H2 Chemistry TYS 2018 suggested answers

Paper 1 Answer Key

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

2018 A level Paper 1 suggested answers

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

Mass of electron is approximately $\frac{1}{2000}$ the mass of a proton, hence electron has a larger angle of deflection.
The charged particles are attracted to the oppositely charged plate.

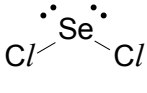
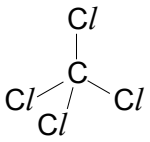
Ans: **D**

2) A*l*C*l*$_3$ is a covalent compound with simple molecular structure.
[Note: A*l*$^{3+}$ has a high charge density with strong polarising power that can polarise the large electron cloud of C*l*$^-$ significantly, leading to overlapping of electron cloud between A*l* and C*l*. This causes the sharing of electron cloud, thus covalent bond is formed between A*l* and C*l*]

A*l*C*l*$_3$ dimerises to A*l*$_2$C*l*$_6$ as the empty 3p orbital of A*l* can accept a pair of electrons from C*l*. Dative bond is from C*l* to A*l*.

Ans: **D**

3)

Se=C=Se		
Around C: 2 b.p. 0 l.p. (linear)	Around Se: 2 b.p. 2 l.p. (bent)	Around C: 4 b.p. 0 l.p. (tetrahedral)
non-polar	polar	non-polar

Ans: **D**

4) Cs$^+$, I$^-$ and Xe are isoelectronic with 54 electrons.
Nuclear charge increases from I$^-$ < Xe < Cs$^+$ while shielding effect remains constant.
Nuclear attraction towards the valence electrons increases from I$^-$ < Xe < Cs$^+$.
Largest amount of energy is required to remove the most loosely held electron from Cs$^+$.

Ans: **B**

5) Option A is false as 1 mole of compound like Br_2, contains 2 mol of atoms.

Option B is false as we should only consider mass of lithium−7 isotope instead of all isotopes.

Option D is false as molecular mass is the sum of average mass of the atoms in compound E.

Ans: **C**

6) Atomic radius increases down a Group and decreases across the Period.

Rb and In are both in Period 5. Atomic radius of Rb > In

Ans: **D**

7) P_{O2} from air at sea level = 0.2 bar

Percentage of O_2 in tank = $\frac{P_{O2}}{P_{total}} \times 100\% = \frac{0.2}{4} \times 100\% = 5\%$

Ans: **C**

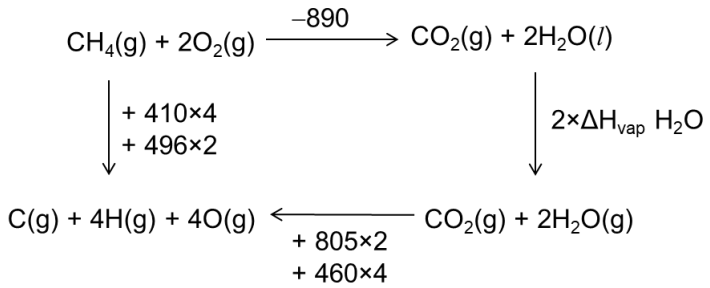
8) Option A is wrong. It represents L.E. of $Al_2O_3(s)$ [L.E. is when one mole of ionic solid is formed from its constituent gaseous ions]

Option B is wrong. It represents $2\times\Delta H_n$ [ΔH_n is when one mole of H_2O is formed from acid-base reaction]

Option D is wrong. It represents $8\times\Delta H_f$ $SO_2(g)$ [ΔH_f is when one mole of compound is formed from its constituent elements in their standard state]

Ans: **C**

9)



$2\times\Delta H_{vap}$ H_2O = 890 + 410×4 + 496×2 − 805×2 − 460×4 = +72

ΔH_{vap} H_2O = +36 kJ mol^{-1}

Ans: **C**

10) 0.001 mol of iodine oxide reacts with 0.01 mol of I^- to gives 0.006 mol of I_2.
Balancing number of I atoms on both sides,
0.006 mol of I_2 contains 0.012 mol of I atoms.
Hence, 0.001 mol of iodine oxide contains 0.002 mol of iodine atoms.

0.002 mol I^{x+} reacts with 0.010 mol I^- to produce 0.006 mol I_2.

[O] $2I^- \longrightarrow I_2 + 2e^-$
0.010 mol I^- gives 0.010 mol of e^-

[R] $I^{x+} + ne^- \longrightarrow I_2$
0.002 mol of I^{x+} gains 0.010 mol of e^-
1 mol of I^{x+} gains 5 mol of e^- to give I_2

During **reduction**, oxidation state of I^{x+} **decreases** by **5** units from **+5** to **0**.

Ans: **B**

11) It is given that order of reaction wrt NO_2 is 2, the slow step should involve two molecules of NO_2 and overall equation of step 1 and 2 must be the same as the given equation.

Ans: **C**

12) For enzyme catalysed reaction, the rate of reaction increases with the concentration of reactants and reach a maximum rate when the active sites of the enzyme are saturated. After which, any increase in concentration of reactants would not increase the rate any further.

Ans: **D**

13) High charge density cation polarises the electron cloud of H_2O ligands and weaken the O−H covalent bond to produce H^+.
Al^{3+} has the highest charge density, the O−H bond is weakened most significantly and produce the largest concentration of H^+.

$[Al(H_2O)_6]^{3+} \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} + H^+$

Ans: **A**

14) $H_2O \rightleftharpoons H^+ + OH^-$
When temperature increases from 10 to 40 °C, the position of equilibrium shifts to the right. $[H^+]$ and $[OH^-]$ increases by the same extent. pH will become lower as there are more $[H^+]$. $pH = -\lg[H^+]$

Ans: **A**

Note: pOH will also become lower. pK_w is a smaller value at higher temperature.
$pH + pOH = pK_w$, $pK_w = 14$ at 25 °C.
$pK_w = 14.5$ at 10 °C
$pK_w = 13.5$ at 40 °C

15) We will need a buffer solution containing a weak base and its conjugate acid to maintain pH at about 10.

Ans: **A**

16) AgC*l* is more soluble than AgBr, meaning ΔG_1 is more negative than ΔG_3.
Option 4 is true
$\Delta G_2 = \Delta G_4$ as formation of complex ion is due to the following equation and unaffected by the identity of the halide ions.

$$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons [Ag(NH_3)_2]^+(aq)$$

Option 2 is true and option 3 is false.

