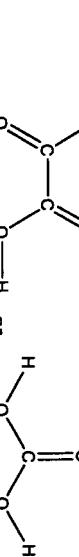
[1]

(c) (i) [CH₃COCH₃(aq)] <u>remains approximately constant throughout the experiment so rate of reaction is independent of [CH₃COCH₃(aq)].</u> Thus experimental results can be used to determine the order of reaction with respect to I₂(aq) and H⁺(aq). [1]

(ii) <u>A straight line/ linear plot is obtained/ graph has a constant (negative) gradient.</u> Rate of reaction is constant regardless of the concentration of I₂. Reaction is independent of [I₂] and reaction is <u>zero order</u> with respect to I₂. [1]

(iii)

[1]

5 (a)(i) Bond energy is the average enthalpy change when <u>one mole of covalent bonds</u> between atoms in <u>gaseous molecules</u> is broken. [1]

(ii) ΔH_r = ΣE(bonds broken) − ΣE(bonds formed)

= $[E(C\text{–}O) + E(C\text{–}H)] - [E(C\text{–}C) + E(C\text{–}O) + E(O\text{–}H)]$

= $[(+740) + (+410)] - [(+350) + (+360) + (+460)]$

= <u>-20 kJ mol^{-1}</u> [2]

(b)(i)

(ii) Reduction [1]

(c)(i)

[1]

(ii) Step 1: conc. HNO$_3$, conc. H$_2$SO$_4$, maintained at 30 °C

Step 3: SOCl$_2$/ PCl$_5$/ PCl$_3$, (room temperature) [2]

(d)(i) Excess concentrated H$_2$SO$_4$, heat

Or Al$_2$O$_3$, heat [1]

(ii)

major   minor

[2]
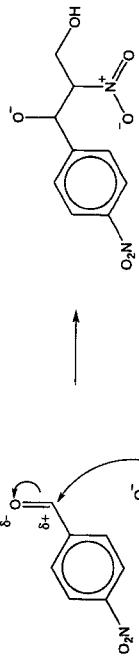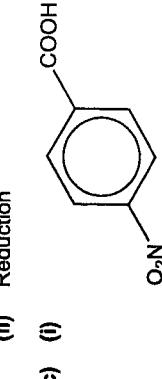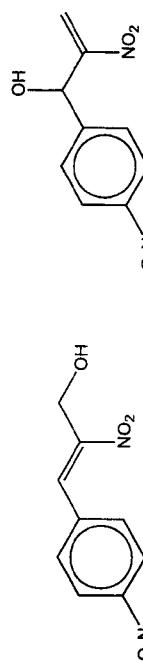
(iii) The major product is more stable because it is the <u>more substituted</u> alkene (Saytzeff rule). [3]

The C atoms in alkenes are sp^2 hybridised. [2]

(iv) Rate of expt 1 = −gradient of expt 1 = $-\left(\dfrac{0.6-0.35}{0-300}\right)$ = 0.000833 s^{-1}

Rate of expt 2 = −gradient of expt 2 = $-\left(\dfrac{0.6-0.1}{0-300}\right)$ = 0.00166 s^{-1}

Since <u>rate of reaction doubled when [H$^+$] is doubled</u>, reaction is <u>first order with respect to H$^+$</u>. [2]

(v) Let the rate equation be   rate = $k[\text{H}^+][\text{CH}_3\text{COCH}_3]^p$

$\dfrac{(\text{Rate})_3}{(\text{Rate})_4} = \dfrac{k[\text{H}^+]_3[\text{CH}_3\text{COCH}_3]_3^p}{k[\text{H}^+]_4[\text{CH}_3\text{COCH}_3]_4^p}$

$\dfrac{(2.45)}{(3.68)} = \dfrac{k(0.002)(0.001)^p}{k(0.001)(0.003)^p}$

$n = 1$

Reaction is first order with respect to CH$_3$COCH$_3$. [1]

(vi) 1. <u>Start the stopwatch</u> when propanone solution, iodine solution and dilute sulfuric acid of <u>known concentrations are mixed.</u>

2. <u>Monitor the change in absorbance/ concentration of the unreacted iodine throughout the reaction</u>

OR

At regular time intervals, a known volume of the reaction mixture <u>is pipetted out and quench before analysis.</u>

3. <u>Plot a graph of iodine concentration against time.</u>

4. <u>The initial rate of reaction can be determined by drawing a tangent to the curve at $t = 0$s, and subsequently calculating the gradient.</u>

5. <u>Substitute the initial concentrations of reactants and initial rate into rate = $k[\text{H}^+][\text{CH}_3\text{COCH}_3]$ and calculate k.</u>

Alternative for steps 3-5:

Plot [I$_2$] vs time graph while making sure CH$_3$COCH$_3$ is in large excess and overall order of reaction is 1. Find half life from graph plotted and calculate k.

rate = k'[H$^+$], where $k' = k$[CH$_3$COCH$_3$]

