H2 Chemistry TYS 2023 suggested answers

Paper 1 Answer Key

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

1 Ans: B

	Nucleon number	Proton	Neutron	Electron
Nd^{2+}	145	60	85	58
Pm^{3+}	145	61	84	58

2 Ans: C

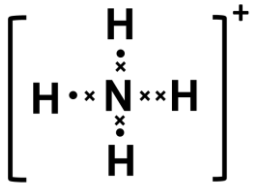
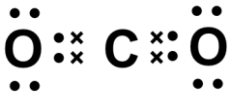
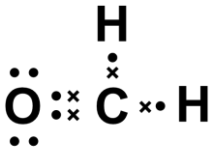
Ionic compound has a large electronegativity difference between the elements while covalent compound has small difference in electronegativity.

A	X and C*l* Electronegativity difference = 1.8	Y and O Electronegativity difference = 2.6
B	X and O Electronegativity difference = 2.3	Y and O Electronegativity difference = 2.6
C	Y and C*l* Electronegativity difference = 2.1	Z and O Electronegativity difference = 1.7
D	Z and C*l* Electronegativity difference = 1.2	X and C*l* Electronegativity difference = 1.8

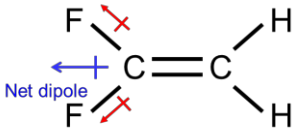
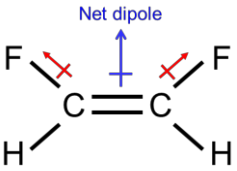
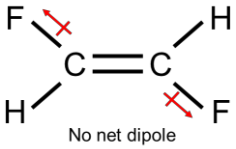
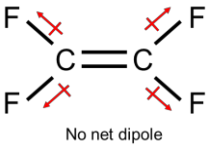
3 Ans: C

Both CH_3Cl and CH_3Br are covalent compound with simple molecular structure. Both are polar molecules with instantaneous dipole-induced dipole (id-id) and permanent dipole-permanent dipole (pd-pd) between molecules. As CH_3Br has a larger electron cloud size, its electron cloud is more easily distorted, and dipoles are more easily induced. The strength of id-id is stronger for CH_3Br, leading to its larger boiling point.

4 Ans: D

 NH_4^+ 4 single bonds, 8 shared e^-	 CO_2 2 double bonds, 8 shared e^-	 HCHO 1 double bond + 2 single bonds 8 shared e^-

5 Ans: B

 1,1-difluroethene	 cis-1,2-difluroethene
 trans-1,2-difluroethene	 tetrafluroethene

6 Ans: D

Period 3 elements with only one orbital in the outermost shell which contains just one electron:
1) Na : [Ne] $3s^1$
2) A*l* : [Ne] $3s^2$ $3p^1$
3) C*l* : [Ne] $3s^2$ $3p^5$ (one of the 3p orbital contains only 1 e^-)

Period 3 elements with only one orbital in the outermost shell which contains a pair of electrons:
1) Mg : [Ne] $3s^2$
2) A*l* : [Ne] $3s^2$ $3p^1$
3) Si : [Ne] $3s^2$ $3p^2$ (e^- occupies the p orbital singly first)
4) P : [Ne] $3s^2$ $3p^3$ (e^- occupies the p orbital singly first)

7 Ans: A

Statement 1 is **correct**. Going down Group 2, $E^{e}(M^{2+}/M)$ becomes more negative. This shows that Ba(s) undergoes oxidation more readily than Mg(s). Hence Ba(s) is a stronger reducing agent than Mg(s).

Statement 2 is **correct**.
Down the group, cationic radius increases and charge density of M^{2+} decreases. This leads to a **decrease in polarising power of the cations**.
The **electron cloud of the CO_3^{2-}** anion is being **distorted to a smaller extent** down the group, **decreasing the extent of weakening of C–O bonds within the CO_3^{2-}** anion.
More energy is required to break the C–O bonds within the CO_3^{2-} anion.
Therefore, **thermal stability of the Group 2 carbonates increases** down the group.

Statement 3 is **incorrect**.
Down the group, cationic radius increases and charge density of M^{2+} decreases.

8 Ans: C

The least complicated way for this question is to work out the A_r of the Si samples in all 4 options.