Since $\Delta G_2 = \Delta G_4$, Option 1 is true.

Ans: **A**

17) [O] $2I^- \rightarrow I_2 + 2e^-$
[R] $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$
$E^{\ominus}_{cell} = +1.77 - (+0.54) = +1.23V$ (reaction is spontaneous)
Brown I_2(aq) is produced. No effervescence as the products are I_2(aq) and H_2O

Ans: **B**

18) Option A is correct, $[Cu(NH_3)_4(H_2O)_2]^{2+}$ can also be represented as $[Cu(NH_3)_4]^{2+}$, a dark blue solution.

Option B is wrong, NH_3 complex of Cu^{2+} is $[Cu(NH_3)_4]^{2+}$, a dark blue solution, NOT ppt.

Option C is wrong, $Cu(OH)_2$ is a pale blue precipitate, NOT solution

Option D is wrong, $[Cu(H_2O)_6]^+C\mathit{l}^-$ is CuC*l*, a white precipitate as Cu^+ has an electronic configuration of $3d^{10}$, hence it does not allow d-d transition and hence it would appear colourless solution/white solid.

Ans: **A**

19) Reaction A is redox reaction and ligand exchange reaction. $Cu + Cu^{2+} + 4C\mathit{l}^- \rightarrow 2[CuC\mathit{l}_2]^-$
Oxidation state of Cu changes from 0 (in Cu) and +2 (in Cu^{2+}) to +1 in $[CuC\mathit{l}_2]^-$.

Reaction B is redox reaction. $Cu^{2+} + Zn \rightarrow Cu + Zn^{2+}$

Reaction C is ligand exchange reaction. $[Cr(H_2O)_6]^{3+} + SO_4^{2-} \rightleftharpoons [Cr(H_2O)_5SO_4]^+ + H_2O$

Reaction D is a redox reaction. $MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$

Ans: **C**

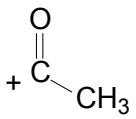
20) Transition metals have high density due to close packing of heavy atoms of small size.
Atomic and ionic radii in the Data Booklet shows the V is smaller in size than Ca.

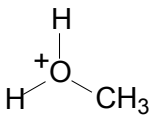
Options 1&2 suggest there are stronger repulsion for V, this would have implied a larger radius for V than C.

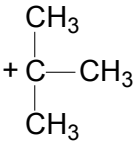
Only option 3 explains the smaller size of Vanadium as compared to Calcium.

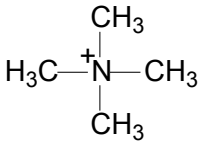
Ans: **D**

21)









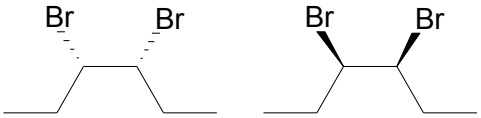
Ans: **C**

22) Tollens' reagent can oxidize aldehydes to $R-COO^-$.

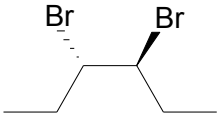
Ans: **A**

23) Note: The initial way of drawing DOES NOT allow us to see the internal plane of symmetry.

Compounds 3 & 4 can also be drawn as the followings.



Compound 2 does not have an internal plane of symmetry.



All four compounds contain chiral carbon. However, compounds 3 & 4 are meso compound with an internal plane of symmetry, rotation of plane−polarised light by each chiral carbon gets cancelled out completely.

Ans: **B**

24) 4 phenol groups and 1 carboxylic acid group would react with 5 mol of NaOH(aq).
1 ester group would react with 1 mol of NaOH(aq) with heating.
Hence, 1 mol of rosmarinic acid reacts with 6 mol of NaOH(aq) with heating.

Ans: **D**

25) Option 1 is correct. In S_N2 mechanism, the nucleophile can only attack from the opposite of the leaving group. This causes the inversion of stereo configuration of the chiral carbon.

Option 2 is correct. In S_N1 mechanism, a trigonal planar carbocation is produced after the first step. In step 2, the nucleophile can attack from either side of the trigonal planar carbocation with equal probability, giving rise to a racemic mixture containing equal amount of the two enantiomers.

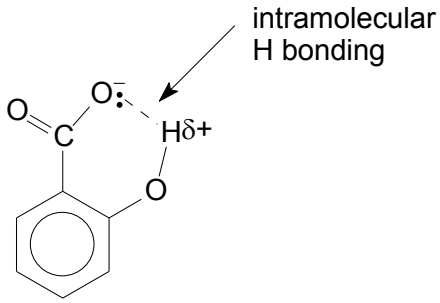
Option 3 is correct. Tertiary chloroalkanes undergo S_N1 mechanism and involve a carbocation that is stabilized by three electron donating alkyl groups.

Ans: **A**

26) $HA \rightleftharpoons H^+ + A^-$

The conjugate base of 2−hydroxybenzoic acid is stabilized by intramolecular H−bonding due to the close proximity of the $–COO^-$ and –OH group. This cause the dissociation equilibrium to favour the forward reaction and release more H^+, giving rise to smaller pK_a value.

For 4-hydroxybenzoic acid, intramolecular H−bonding is not possible.

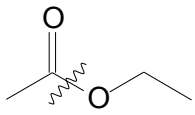


Ans: **B**

27) Reaction 2 is wrong. $LiAlH_4$ cannot reduce alkene. (electron rich C=C repels H^- from $LiAlH_4$)
Reaction 3 is wrong. H_2, Ni cannot reduce carboxylic acid. (−COOH is resonance stabilized, it can only be reduced by $LiAlH_4$)

Ans: **B**

28) The hydrolysis of ester involves the breaking of the C−O bond in ester as shown. δ+ C gains ^{18}OH from $H_2{}^{18}O$ and δ− O gains H from H_2O.