$k' = \ln 2 / t_{1/2}$

k[CH$_3$COCH$_3$] = $\ln 2 / t_{1/2}$

[3]

[Total: 20]

(e) (i) $K_{sp} = [Ag^+][NO_2^-]$ [1]

(ii) $[AgNO_2] = \dfrac{0.155/153.9}{100/1000}$

= 0.01007 $mol\ dm^{-3}$

$K_{sp} = (0.01007)^2 = 1.01 \times 10^{-4}\ mol^2\ dm^{-6}$ [2]

(f) (i) $E^{\ominus}_{cell} = +1.52 - (+0.42) = +1.10$ V [1]

(ii) $\Delta G^{\ominus} = -nFE^{\ominus}_{cell}$

$= -(10)(96500)(+1.10)$

$= -1.06 \times 10^6$ J mol^{-1} [1]

p orbitals

sp² orbitals

σ

π

[Total: 20]

2022 H2 Chemistry Preliminary Examination Paper 4

Suggested Answers

1 Investigation of the oxidising ability of substances

(a) (i) Table 1.1

	Test	Observations
1	To a 1 cm depth of **FA 1** in a test-tube, add 1 cm depth of **FA 4**, then gradually add **FA 2** till 1 drop in excess.	<u>Purple **FA 2** decolourised.</u> Pale green/colourless **FA 1** turned pale <u>yellow</u> and finally <u>orange/ pink.</u>
2	To a 1 cm depth of **FA 3** in a test-tube, add 1 cm depth of **FA 2.**	<u>Purple KMnO₄ decolourised.</u> A brown solution/ppt formed. Effervescence/ bubbles of gas evolved rapidly. Colourless, odourless gas evolved relight a glowing splint. The gas is oxygen.
3	To a 1 cm depth of **FA 1** in a test-tube, add about 1 cm depth of **FA 4**, followed by 1 cm depth of **FA 3.** To a portion of resulting solution, add aqueous sodium hydroxide till excess.	Pale green/colourless **FA 1** turned <u>yellow.</u> Red-brown ppt formed is insoluble in excess NaOH(aq). Effervescence/ bubbles of gas evolved (rapidly).

(ii) Purple MnO₄⁻ oxidised (pale green) iron(II) to (yellow) iron(III) ions.

Itself is reduced to colourless Mn²⁺. (reject pale Mn2+)

(iii) $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$

$Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$

(iv) Compound **A / FA 3**

(b) (i) Titration results

Titration number	1	2
Final burette reading /cm³	24.20	24.25
Initial burette reading /cm³	0.00	1.00

Volume of **FA 2** (added) /cm³	24.20	24.25

(ii) average volume of **FA 2** used $= \dfrac{24.20 + 24.25}{2}$

$= 24.23$ cm³

(c) (i) $[KMnO_4] = \dfrac{0.750}{39.1 + 54.9 + (4 \times 16.0)} \times \dfrac{1000}{250} = 0.01899$ mol dm⁻³

amount of MnO₄⁻ $= 0.01899 \times \dfrac{V_{FA2}}{1000}$ mol

$= 0.000460$ mol

(ii) amount of Fe²⁺ in 25.0 cm³ $= (c)(i) \times \dfrac{5}{1}$ mol

$[Fe^{2+}] = (c)(i) \times \dfrac{5}{1} \times \dfrac{1000}{25.0}$ mol dm⁻³

$= 0.0920$ mol dm⁻³

(d) Identify the cause: Chloride is oxidised by/ reacts with MnO₄⁻

And any one of the following modification : **M16**

- The titration needs to be carried out in the fumehood. Chloride is oxidised by MnO₄⁻ to give toxic chlorine gas.

- Iron(II) chloride needs to be diluted prior to titration. The titre will exceed 50.00 cm³ if iron(II) chloride is not diluted.

- Prepare higher concentration of MnO₄⁻ for used. The titre will exceed 50.00 cm³ if **FA 2** with original concentration is used.

- Using a smaller pipette/ burette, measure a smaller volume of iron(II) chloride for titration, so that the titre will not exceed 50.00 cm³.

$(5FeCl_2(aq) + 3MnO_4^-(aq) + 24H^+(aq) \rightarrow 5Fe^{3+}(aq) + 5Cl_2(g) + 3Mn^{2+}(aq) + 12H_2O(l))$

**(e) (i)** As V_{FA3} increases, <u>more compound **A/FA 3** was added to oxidise Fe²⁺</u> in **FA 1**. This leaves <u>less Fe²⁺ to be oxidised by MnO₄⁻</u> in **FA 2.**

(ii) • Not an anomaly.

- (Compound **A** in **FA 3** is both an oxidising and reducing agent.)