	^{28}Si	^{29}Si	^{30}Si	A_r
A	92.23%	2.23%	5.54%	28.13
B	92.23%	3.89%	3.89%	28.12
C	92.23%	5.54%	2.23%	28.10
D	92.23%	7.77%	0%	28.08

9 Ans: A

$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$

Amount of H_2SO_4 used = $\frac{50.0}{1000} \times 2.00 = 0.1$ mol
Amount of NaOH used = $\frac{100.0}{1000} \times 1.00 = 0.1$ mol
NaOH is the limiting reagent, amount of H_2O produced = 0.1 mol

$$\Delta H_n = -\frac{mc\Delta T}{n_{H2O}}$$
$$= -\frac{150 \times 4.18 \times (29.0 - 20.0)}{0.1}$$
$$= -56430 \text{ J mol}^{-1} \approx \textbf{–56.4 kJ mol}^{-1}$$

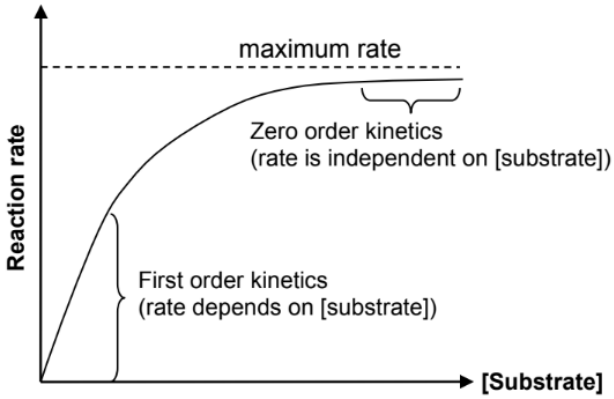
10 **Ans: A**

$$|\text{L.E.}| \propto \left|\frac{q_+ \times q_-}{r_+ + r_-}\right|$$

CaC*l* contains Ca^+ and Cl^-, hence the smallest magnitude of L.E

Ionic radius of Ca^{2+} is smaller than Mg^{2+}, hence $CaCl_2$ has a smaller magnitude of L.E. than $MgCl_2$.

11 **Ans: D**



At low [substrate], not all of the active sites are occupied. The rate of reaction increases proportionally with substrate concentration. It is first order with respect to the substrate.

At high [substrate], all the active sites of the enzyme are saturated. Any increase in the substrate concentration cannot increase the rate of reaction. The rate of reaction no longer depends on the substrate concentration and is zero-order with respect to the substrate.

12 **Ans: D**

Statements A, B and C are **incorrect**. K_p value is only affected by change in temperature.

Statement D is **correct**. As temperature increases, by Le Chatelier's Principle, the equilibrium system would partially remove the excess heat by favouring the reverse endothermic reaction. At the new equilibrium, the ratio of $\frac{\text{product}}{\text{reactant}}$ decreases, hence the value of K_p decreases.

13 **Ans: C**

	$N_2(g)$	$+ 3H_2(g)$	$\rightleftharpoons$	$2NH_3(g)$
I /mol	x	3x		0
C / mol	–y	–3y		+2y
E / mol	x–y	3x–3y		2y

$P_{N2} + P_{H2} + P_{NH3} = 100$ atm

$P_{N2} + P_{H2} = 100 - 92 = 8$ atm

As equilibrium amount of $N_2 : H_2 = 1 : 3$, and $pV = nRT$

$P_{N2} : P_{H2} = 1 : 3$

$P_{N2} = 2$ atm, $P_{H2} = 6$ atm, $P_{NH3} = 92$ atm

$$K_p = \frac{(P_{NH3})^2}{P_{N2} \times (P_{H2})^3} = \frac{(92)^2}{2 \times (6)^3} = \underline{\mathbf{19.6\ atm^{-2}}}$$

14 Ans: C

$Br_2 + KOH \longrightarrow KBr + KBrO_x + H_2O$ (not balanced)

Amount of Br_2 used = $\frac{30.0}{1000} \times 0.500 = 0.015$ mol

Amount of KBr formed = $\frac{2.98}{39.1 + 79.9} = 0.02504$ mol

Method 1:

Total amount of Br in reactant = $0.015 \times 2 = 0.030$ mol (2 Br in a Br_2 molecule)