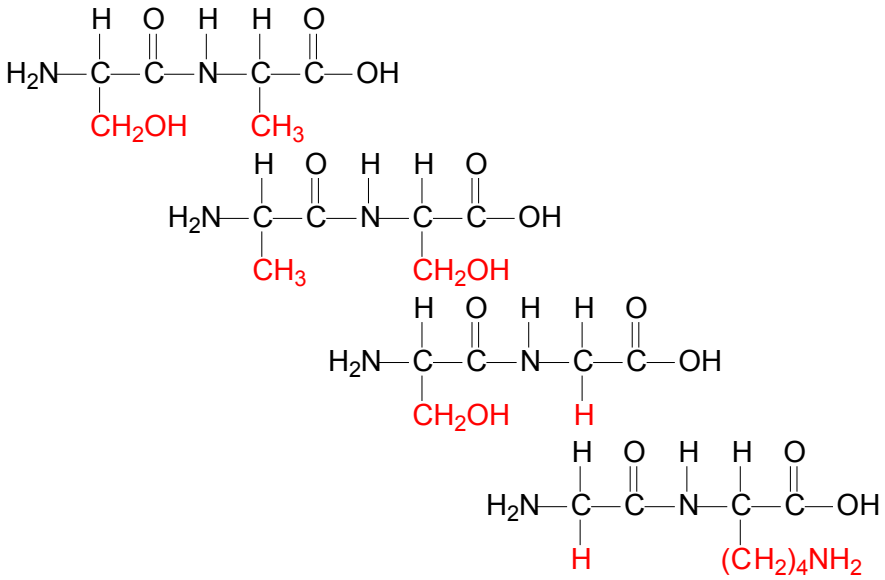


Ans: **C**

29) Amide undergoes alkaline hydrolysis to give $R−COO^-$ and amine. (Hydrolysis produces RCOOH, which undergoes further acid-base reaction with NaOH(aq) to give $RCOO^-Na^+$)

Ans: **D**

30)



Using the “stacking” method(by matching the R group of amino acid from each dipeptide fragment), we can deduce that the pentapeptide is D.

Note: We can also check that D is the only pentapeptide that can undergo partial hydrolysis to give the four dipeptides.

Ans: **D**

2018 A level Paper 2 suggested answers

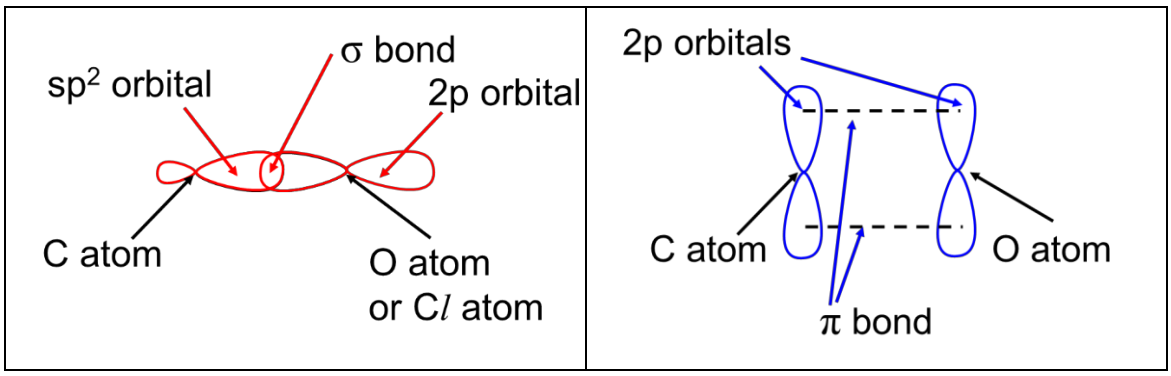
1 (a) (i)

	similarity	difference
1s and 2s orbital	1s and 2s orbital are spherical in shape each orbital can hold a maximum of 2 electrons	2s orbital is larger than 1s orbital 2s orbital is at higher energy level than 1s orbital
2s and 2p orbital	each orbital can hold a maximum of 2 electrons	2s orbital is spherical in shape 2p orbital is dumb-bell shape 2p orbital is at higher energy level than 2s orbital

1 (a) (ii) VSEPR theory states that electron pair regions around the central atom arrange themselves to be as far apart as possible to minimise mutual repulsion.

There are 3 bond pair regions and 0 lone pair regions around the C atom of phosgene. The shape is trigonal planar.

1 (a) (iii)



Note:
C atom in phosgene is sp^2 hybridized. Hybrid orbitals are used for formation of σ bond.
O and C*l* atoms are terminal atom, they uses 2p orbital of O or 3p orbital of C*l* for formation of σ bond.

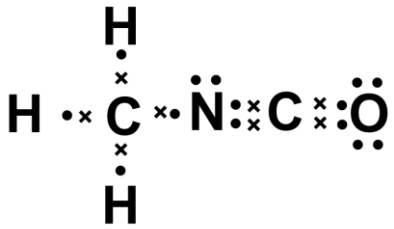
1 (b) (i) Electronegativity is the measure of the ability of an element to attract a shared pair of electrons in a covalent bond towards itself.

1 (b) (ii) Phosgene molecules have intermolecular forces of instantaneous dipole−induced dipole(id−id) and permanent dipole−permanent dipole(pd−pd).

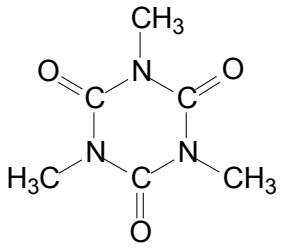
Id−id arises due to random movement of electrons giving rise to uneven distribution of electron cloud of a molecule, creating a instantaneous dipole. The instantaneous dipole induces a similar dipole moment on adjacent molecules.

Pd−pd arises due to overall net dipole moment of the molecule. Electronegativity differences between the C=O and C−C*l* creates a dipole moment for the bonds, the dipoles are not cancelled out completely. The $\delta+$ C atom on a phosgene molecule would have pd−pd interaction with $\delta-$ O or C*l* atom on another phosgene molecule.

1 (c) (i)



1 (c) (ii)



1 (c) (iii) **A** is a much larger molecule than methyl isocyanate, the larger electron cloud is more easily distorted and instantaneous dipoles are more easily induced. More energy is required to overcome the significantly stronger instantaneous dipole−induced dipole (id−id) interactions between molecules of **A** as compared to the permanent dipole−permanent dipole and id−id forces between methyl isocyanate molecules. Hence **A** has a higher boiling point and exists as a solid at room temperature.

2 (a) Dynamic equilibrium is when the rate of forward reaction is the same as rate of backward reaction, and there is no net change in the concentrations of reactants and products.

2 (b) $K_p = \dfrac{(P_{NO})^2}{(P_{N2})(P_{O2})}$

2 (c) As temperature increases, it is observed that the value of K_p increases as well, showing that position of equilibrium shifted to the right. By Le Chatelier's Principle, higher temperature would favour endothermic reaction.
Hence we can conclude the forward reaction is endothermic and its enthalpy change has a positive sign.