- In experiment 5, compound **A** is in <u>excess</u>/ Fe²⁺ is <u>limiting.</u>

- The (excess) compound **A** is <u>oxidised by MnO₄⁻.</u>

2

(iii) percentage uncertainty $= \dfrac{2 \times 0.05}{1.25} \times 100 = 8.0\,\%$

Results

Expt	V_{FAS} / cm³	V_{H_2O} / cm³	Reaction time, t /s	lg(V_{FAS})	lg (rate)
1	20.00	0.00	15.1	1.30	2.38
2	10.00	10.00	56.5	1.00	1.80
3	15.00	5.00	26.9	1.18	2.13
4	6.00	14.00	144.5	0.778	1.40

(b)

lg(rate) plotted against lg(V_{FAS}), with points marked at (0.78, 1.40) and (1.21, 2.20), and dashed construction lines at 1.62.

(c) (i) Gradient of line $= \dfrac{1.40 - 2.20}{0.78 - 1.21}$

= 1.86 (3 s.f.)

m = 2 (nearest integer)

(ii) From graph, when lg(7.9) = 0.898,

$\lg\left(\dfrac{3600}{\text{reaction time}}\right) = 1.62$

reaction time $= \dfrac{3600}{10^{1.62}} = 86.4$ s

(d) (i) Experiment 1: [KI] = $0.0500 \times \dfrac{20.00}{60.00} = 0.016667$ mol dm⁻³

Experiment 2: [KI] = $0.0500 \times \dfrac{10.00}{60.00} = 0.008333$ mol dm⁻³

$\dfrac{20.00}{10.00} = \dfrac{0.016667}{0.008333} = 2$
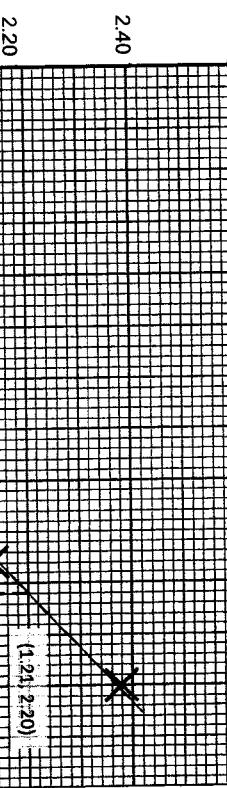
(ii) Using results of experiment 1 and 2,

$\dfrac{\text{rate in experiment 1}}{\text{rate in experiment 2}} = \dfrac{\dfrac{3600}{t_1}}{\dfrac{3600}{t_2}} = \dfrac{t_2}{t_1} = \dfrac{56.5}{15.1} = 3.74 \approx 4$

When [KI] doubled, rate of experiment 2 is 4 times that of experiment 1.

(e) (i) $S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(aq/g) + H_2O(l)$
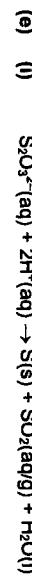
(ii) Not as good as that in (a). With any of the following reasons:

• There is less thiosulfate left in the reaction mixture to react with iodine formed/ so shorter time recorded. (or words to the effect)

• More time is needed to transfer the content in measuring cylinder/ 20.00 cm³ of solution into the beaker for mixing

Or

As good as that in (a). With any of the following reasons:

• [$S_2O_3^{2-}$] is very small, so reaction with iron(III) ions/H⁺/acid will be very slow and negligible.

• [$S_2O_3^{2-}$] decrease by similar extent for each experiment, the relative rate of experiments is not affected.

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4 **(a)** **(i)** $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

(ii) Amount of OH⁻ in 25.0 cm³ = $2 \times 1.00 \times \dfrac{25.00}{1000}$

= 0.0500 mol

Volume of HCl required for complete neutralisation = $\dfrac{0.0500}{1.50} \times 1000$

= 33.33 cm³

Heat evolved = 57 000 × 0.0500 = (25.0 + 33.33) × 4.18 × ΔT

ΔT = 11.7 °C

(b) **Procedure**

1. Fill a 50.00 cm³ burette to 0.00 cm³ mark with 1.50 mol dm⁻³ HCl(aq).
2. Place a Styrofoam cup in a 250 cm³ beaker to prevent it from toppling.
3. Pipette 25.0 cm³ Ba(OH)₂ into the Styrofoam cup.
4. Using a thermometer, measure and record the initial temperature of the Ba(OH)₂, T_Initial.
5. Place a lid on the Styrofoam cup to minimise heat loss to the surroundings.
6. Run 5.00 cm³ of HCl(aq) from the burette into the cup though an opening in the lid, stir the solution carefully with the thermometer and record the highest temperature reached, T.
7. Immediately run a further 5.00 cm³ of HCl(aq) from the burette into the cup, stir and record the highest temperature reached, T.
8. Continue the addition of HCl(aq), in 5.00 cm³ portions, until 50.00 cm³ have been run from the burette.

Recognition of Equivalence Point

After equivalence point, highest temperature reached will be lower for each portion of HCl(aq) added.