Amount of Br in $KBrO_x = 0.030 - 0.02504 = 0.00496$ mol

Mol ratio $Br_2 : KBr : KBrO_x = 3 : 5 : 1$

Balancing the equation,

$3Br_2 + 6KOH \longrightarrow 5KBr + KBrO_x + 3H_2O$

x = 3

Method 2:

[R] $Br_2 + 2e^- \longrightarrow 2Br^-$

[O] $Br_2 \longrightarrow 2BrO_x^- + ne^-$ (not balanced)

From the reduction half equation, 0.0125 mol of Br_2 gains 0.0250 mol of e^- to give 0.0250 mol of Br^-.

Amount of Br_2 that undergoes oxidation = $0.0150 - 0.0125 = 0.00250$ mol

During oxidation, 0.0025 mol of Br_2 lose 0.0250 mol of e^-

Mol ratio $Br_2 : e^- = 1 : 10$

During oxidation, oxidation state of EACH Br increases by 5 units from 0 (in Br_2) to +5 (in BrO_x^-)

Hence x = 3.

15 Ans: B

Observations from first student:

Reaction 1.1 : $AgNO_3 + CH_3COO^-Na^+ \longrightarrow CH_3COO^-Ag^+$ (white ppt) + $NaNO_3$

Reaction 1.2 :$CH_3COO^-Ag^+$ (white ppt) + $KBr \longrightarrow$ AgBr (cream ppt) + $CH_3COO^-K^+$

Observations from first student:

Reaction 2 :$AgNO_3 + KBr \longrightarrow$ AgBr (cream ppt) + KNO_3

$AgBr + CH_3COO^-Na^+ \longrightarrow$ no reaction

Statement 1 is **correct**. We observed that white ppt of $CH_3COO^-Ag^+$ is formed in reaction 1.1

Statement 2 is **correct**. We observed that cream ppt of AgBr is formed in reaction 1.2

Statement 3 is **wrong**. Br^- is not oxidised to Br_2 in the above reactions.

16 Ans: C

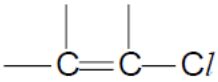
Propane : 3 sp^3 hybridized C atoms ($9 \times$ 2p orbitals hybridized with 2s)

Benzene : 6 sp^2 hybridized C atoms ($12 \times$ 2p orbitals hybridized with 2s)

Ethyne : 2 sp hybridized C atoms ($2 \times$ 2p orbitals hybridized with 2s)

Total : 23 × 2p orbitals hybridized with 2s

17 Ans: C

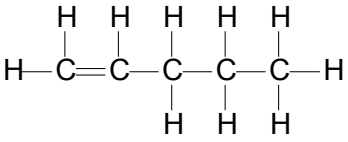


Note: Halogen directly bonded to C=C does not undergo Nucleophilic Substitution due to the same reasons as halogenoarene.

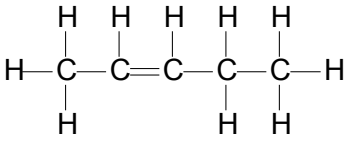
1. The p-orbital of the halogen atom overlaps with the π electron system of C=C. The lone pair electrons on halogen is delocalized into C=C. As a result, there is some double bond character in the C–*X* bond. The C–*X* bond is shorter and stronger than that in halogenoalkane and thus is very difficult to break.

2. The C in δ+C–*X* bond is less accessible to the nucleophilic reagents that attack halogenoalkanes since the electron rich C=C repels the approaching nucleophile.