2 (d) (i) When volume of container increases from 1 dm^3 to 5 dm^3, the total pressure of the equilibrium system decreases 5 times. There is no change in composition of the reaction mixture as the number of gas particles remain the same after the reaction.

Hence the partial pressure of the individual gases would decrease by 5 times.

2 (d) (ii) Value of K_p does not change and it is only affected by temperature.

2 (e) A catalyst speeds up the rate of reaction by providing an alternative reaction pathway of lower activation energy. It allows the equilibrium to be attained faster by increasing both the rate of forward and backward reaction by the same extent.

However catalyst does not affect the position of equilibrium. Hence the value of K_p does not change.

2 (f) (i) Extremely small value of K_p at 298K shows that the forward reaction is not favourable.
This means that ΔG is likely to be a large, positive value.

Note: $\Delta G^{\ominus} = -RT\ln K$

2 (f) (ii) A negative value of ΔG shows that the forward reaction is spontaneous at 298K.
Hence the ratio of [products]/[reactants] at equilibrium will be greater than 1.

Note: $\Delta G^{\ominus} = -RT\ln K$

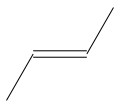
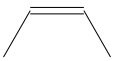
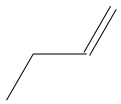
3 (a) (i) Nucleophilic substitution

3 (a) (ii) 1. Heat halogenoalkane **B** with NaOH(aq)
2. Cool and followed by excess HNO_3(aq)
3. Add $AgNO_3$(aq)

If **B** is chloroalkane, a white precipitate of AgC*l* will be observed. The white ppt can dissolves in excess NH_3(aq)

3 (b) (i) Ethanolic NaOH and heat.

3 (b) (ii)

D	**E**	**F**
		
trans−but−2−ene	cis−but−2−ene	but−1−ene

Note: Must use skeletal formula

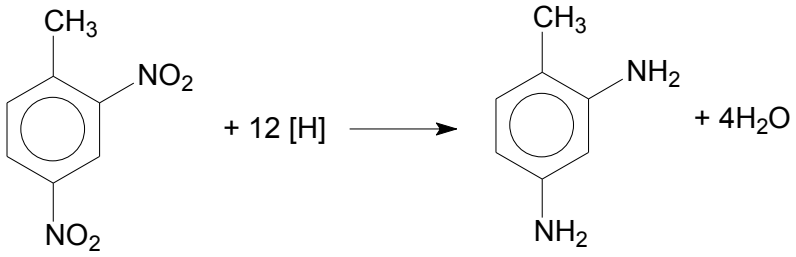
3 (b) (iii) All the compounds contain C=C with restricted rotation.
Compounds **D** & **E** contain 2 different groups bonded to each C of the C=C.
Cis and trans isomers have different spatial arrangement of the bonds.

Compound **F** contains 2 identical group bonded to one of the C in C=C. Hence it cannot exhibit stereoisomerism.

4 (a) (i) step 1 : conc HNO_3, conc H_2SO_4, 30 °C

step 2: 1) Sn, conc HC*l*, heat under reflux
2) followed by excess NaOH(aq)

4 (a) (ii)



4 (a) (iii) Positional isomerism.

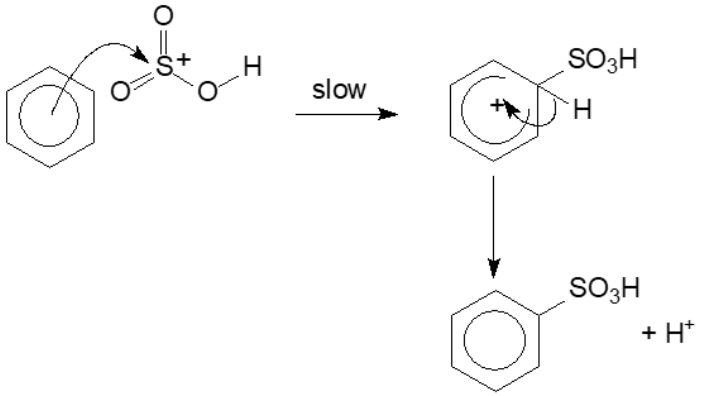
The isomers have same molecular formula but the substituents are at different position of the molecule.

4 (a) (iv) $C_9H_6N_2O_2$

4 (b) (i) The $–CH_3$ group of methylbenzene is 2,4−directing. The formation of **H** involves a less stable intermediate and hence formation of **H** is not favourable.

4 (b) (ii) During the mechanism of electrophilic substitution, the presence of $–CH_3$ group in methyl benzene causes steric hindrance when the electrophile is attacking position 2 of the methylbenzene. Hence the electrophilic substitution at position 2 is less favoured as compared to position 4.

4 (c) (i)



4 (c) (ii) Benzene rings prefer to undergo substitution rather than addition due to the resonance stabilisation from delocalisation of the π−electron cloud.
After substitution reaction, the product retains the resonance stability. However after addition reaction, the resonance stability is loss.

4 (c) (iii) Reactivity with fuming sulfuric acid: **K** < benzene < methylbenzene.

The $-CH_3$ group is an electron donating group that increases the electron density of the π−electron cloud of the benzene ring, making it more susceptible to electrophilic substitution as compared to benzene.

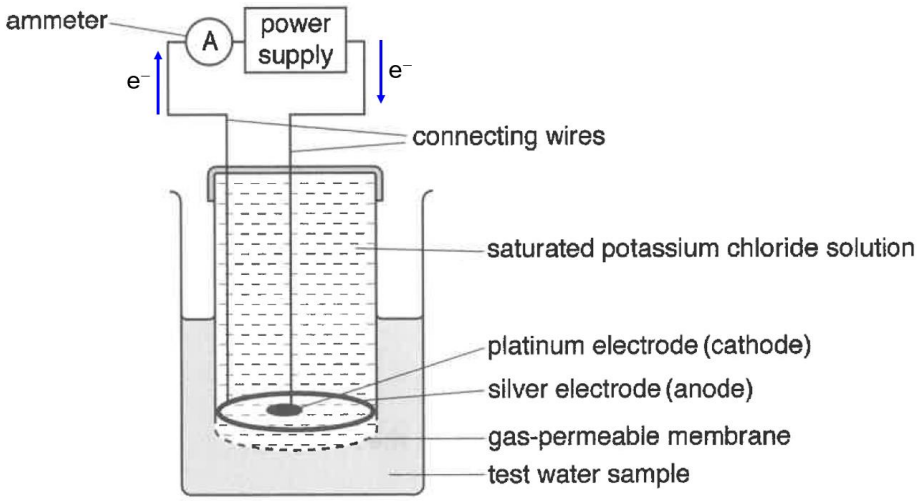
The $-COCH_3$ group in K is an electron withdrawing group that decreases the electron density of the π−electron cloud of the benzene ring, making it less susceptible to electrophilic substitution as compared to benzene.