M47 – **Appropriate apparatus for volumes measurement**

M48 – **Details for measurement of volumes using burette**

M49 – **Measurement of temperatures**

M50 – **Ensuring accuracy**

M51 – **Recognition of equivalence point**

---

3 **(a)**

Table 3.1

	Test	Observations
1	Place a test-tube containing 2 cm depth of **FA 9** in an almost boiling water bath for a few minutes.	Blue/ bluish-green **FA 9** turned green.
2	To a 2 cm depth of **FA 9** in a test-tube, add gradually add 2 cm depth of **FA 10**. Pour half of this mixture into another test-tube and place it in the almost boiling water bath for a few minutes for comparison.	(Blue/ bluish-green) **FA 9** turned green upon adding **FA 10**. The resultant solution turned yellowish-green/ brighter green after warming.
3	To a 1 cm depth of **FA 9** in a boiling-tube, gradually add 3 cm depth of aqueous sodium hydroxide. Filter the resultant mixture and collect the filtrate. Keep the filtrate for Test 4.	Pale blue/ Blue-green/greenish-blue ppt formed is insoluble in excess NaOH(aq). The residue is dark blue. The filtrate is a colourless solution.
4	To a 1 cm depth of filtrate in a test-tube, add 1 cm depth of nitric acid, followed by AgNO₃(aq). To a portion of the resultant mixture, add NH₃(aq).	White ppt formed with AgNO₃(aq) is soluble in aqueous ammonia to give a colourless solution.

(b) **(i)** **Cation**   Copper(II) ion/ Cu²⁺

(ii) Either one of the following:
- Colour of the white ppt cannot be seen clearly in dark-coloured **FA 9** solution.
- Addition of NH₃(aq) could precipitate/form dark blue complex with Cu²⁺ if present.

(c) **(i)** [CuCl₄]²⁻

In Test 2, when **FA 10**/ saturated NaY/Y⁻ is added to **FA 9**, a yellow complex is formed.

The solution is green due to presence of both blue and yellow complexes/ The solution turned green due to more yellow complex formed.

(ii) The conversion of blue to yellow complex is an endothermic process.

Upon warming, the formation of yellow complex is favoured/ POE of Equation 1 shift to the right to absorb some of the added heat.

(c) (i)

(ii) M53 – Explain T rise due to more reaction occurs.

Initially as V_{HCl} increases, larger amount of $Ba(OH)_2$ is neutralised to produce more heat. Therefore, T increases.

M54 – Explain T fall

(After equivalence point, $Ba(OH)_2$ is completely neutralised.)

Either one of the following:

• Same amount of heat is distributed over an increasingly larger total volume of solution, causing T to fall.

• Excess HCl at lower temperature/ room temperature cools down the mixture.
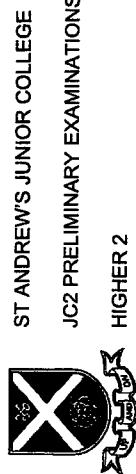
ST ANDREW'S JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATIONS

HIGHER 2

CANDIDATE NAME

CLASS	2	1	S

CHEMISTRY

9729/01

Paper 1 Multiple Choice

15 September 2022

1 hour

Additional Materials: Multiple Choice Answer Sheet

Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

Do not use staples, paper clips, glue or correction fluid.

Write your name and class on the Answer Sheet in the spaces provided.

There are **thirty** questions on this paper. Answer all questions. For each question there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate.

This document consists of **19** printed pages (including this cover page) and **1** blank page.

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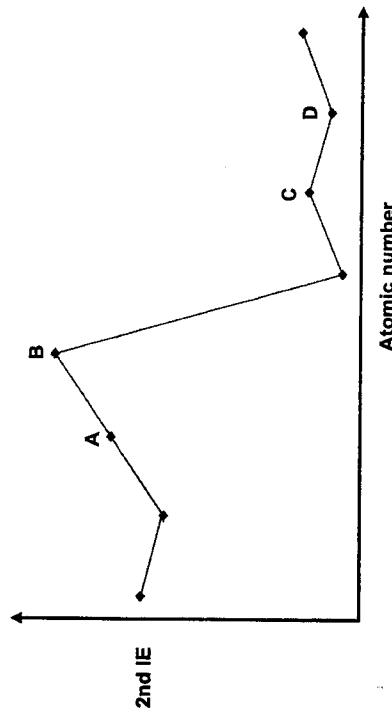
1 *Use of the Data Booklet is relevant to this question.*

Which statements about chromium and its compounds are correct?

1 The valence electronic configuration of Cr contains both an unpaired s electron and an unpaired p electron.

2 One of the 3d orbitals in chromium atom has only 2 lobes.

3 There are 58 electrons and 60 neutrons in the $^{52}Cr^{16}O_4^{2-}$ ion.

A 1, 2, and 3

B 1 and 2

C 2 and 3

D 1 only

2 The following graph shows the second ionisation energy of eight consecutive elements in Period 2 and 3.

Which of the options **A, B, C** or **D** is silicon?