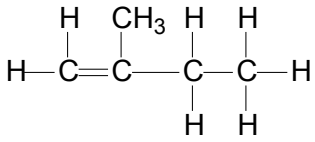
18 Ans: C



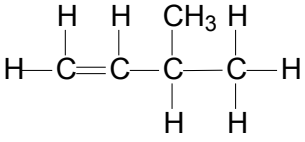
pent-1-ene



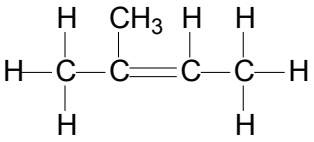
pent-2-ene



2-methylbut-1-ene



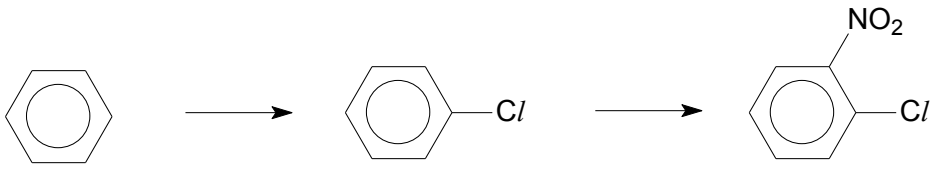
3-methylbut-1-ene



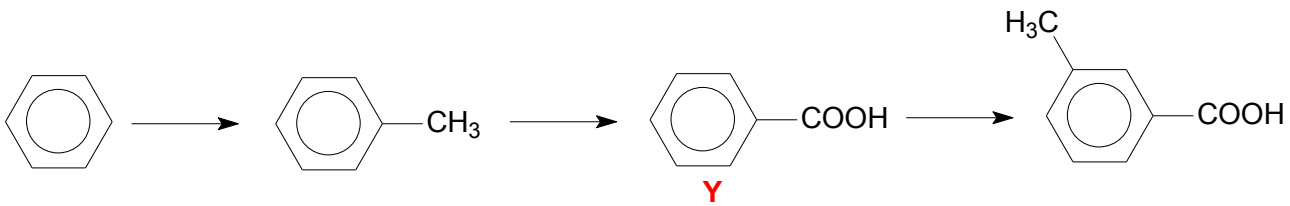
2-methylbut-2-ene

19 Ans: A

Refer to the Data Booklet for directing effect of substituents towards subsequent electrophilic sub.
–C*l* is 2,4-directing
–NO_2 is 3-directing
–CH_3 is 2,4-directing
–COOH is 3-directing



X



Y

20 **Ans: C**

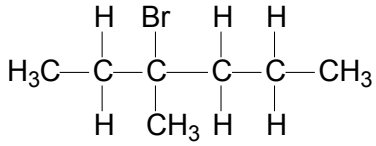
Statement A is **wrong**. Benzene undergoes electrophilic substitution reaction with Br_2 and $AlBr_3$.

Statement B is **wrong**. Benzene is resonance stabilized and it cannot undergo addition reaction as that would disrupt the aromaticity.

Statement C is **correct**. π electron of benzene can donate an electron pair to react with a carbocation electrophile.

Statement D is **wrong**. The sideway overlap of p orbitals in benzene give rise to a resonance structure with partial double bond character. All the six C–C bonds are partial double bond.

21 **Ans: A**



3-bromo-3-methylhexane is a tertiary halogenoalkane. Due to steric hindrance of the three alkyl groups, it undergoes S_N1 reaction mechanism to produce a carbocation.

The electron deficient (+) carbocation attracts an electron rich (–) nucleophile.

22 **Ans: B**

Statement A and D is **wrong**. Propanoyl chloride is an acyl chloride, it reacts most readily with water as two electronegative atoms are bonded to a C atom, making the C atom highly electron deficient and reacts readily with nucleophile.

Statement B is **correct**. Due to the continuous overlap of the p orbital of C*l* and the π electron system of benzene, lone pair electron of C*l* is delocalised into the benzene ring, giving rise to a resonance structure with a partial double bond for C–C*l*. The C–C*l* bond is the strongest among the 3 chlorine containing compounds.

Statement C is **wrong**. Cl^- is produced in both the hydrolysis of 1-chloropropane and propanoyl chloride.