5 (a) (i) $E^{e}_{cell} = +1.23 - (-0.22) = +1.45V$

Electron will flow when external voltage (+1.45V) is greater than E_{cell}. This means that E_{cell} is less than +1.45V.
The measurement is likely to be under non-standard condition. For example, the concentration of dissolved O_2 is less than 1 mol dm^{-3} or pressure is not 1bar.

5 (a) (ii) Reduction occurs at the platinum electrode. The oxidation state of oxygen decreases from 0 (in O_2) to −2 (in H_2O).

5 (a) (iii)



Note: Anode loses electron and cathode gains electron.

5 (a) (iv) In one minute,
$Q = It = n_eF$
$(0.85)(60) = n_e(96500)$
$n_e = 0.0005284$ mol

$n_{O2} = \frac{1}{4} \times 0.0005284 = 0.0001321$ mol
rate of reaction $= 0.0001321 \times 6.02 \times 10^{23} = 7.95 \times 10^{19}$ O_2 molecule per minute

5 (a) (v) The sign of ΔS is "−" as there is a decrease in entropy due to decrease in the amount of gaseous molecules.

5 (a) (vi) This is to ensure that O_2 dissolved in the water sample is constantly difussing through the membrane after O_2 is used up during the electrolysis.

5 (a) (vii) Silver chloride, AgC*l*(s) would be formed at the silver electrode.

5 (a) (viii) KC*l* solution is kept saturated to ensure that [Cl^-] is in high concentration. During the electrolysis reaction, the decrease in [Cl^-] would be insignificant and hence the electrode potential would remain approximately constant.

If a much lower concentration of Cl^- was used, position of equilibrium for $AgCl + e^- \rightleftharpoons Ag + Cl^-$ would shift to the right, causing E(AgC*l*//Ag) to increase. This would cause E_{cell} to decrease.

5 (b) (i) Manganese exhibits variable oxidation state during these reactions.

5 (b) (ii) $1s^22s^22p^63s^23p^63d^4$

5 (b) (iii)
Amount of $S_2O_3^{2-} = \frac{11.20}{1000} \times 0.0100 = 0.000112$ mol
Mole ratio of $O_2 : Mn(OH)_3 : I_2 : S_2O_3^{2-}$ = ½ : 2 : 1 : 2
Amount of $O_2 = \frac{1}{4} \times 0.000112 = 0.000028$ mol
Concentration of dissolved $O_2 = \frac{0.000028}{(100/1000)} = 0.00028$ mol dm^{-3}

5 (c) (i) Mass of O_2 escaped = 8.24 – 6.93 = 1.31 mg
Amount of O_2 escaped $= \frac{(1.31/1000)}{32.0} = 0.0000409$ mol

5 (c) (ii) Amount of O_2 escaped from 1 dm^3 of distilled water = 0.00004094 mol
Using pV = nRT,
$p(1\times10^{-3}) = 0.00004094\times8.31\times(35+273)$
p = 104.8 Pa (partial pressure of 0.00004094 mol of O_2)

P_{O2} total $= 103.4 + \frac{104.8}{1000} = 103.5$ kPa (1d.p.)

5 (c) (iii) Water vapour also contributes to the total pressure in the container.
At 35 °C, $P_{water\ vapour}$ would also be greater than that of 25 °C.
Hence, the actual value of the pressure recorded is slightly higher than the calculated value as $P_{total} = P_{O2} + P_{water\ vapour}$

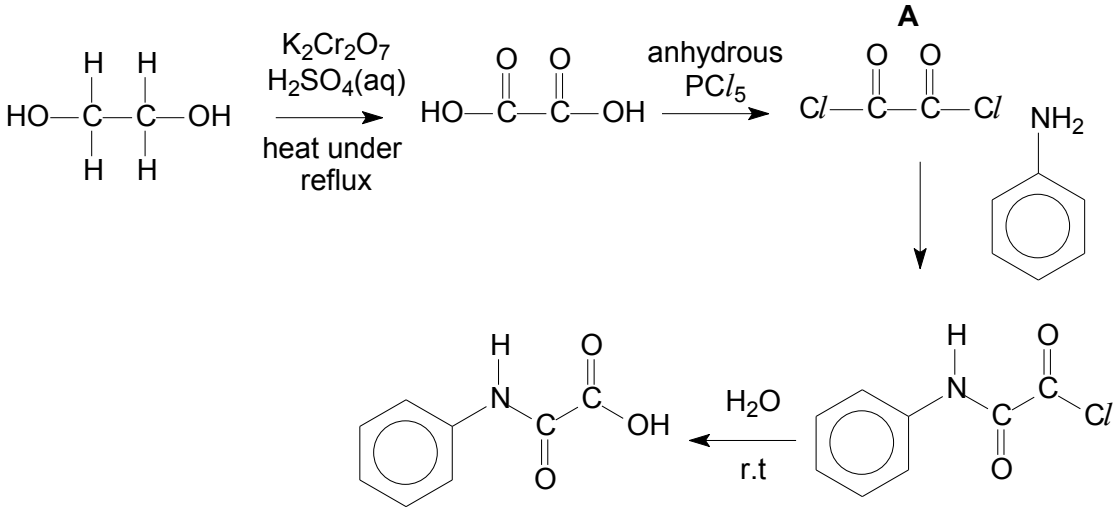
2018 A level Paper 3 suggested answers

1 (a) Thermal stabilities of Group 2 carbonates increases down the group.
Down the group, the charge of cation remains as +2 but the ionic radius increases.
This lead to a decrease in charge density and the cations have decreasing polarizing power.
Down the group, the electron cloud of CO_3^{2-} is polarized to a smaller extent, and hence the C−O covalent bond is weakened to a lesser extent.
Down the group, more energy is required to overcome the increasingly stronger C−O covalent bond during thermal decomposition and hence the thermal stability increases.