3 Which option is correct?

	Molecule	Planar	Polarity
A	Xenon difluoride	Yes	Polar
B	Chlorine(I) oxide	No	Non-polar
C	Methanal	Yes	Polar
D	Dichloromethane	No	Non-polar

[TURN OVER

3

4 Which statements about ethanoic acid are correct?

1 1 molecule of ethanoic acid has 4 lone pairs of electrons.
2 Gaseous ethanoic acid forms a dimer comprising of two hydrogen bonds within a ring of 8 atoms.
3 The C–C bond in ethanoic acid is formed from a sp^3–sp^2 orbital overlap.

A 1, 2 and 3
B 1 and 2
C 2 and 3
D 1 only

5 Which description of Dalton's law is correct?

A Equal volumes of gases at the same temperature and pressure contain equal numbers of molecules.
B The total pressure of a mixture of gases is equal to the sum of the partial pressures of those gases.
C The partial pressure of a gas in mixture is given by the product of its mole fraction and the total pressure.
D The partial pressure of a gas in a mixture is given by the product of its percent by mass and the total pressure.

4

6 Which graph shows the correct trends when the physical property of each of the elements Na, Al, Si and S is plotted against its atomic radius?

A Melting point
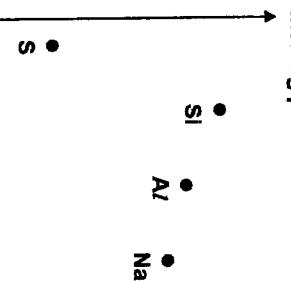
B Electronegativity
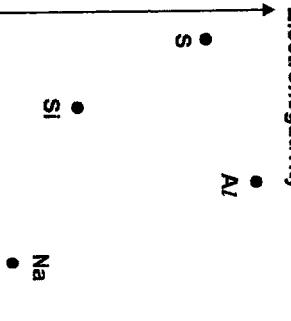
C Electrical Conductivity
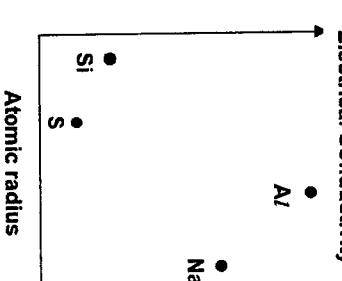
D Ionic Radii
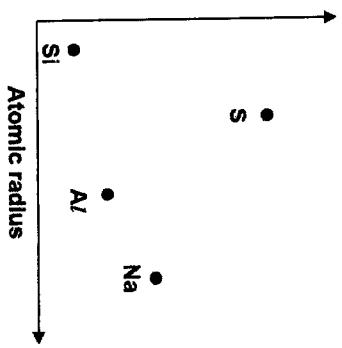
7 Which property describes the trend for the hydrogen halides as stated below?

HCl > HBr > HI

A thermal stability
B boiling point
C ease of oxidation
D acidity

5

**8** *Use of the Data Booklet is relevant to this question.*

Which contains the largest number of molecules?

A   810 cm³ of sulfur dioxide gas (measured at r.t.p.)

B   1.56 g of methyl methanoate

C   5.25 cm³ of ethanol where the density of ethanol is 0.755 g cm⁻³

D   1.70 x 10²² molecules of hydrogen peroxide.

9 Silane, SiH_4, exists as a gas at standard temperature and pressure. Hess' Law can be used to calculate the average Si–H bond energy in gaseous SiH_4. Which information is needed to perform the calculation?

A $\Delta H^\ominus_{formation}(SiH_4)$ only

B $\Delta H^\ominus_{atomisation}(Si)$, $\Delta H^\ominus_{atomisation}(H)$, $\Delta H^\ominus_{formation}(SiH_4)$

C $\Delta H^\ominus_{combustion}(Si)$, $\Delta H^\ominus_{combustion}(H_2)$, $\Delta H^\ominus_{combustion}(SiH_4)$

D $\Delta H^\ominus_{combustion}(Si)$, $\Delta H^\ominus_{combustion}(H_2)$, $\Delta H^\ominus_{formation}(SiH_4)$

[TURN OVER

6

10 The decomposition of Arsine, AsH_3, is catalysed by Arsenic, As, and can be represented by the following equation.

$$AsH_3 \rightarrow As + \frac{3}{2} H_2$$

Which graph does **not** describe the above reaction?