23 **Ans: A**

$$C_xH_y + (x + \frac{y}{4})\ O_2 \longrightarrow xCO_2 + \frac{y}{2}\ H_2O$$

Comparing the volume ratio,
Mol ratio $C_xH_y : O_2 : CO_2 = 1 : 7.5 : 5$

Hence x = 5, $\quad x + \frac{y}{4} = 7.5$

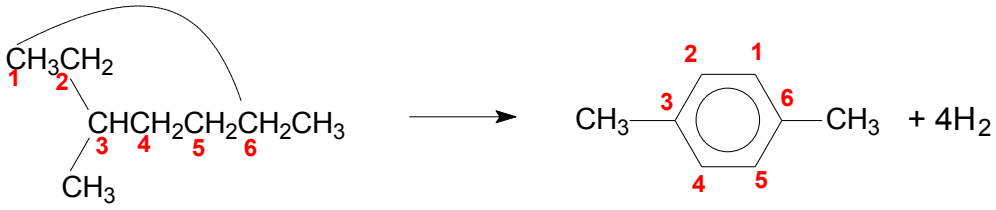
$y = 10$

The hydrocarbon is C_5H_{10}.
Statement 1 is **correct**. C_5H_{10} could be a cycloalkane, e.g. cyclopentane.
Statement 2 is **correct**. C_5H_{10} could have a branched chain, e.g. 2–methylbut-1-ene.
Statement 3 is **correct**. C_5H_{10} could be an alkene that reacts with Br_2(aq), e.g. pent-1-ene.

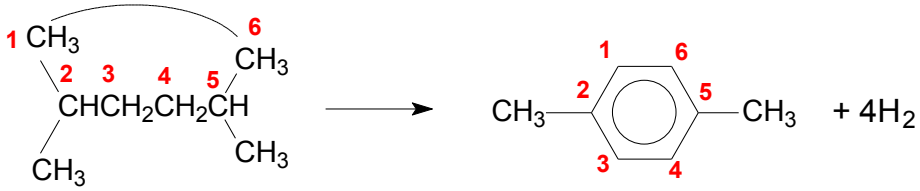
24 **Ans: B**

Following the pattern stated in the question, carbon-1 and carbon-6 will form a new bond to produce the benzene ring.

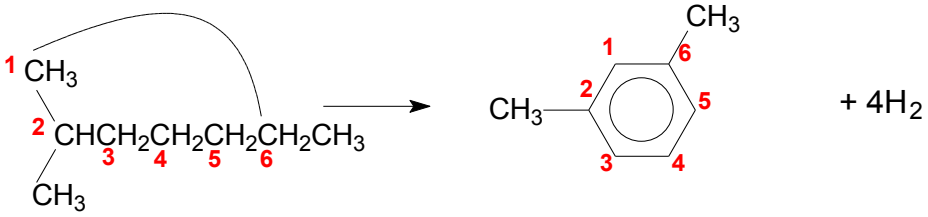
Option 1 is **correct**.



Option 2 is **correct**.

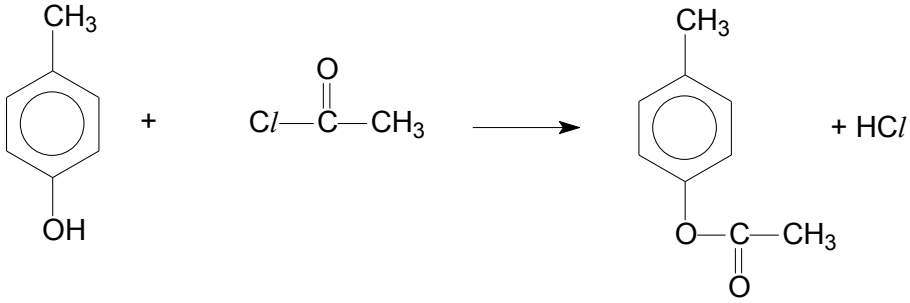


Option 3 is **wrong**.



25 **Ans: D**

Acyl chloride undergoes condensation reaction with phenol to form an ester.



26 **Ans: B**

The H^+ in phenol and carboxylic acid can be dissociated due to the equilibrium of acids.

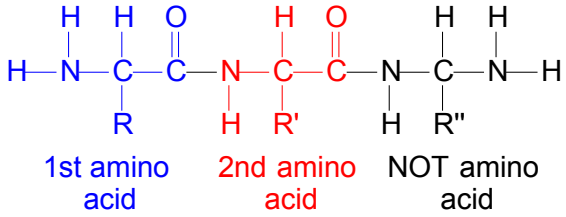
$D_2O \rightleftharpoons DO^- + D^+$
$C_6H_5OH \rightleftharpoons C_6H_5O^- + H^+$
$RCOOH \rightleftharpoons RCOO^- + H^+$

The phenolic H atom and carboxylic H atom can be replaced by D isotopes from heavy water D_2O.