1 (b) (i) $CaCO_3 + 2NH_4(C_8H_6NO_3) \rightarrow Ca(C_8H_6NO_3)_2 + (NH_4)_2CO_3$

1 (b) (ii) Let solubility of $Ca(C_8H_6NO_3)_2$ be s mol dm^{-3}
$K_{sp} = [Ca^{2+}][\ C_8H_6NO_3^-]^2 = (s)(2s)^2$
$1.75 \times 10^{-5} = 4s^3$
s = 0.01636 mol dm^{-3}
concentration in g dm^{-3} = 0.01636 × (40.1 + 12.0×16+1.0×12+14.0×2+16.0×6)
= 6.02 g dm^{-3}

1 (c)

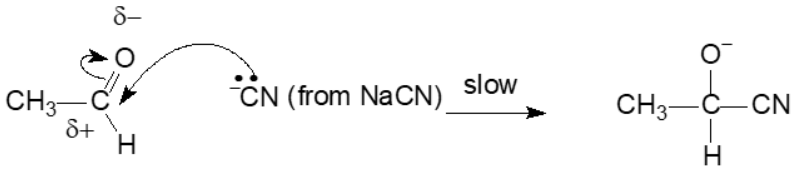


Note: Hot acidified $KMnO_4$ will oxidized $HOCH_2CH_2OH$ to CO_2 and H_2O.

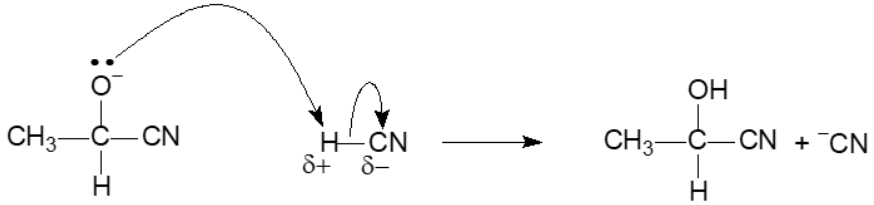
1 (d) In $RCONH_2$, the lone pair of electrons on N is **delocalized significantly to adjacent C=O (highly electronegative O atom)**, and it is **not available** to accept H^+.
Hence amide is **neutral**.

1 (e) (i) Nucleophilic addition

Step 1: Nucleophile ($^-$CN from NaCN) reacts with δ+ C of C=O to give anion intermediate

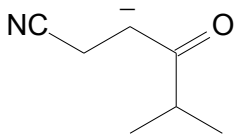


Step 2: HCN reacts with anion intermediate to give cyanohydrin and regenerate $^-$CN

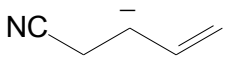


1 (e) (ii) **B** is not formed as the nucleophile CN^- is less likely to attack carbonyl C due to steric hindrance by the neighboring groups.

During formation of **C**, the nucleophile CN^- would preferentially attack the C=C as there is less steric hindrance, and the intermediate formed is also resonance stabilized by C=O which contains an electronegative O atom.



1,3−butadiene does not undergo nucleophilic addition as the intermediate formed is less stable due to absence of electronegative O atom.



2 (a) (i) Oxidation number of C increases from −4 (in CH_4) to +2 (in HCN)
Oxidation number of N remains as −3 (in both NH_3 and HCN)
Oxidation number of O decreases from 0 (in O_2) to −2 (in H_2O)

2 (a) (ii) $\Delta H_{rxn} = \Sigma$ (BE of reactants) $- \Sigma$ (BE of products)
= [8×BE(C−H) + 6×BE(N−H) + 3×BE(O=O)] – [2×BE(C−H) + 2×BE(C≡N) + 12×BE(O−H)]
= [8×410 + 6×390 + 3×496] – [2×410 + 2×890 + 12×460]
= 7108 – 8120
= −1012 kJ mol^{-1}
≈ −1010 kJ mol^{-1} (3s.f.)

2 (a) (iii)
$$pH = pK_a + \lg\frac{[CN^-]}{[HCN]}$$
$$10 = -\lg(7.2\times10^{-10}) + \lg\frac{[CN^-]}{[HCN]}$$
$$0.8573 = \lg\frac{[CN^-]}{[HCN]}$$
$$\frac{[CN^-]}{[HCN]} = 10^{0.8573} = 7.2$$

2 (b) (i) $KMnO_4$ in acidic medium
$E^{\ominus}_{cell} = +1.52 - (+0.37) = +1.15V > 0$ (reaction is spontaneous)
$2MnO_4^- + 6H^+ + 10HCN \rightarrow 5C_2N_2 + 2Mn^{2+} + 8H_2O$

Note: Can use any oxidizing agent with $E^{\ominus} > +0.37V$

2 (b) (ii)

sp hybridization

2 (b) (iii) C≡N bond is polar with the dipole towards N atom. However due to the linear arrangement of atoms in cyanogen, the molecule has no overall dipole moment and is non-polar.

2 (c) (i) Nucleophilic substitution

2 (c) (ii) Rate = k[C*l*CN][H_2O]
as water is present in large excess and its concentration would remain approximately constant.
Rate = k_2[C*l*CN] where k_2 = k[H_2O]
Hence the units of k_2 is s^{-1}.

2 (c) (iii) H_2O is acting as a nucleophile in reaction 2 as it uses its electron rich O atom to attack the δ+ C in C−C*l*.

2 (c) (iv) Rate = k_3[C*l*CN][OH^-]

2 (c) (v) $[C\mathit{l}CN] = \frac{0.010}{(100/1000)} = 0.100$ mol dm^{-3}
$[OH^-] = 10^{-4}$ mol dm^{-3} at pH 10.0

rate 2 = $5.1 \times 10^{-7} \times 0.100 = 5.1 \times 10^{-8}$ mol dm^{-3} s^{-1}
rate 3 = $4.2 \times 0.100 \times 10^{-4} = 4.2 \times 10^{-5}$ mol dm^{-3} s^{-1}

rate 2 : rate 3 = 1 : 824 or 0.00121 : 1

2 (d) We can follow the rate of reaction by titrimetric method through samplings of the reaction mixture.

Procedures for titrimetric method through samplings of the reaction mixture

1) Add 90 cm^3 of water to a beaker containing 10 cm^3 of C*l*CN. Start the stop watch and swirl the beaker a few times to ensure even mixing. (Can propose any reasonable volumes)

2) Use a 10 cm^3 pipette to transfer 10 cm^3 of reaction mixture into a conical flask.

3) Prepare 50 cm^3 of ice cold water and add quickly to the reaction mixture at t = 5mins.