A   [Arsine] vs Time

B   Rate vs Time

C   Rate vs Time

D   Pressure of H₂ vs Time
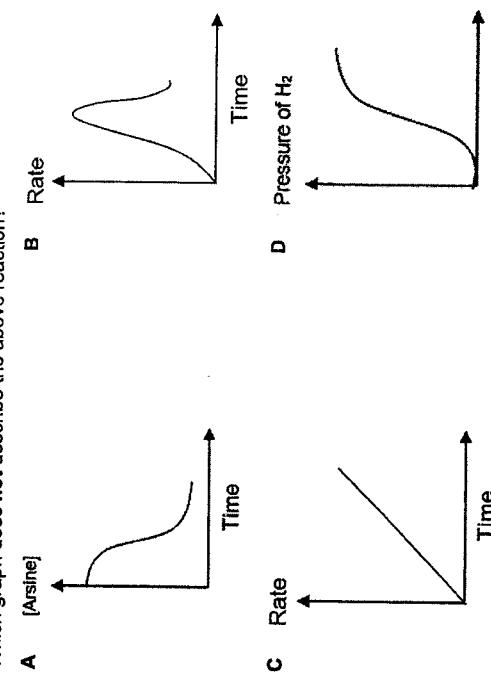
11 Steam reforming process is the most common method used for the industrial production of hydrogen.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad K_c = 6.50 \ mol^2 \, dm^{-6}$$
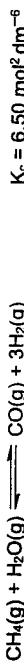
What is the number of moles of steam used to react with 0.60 mol of methane, to form 0.90 mol of hydrogen in a 1 dm³ vessel?

A   0.304 mol   C   0.412 mol

B   0.112 mol   D   0.346 mol

[TURN OVER

7

12 Deuterium oxide, otherwise known as 'heavy water', consists of an oxygen atom bonded to two atoms of the hydrogen isotope, deuterium ($^2_1$D).

Like water, deuterium oxide can undergo autoionisation. For D_2O, we can use the term K_D instead of K_W.

$$2D_2O \rightleftharpoons D_3O^+ + OD^-$$

The following graph show how the values of K_W of H_2O and K_D of D_2O vary with temperature.
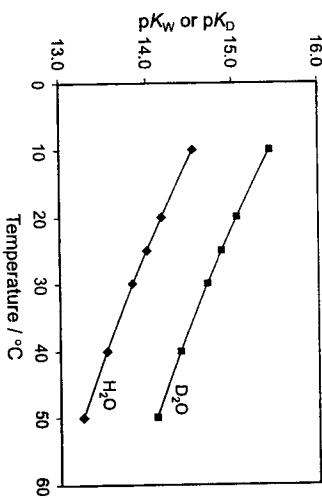
Which deduction is correct?

A The enthalpy changes of autoionisation for both H_2O and D_2O are negative.

B The extent of ionisation is smaller for D_2O.

C $[OH^-]$ and $[OD^-]$ decrease with increasing temperature.

D O–D bond is weaker than O–H bond.

8

13 The numerical values of the solubility product of calcium hydroxide and calcium carbonate are 6.5×10^{-6} and 8.0×10^{-7} respectively at 25 °C.

Which statements are correct?

1 A precipitate is formed when equal volumes of 0.001 mol dm^{-3} calcium nitrate and a solution of pH 12.5 are mixed.

2 The solubility of calcium hydroxide in a solution of pH 12.5 is higher than the solubility of calcium carbonate in water.

3 The solubility product of calcium carbonate and calcium hydroxide decrease in a solution containing calcium nitrate.

A 1, 2, and 3

B 1 and 2

C 2 and 3

D 2 only

14 How many stereoisomers does the following molecule have?


A 16

B 64

C 128

D 256
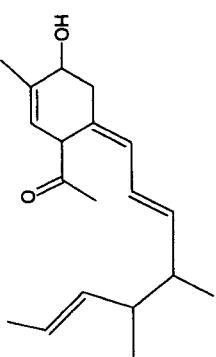
9

15 Rosmarinic acid can be found in herbs such as rosemary, sage and thyme. It has the following structure.
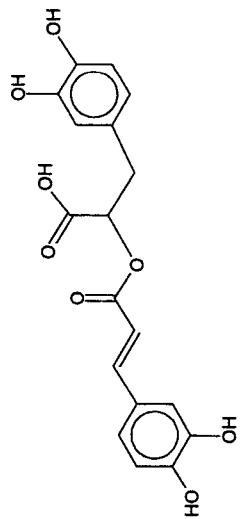
Which functional groups will remain in the product after rosmarinic acid reacts with excess hydrogen gas in the presence of platinum?

1   Alkene
2   Carboxylic acid
3   Ester
4   Phenol

A   1 and 2
B   3 and 4
C   2, 3 and 4
D   4 only

[TURN OVER

10

16 Methylbenzene can undergo the following reaction.
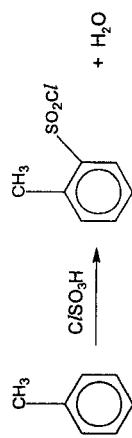
Which statement about the mechanism of this reaction is correct?

A   The hybridisation states of the carbon atoms in benzene do not change during the reaction.
B   The π electron cloud of benzene will attack the O atom in $ClSO_3H$.
C   The mechanism of this reaction is electrophilic addition.
D   The bond broken in $ClSO_3H$ is the S-O bond.

17 1-bromo-2,2-dimethylpropane, $(CH_3)_3CCH_2Br$, can be obtained from 2,2-dimethylpropane, $(CH_3)_4C$, via free radical substitution with excess bromine. The yield however is low.

What is the main reason for this?

A   Different mono-substituted products are formed.
B   The Br-Br bond requires a lot of energy to break.
C $(CH_3)_3CCH_2Br$ is very unstable.
D   The bromine radical is regenerated during the formation of $(CH_3)_3CCH_2Br$.

[TURN OVER

18 Molecule **M** is a halogenoalkane. It is reacted with various reagents to give the following results.

- **M** is first heated with NaOH(aq). After it has cooled, HNO$_3$ is added followed by AgNO$_3$. A precipitate appears and is only soluble in concentrated NH$_3$.

- **M** reacts with ethanolic KCN when heated. The product reacted with LiAlH$_4$ in dry ether to yield a product that has the molecular formula C$_5$H$_{13}$N.

Which conclusion can be drawn from these results?

A There are 4 possible constitutional isomers for molecule **M**.

B When treated with ethanolic AgNO$_3$, the precipitate for molecule **M** will appear slower than 1-chlorobutane.

C Molecule **M** contains 5 carbon atoms.

D Molecule **M** is a tertiary halogenoalkane.

19 Which statement about S$_N$1 nucleophilic substitution mechanism is correct?

A The rate of the reaction is dependent on the concentration of the nucleophile.

B If the product formed is chiral, it will be able to rotate the plane of polarised light.

C Transition states are formed but not intermediates.

D This usually takes place for tertiary halogenoalkanes.

20 Compound **E** has the following structure.
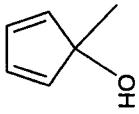
Which statements are correct about the organic product formed after compound **E** has reacted with hot acidified KMnO$_4$?

1 It contains 6 carbon atoms.

2 It can react with 3 moles of PCl$_5$.

3 It gives a yellow ppt with alkaline aqueous iodine.

4 It can react with 2 moles of aqueous NaOH.

A 1 and 2

B 1 and 3

C 2 and 4

D 3 and 4

13

21 Alcohol **Q** undergoes the following reactions.

- With concentrated H_2SO_4 at 170°C, only one product is formed.
- With hot acidified $K_2Cr_2O_7$, a green solution is formed that does not produce effervescence with Na_2CO_3.

What could be the identity of **Q**?

A

OH

B

OH

C

OH

D

OH
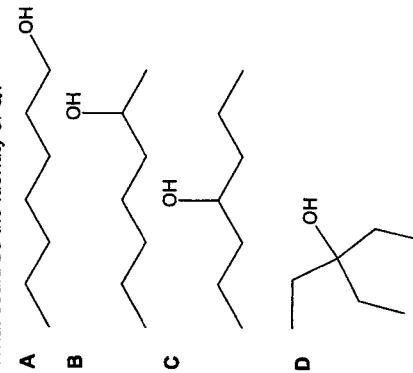
22 Compound **L** has the following structure.
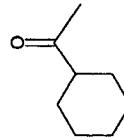
Which statement about compound **L** is **incorrect**?

A It can undergo a condensation reaction.

B It can undergo a hydrolysis reaction

C It can undergo reduction reaction.

D It can be attacked by a nucleophile.

14

23 Mandelic acid and 4-hydroxyphenylacetic acid are isomers. They have the following structures.

Mandelic acid
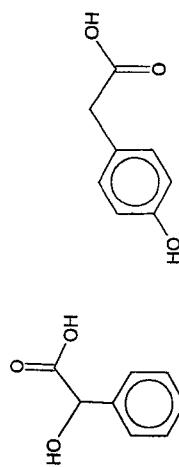
4-hydroxyphenylacetic acid

Given that the pK_a value of the carboxylic acid in mandelic acid is 3.75, which option about 4-hydroxyphenylacetic acid is correct?

|	pK_a of the carboxylic acid in 4-hydroxyphenylacetic acid	Reason
A	3.25	Lone pair of electrons on O of the phenol in 4-hydroxyphenylacetic acid can delocalise into the benzene ring
B	3.25	The alcohol group of mandelic acid is an electron withdrawing group
C	4.05	Lone pair of electrons on O of the phenol in 4-hydroxyphenylacetic acid can delocalise into the benzene ring
D	4.05	The alcohol group of mandelic acid is an electron withdrawing group

24 Compounds **X** and **Y** have the following structures.


Compound **X**

Compound **Y**
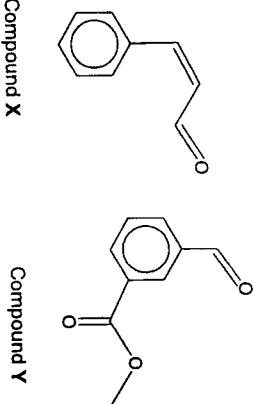
Which reagents can be used to distinguish them?

1    $Br_2(aq)$
2   Fehling's solution and warm
3   Tollens' reagent and warm

A   1 only
B   1 and 2
C   2 and 3
D   1, 2 and 3

25 Phthalate esters are mainly used in plasticisers to increase their flexibility, transparency and durability. They have the following structure.
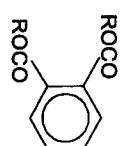
Which pair of compounds can react to form a phthalate ester?