4) Titrate the resulting solution with NaOH(aq) of suitable concentration using thymolphthalein indicator until the solution turns pale blue. Record the initial and final burette readings.

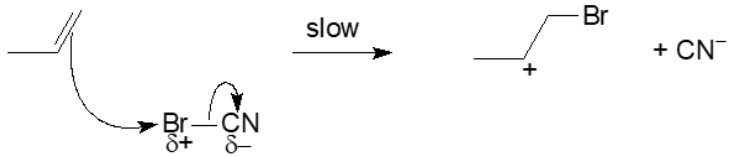
5) Repeat step 2 to 4 to obtain 6 further readings with quenching at t = 10,15,20,25,30,35 mins.

Analysis of results

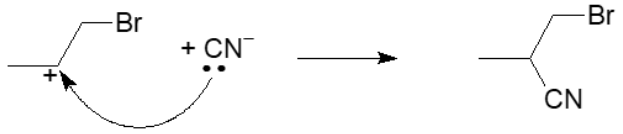
1) Plot a graph of vol. of NaOH used vs time.
2) Since vol. of NaOH used is directly proportional to the concentration of the acidic products in the reaction mixture, the graph would be similar to [product] vs time graph.
3) We can obtain the $t_{½}$ of the reaction from the vol. of NaOH vs time graph.
4) Since it is a first order reaction, we can find k_2 using the relationship $t_{½} = \frac{\ln 2}{k_2}$

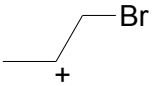
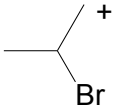
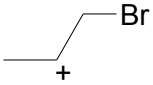
2 (e) Electrophilic addition

Step 1:



Step 2:



In step 1 of the reaction mechanism, the carbocation  (containing greater number of electron donating alkyl group) is more stable than carbocation  . Hence greater proportion of  is formed, leading to **D** being formed in a great amount than **E**

3 (a) (i) Lewis bases are electron pair donor. Amine can donate electron pair to H^+ in an acid-base reaction.

$CH_3NH_2 + H^+ \rightarrow CH_3NH_3^+$

3 (a) (ii) In gas phase, base are electron pair donor. (not H^+ acceptor as there is no H^+ in gas phase)
Basicity of methylamine < dimethylamine < trimethylamine
Alkyl groups are electron donating groups that intensify the electron density on N atom of the amine. The greater number of electron donating groups would base the N atom more electron rich and trimethylamine is the strongest base in the series.

3 (b) (i) $$K_b = \frac{[CH_3CH_2NH_3^+][OH^-]}{[CH_3CH_2NH_2]}$$

3 (b) (ii) Ethylamine is a stronger base than ammonia as the electron donating alkyl group increases the electron density on the N atom, making ethylamine more likely to accept an H^+ than ammonia.

Both phenylamine and 4−chlorophenylamine are weaker base than ammonia as the lone pair of electron on N atom is delocalised into the π electron cloud of the benzene ring, decreasing the electron density on the N atom, making phenylamine and 4−chlorophenylamine less likely to accept an H^+ than ammonia.

4−chlorophenylamine is a weaker base than phenylamine as the presence of additional electron withdrawing –C*l* group further decreases the electron density on the N atom, making 4−chlorophenylamine less likely to accept an H^+ than phenylamine.

3 (c) (i) Ligand exchange reaction
$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightleftharpoons [Cu(NH_3)_4]^{2+} + 6H_2O$

Note: ligand exchange reaction is REVERSIBLE

3 (c) (ii) Ethane−1,2−diamine acts as ligand and displaces NH_3 from $[Cu(NH_3)_4]^{2+}$ complex

$[Cu(NH_3)_4]^{2+} + 2\ \textbf{\textit{en}} \rightleftharpoons [Cu(\textbf{\textit{en}})_2]^{2+} + 4NH_3$

Note: ***en*** is a bidentate ligand.

3 (d) Pentane, butylamine and propanoic acid are covalent compounds with simple molecular structure, weak intermolecular forces of attractions are present between the molecules.
Glycine exist as zwitterions, it is an ionic compound with ionic lattice structure, strong ionic bonds are present between the zwitterions.
Hence a much larger amount of energy is required to overcome the stronger ionic bonds between zwitterions of glycine during melting, hence it has a high melting points.

Pentane molecules only have instantaneous dipole−induced dipole (id−id) forces of attraction while both butylamine and propanoic acid have id−id and H−bonding between their molecules.
Less energy is required to overcome the id−id forces of attraction between pentane molecules during melting as compared to the stronger intermolecular forces between butylamine and propanoic acid molecules. Hence Pentane has the lowest melting point.

Both CH_3CH_2COOH and $CH_3CH_2CH_2CH_2NH_2$ has the same average number of H−bonding. The O−H bond in propanoic acid is more polar than N−H bond in butylamine, more energy is overcome the stronger H−bonding between propanoic acid molecules during melting, hence propanoic acid has a higher melting point than butylamine.

4 (a) (i) Reactivity of halogens as oxidising agent decreases down the group.
The $E^{\ominus}$ value for (X_2/X^-) becomes less positive down the group, this means that I_2 undergoes reduction less readily as compared to Cl_2. Hence Cl_2 is a stronger oxidising agent than I_2.

4 (a) (ii) Cl_2 can oxidise Fe^{2+} to Fe^{3+} but I_2 is not able to.

$Cl_2 + 2Fe^{2+} \rightarrow 2Cl^- + 2Fe^{3+}$
$E^{\ominus}_{cell} = +1.36 - (+0.77) = +0.59V$ (reaction is spontaneous)

$I_2 + 2Fe^{2+} \rightarrow 2I^- + 2Fe^{3+}$
$E^{\ominus}_{cell} = +0.54 - (+0.77) = -0.23V$ (reaction is not spontaneous)

4 (b) (i) $MgCl_2$ dissolves in water to give a colourless solution of pH 6.5.
$MgCl_2(s) + 6\ H_2O(l) \rightarrow [Mg(H_2O)_6]^{2+}(aq) + 2\ Cl^-(aq)$
$[Mg(H_2O)_6]^{2+}(aq) \rightleftharpoons [Mg(H_2O)_5(OH)]^+(aq) + H^+(aq)$

$AlCl_3$ dissolves in water to give a colourless solution of pH 3.
$AlCl_3(s) + 6\ H_2O(l) \rightarrow [Al(H_2O)_6]^{3+}(aq) + 3\ Cl^-(aq)$
$[Al(H_2O)_6]^{3+}(aq) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H^+(aq)$

$SiCl_4$ dissolves in water to give a colourless solution of pH 1, white precipitate of SiO_2 would be formed.
$SiCl_4(l) + 2\ H_2O(l) \rightarrow SiO_2(s) + 4\ HCl(aq)$

4 (b) (ii) $MgCl_2$ is an ionic compound with ionic lattice structure that dissolves in water to give $[Mg(H_2O)_6]^{2+}$, which undergoes slight hydrolysis to give some H^+.