A

B

C

D
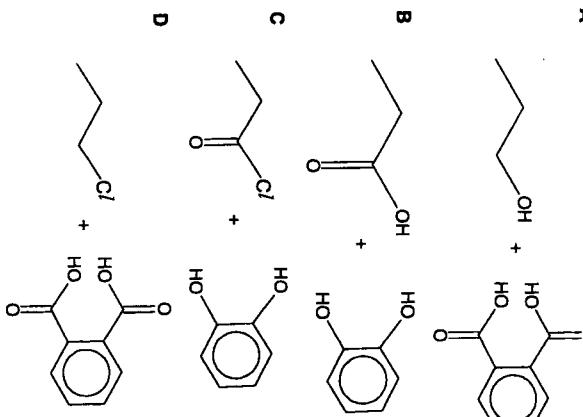
26 Which option correctly shows the product and observation of the resultant solution when aqueous propanoic acid is added dropwise to aqueous propylamine until the reaction is complete?

|	Product formed	Observations
A	$CH_3CH_2CONHCH_2CH_2CH_3$	One homogenous solution
B	$(CH_3CH_2CH_2NH_3)^+(CH_3CH_2COO)^-$	One homogenous solution
C	$CH_3CH_2CONHCH_2CH_2CH_3$	Two distinct layers
D	$(CH_3CH_2CH_2NH_3)^+(CH_3CH_2COO)^-$	Two distinct layers

27 Aspartic acid is used in the biosynthesis of proteins and has the following structure.
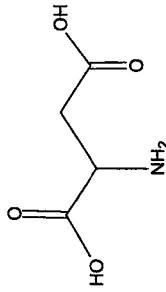
Aspartic acid has pK_a values of 2.0, 3.7 and 9.7.

At what pH will the major species in the solution be the zwitterion of aspartic acid?

A   1.5

B   3.4

C   7.0

D   10.3

28 A pentapeptide has the following structure.
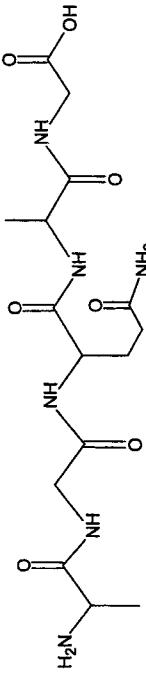
Which statement about this pentapeptide is **incorrect**?

A   When this pentapeptide reacts with aqueous H_2SO_4, the product will have an overall charge of 1+.

B   This pentapeptide contains 4 peptide bonds.

C   This pentapeptide is made up of 4 different types of α-amino acids.

D M_r of this pentapeptide = (Sum of M_r of all the α-amino acids residues) − 72

**29** *Use of the Data Booklet is relevant to this question.*

Given the following information on the colours of the aqueous vanadium-containing ions, what is likely to be the colour change when excess nickel is added to a solution containing VO_2^+?

| Aqueous vanadium-containing ions	Colour
VO_2^+	Yellow
VO^{2+}	Blue
V^{3+}	Green
V^{2+}	Purple

A   Blue to yellow

B   Blue to green

C   Blue to purple

D   Yellow to green

30 Fe²⁺ forms a red complex with *ortho*-phenanthroline. Various samples containing different volumes of 1×10^{-5} mol dm⁻³ Fe²⁺ and 3×10^{-5} mol dm⁻³ *ortho*-phenanthroline were prepared. The structure of *ortho*-phenanthroline is shown below. Each *ortho*-phenanthroline molecule is a bidendate ligand.
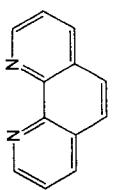
ortho-phenanthroline

The following graph was obtained when the colour intensity of the samples was measured using a colorimeter.

Absorbance

Vol. of Fe²⁺ solution/ cm³
20 18 16 14 12 10 8   6   4   2   0
Vol. of *ortho*-phenanthroline solution/ cm³
0   2   4   6   8   10 12 14 16 18 20
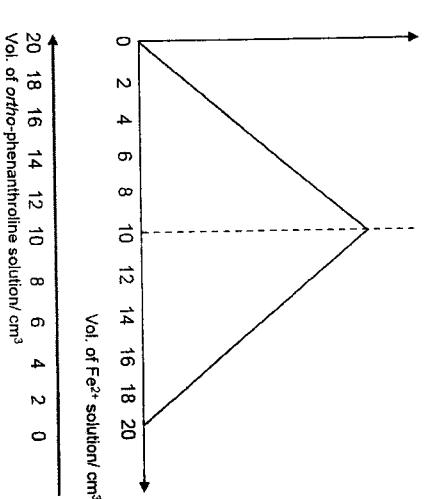
Which statement about the complex ion is correct?

A   The complex ion absorbs red light.

B   The overall charge of the complex ion is 4−.

C   The co-ordination number of the complex ion is 3.

D   The geometry of the complex ion is octahedral about Fe²⁺.

END OF PAPER

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