$SiCl_4$ is a covalent compound with simple molecular structure. $SiCl_4$ undergoes complete hydrolysis in water to give $HCl(aq)$, a strong acid, that dissociates fully into $H^+(aq)$.

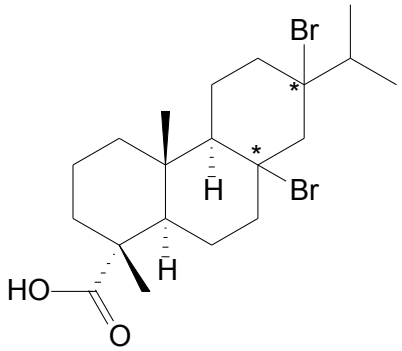
4 (c) (i) $K_c = \dfrac{[HXO][X^-][H^+]}{[X_2]}$ units = $mol^2\ dm^{-6}$

4 (c) (ii)

	I_2	+ $2OH^-$	⇌	IO^-	+ I^-	+ H_2O
Initial / mol dm^{-3}	0.1	0.50		0	0	-
Change / mol dm^{-3}	–0.097	-0.097×2		+0.097	+0.097	-
Eqm / mol dm^{-3}	0.003	0.306		0.097	0.097	-

$$K_c = \frac{[IO^-][I^-]}{[I_2][OH^-]^2} = \frac{[0.097][0.097]}{[0.003][0.306]^2} = 33.5 \text{ mol}^{-1} \text{ dm}^3$$

4 (d) (i)



2 additional chiral centres are formed.

4 (d) (ii) KC*l* is an ionic compound with ionic lattice structure, strong ionic bonds are present between the K^+ and Cl^- ions. Large amount of energy is required to overcome the strong ionic bond during melting and boiling. Hence KC*l* has a high boiling point and it is not volatile.

4 (d) (iii) Molecular formula of tetranitratoethane is $C_2H_2N_4O_{12}$.

Percentage by mass of oxygen = $\frac{16.0\times12}{12.0\times2+1.0\times2+14.0\times4+16.0\times12} \times 100\% = 70.1\%$

4 (d) (iv) $7C + 2C_2H_2N_4O_{12} \rightarrow 11CO_2 + 2H_2O + 4N_2$

4 (d) (v) $7C(s) + 2C_2H_2N_4O_{12}(s) \rightarrow 11CO_2(g) + 2H_2O(g) + 4N_2(g)$

There is a large increase in the number of gas molecules after the reaction. Gases have a much higher entropy as compared to solid. Hence the entropy change is a large, positive value.

The reaction is exothermic, the increase in temperature would cause the molecules to move with higher kinetic energy. This also cause the entropy change to be a large positive value.

5 (a) (i) In the **presence of ligands, electronic repulsion** between lone pair electrons of ligands and the d orbitals electrons causes the **degenerate d-orbitals** of the transition element ion **to split into two different energy levels with a small energy gap, ∆E. (d splitting)**

Electrons in the **lower energy d-orbitals** can absorb light of a certain wavelength with energy corresponding to the energy gap, ∆E, and be **promoted to the higher energy d-orbitals (d-d transition).**

The colour observed is the **complementary colour of the wavelength of light absorbed**.

5 (a) (ii) V^{3+} : $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2$
V^{5+} : $1s^2 2s^2 2p^6 3s^2 3p^6$

V^{3+} contains partially filled d subshell and hence d−d transition is possible, giving rise to a coloured solution.

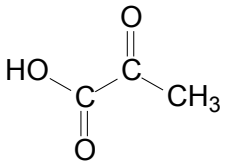
V^{5+} has empty d subshell, d−d transition is not possible and hence no light is absorbed and the solution appears colourless.

5 (b) (i) $VO_3^- + 4H^+ + e^- \rightleftharpoons VO^{2+} + 2H_2O$
$VO_2^+ + 2H^+ + e^- \rightleftharpoons VO^{2+} + H_2O$

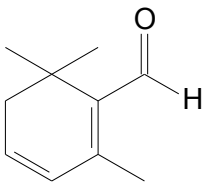
An increase in pH would cause $[H^+]$ to decrease.
Position of equilibrium would shift to the left for both equilibrium, decreasing their oxidizing ability.
Position of equilibrium for VO_3^-/VO^{2+} would shift to the left more significantly as compared to the VO_2^+/VO^{2+} equilibrium.
At pH 7, VO_2^+ would be a stronger oxidant.

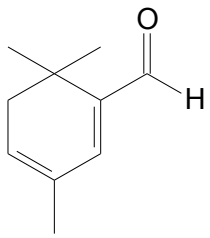
5 (b) (ii) Reaction of VO_3^- and SO_2
$2VO_3^- + 4H^+ + SO_2 \rightarrow 2VO^{2+} + 2H_2O + SO_4^{2-}$
$E^{\ominus}_{cell} = +1.00 - (+0.17) = +0.83V$ (reaction is spontaneous)

5 (c) (i)



5 (c) (ii)

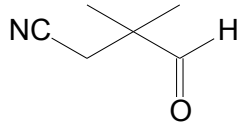
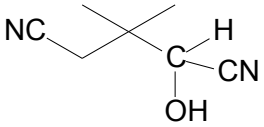
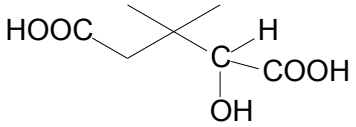




5 (c) (iii) $C_{10}H_{20}O$

5 (d) (i) **J** does not contain phenol, carboxylic acid, aldehyde, ketone and alkene functional groups.
J contains alcohol functional group.

5 (d) (ii)

H	**J**	**K**
		

5 (d) (iii) step 1: ethanolic KCN, heat
step 3: H_2SO_4(aq), heat (any strong acid)
step 4: $KMnO_4$, H_2SO_4(aq), heat OR $K_2Cr_2O_7$, H_2SO_4(aq), heat