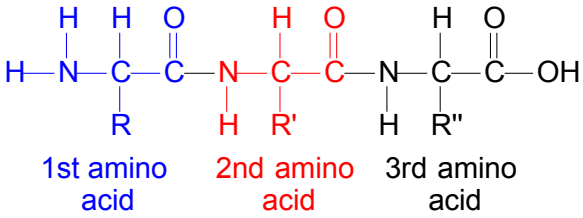
27 Ans: D

In tripeptide, three amino acids undergo condensation reaction to form two peptide (amide) linkages.

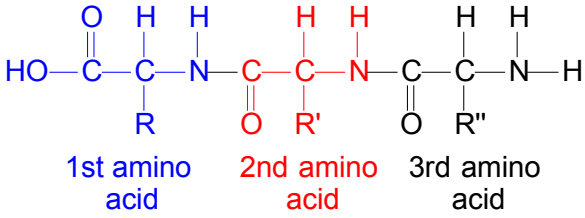
Option 1 is **wrong**, it is formed by two amino acids and a diamine.



Option 2 is **correct**, it is formed by three amino acids.



Option 3 is **correct**, it is formed by three amino acids.



28 Ans: A

Statement 1 is **correct**. H_2 / O_2 fuel cell only produces H_2O as the product.

Statement 2 is **correct**. H_2 / O_2 fuel cell converts chemical energy directly to electrical energy, it is more energy efficient compared to other conventional methods of generating electricity.

Statement 3 is **correct**. In the anode, [O] $H_2 \longrightarrow 2H^+ + 2e^-$

29 Ans: B

Statement 1 is **correct**. When standard hydrogen electrode (SHE) is connected to a half-cell with a negative standard electrode potential, SHE would preferentially undergoes reduction.
[R] $2H^+ + 2e^- \longrightarrow H_2$

Statement 2 is **wrong**. The standard redox potential of the standard hydrogen electrode is 0.00V (can refer to Data Booklet).

Statement 3 is **wrong**. In SHE, concentration of $H^+(aq)$ is 1.00 mol dm^{-3}. The electrolyte should be either 1.00 mol dm^{-3} HC*l* or 0.50 mol dm^{-3} H_2SO_4

30 Ans: C

[R] $Cu^{2+} + 2e^- \longrightarrow Cu$

Initial amount of $Cu^{2+} = \frac{250}{1000} \times 0.200 = 0.05$ mol

amount of Cu^{2+} in 0.100 mol $dm^{-3} = \frac{250}{1000} \times 0.100 = 0.025$ mol

Amount of Cu^{2+} to be used up during reduction = 0.05 − 0.025 = 0.025 mol

Amount of e^- required = $2 \times 0.025 = 0.05$ mol

$Q = It = n_eF$

$0.65 \times t = 0.05 \times 96500$

$t = 7423$ s

1 (a) (i) Halogen acts as an oxidising agent in these reactions, S is oxidised from H_2S (O.S. of S = –2) to S (O.S. of S = 0).

Br_2 is a better oxidising agent than I_2 as $E^{\ominus}(Br_2/Br^-)$ is more positive than $E^{\ominus}(I_2/I^-)$. Hence Br_2 has a greater reactivity with H_2S.

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1 (a) (ii) [O] $H_2S \longrightarrow S + 2H^+ + 2e^-$
(construct half equation using balance EOHC method)

$E^{\ominus}_{cell} = E^{\ominus}(Br_2/Br^-) - E^{\ominus}(S/H_2S)$
$+0.93 = +1.07 - E^{\ominus}(S/H_2S)$
$E^{\ominus}(S/H_2S) =$ **+0.14 V**

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1 (b) (i) Br_2 and ICl are covalent compounds with simple molecular structure. Both compounds have instantaneous dipole–induced dipole (id-id) interaction between molecules. The strength of the id-id is similar as the size of electron clouds of Br_2 and ICl are similar.

Br_2 is non-polar molecule while ICl is a polar molecule. There are permanent dipole-permanent dipole (pd-pd) interactions between ICl molecules but not for Br_2.

The total intermolecular forces are stronger in ICl, more energy is required to overcome these forces of attractions and hence the melting point of ICl is greater than Br_2.

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1 (b) (ii) Both ICl and IBr are polar molecules with instantaneous dipole-induced dipole (id-id) attractions and permanent dipole-permanent dipole (pd-pd) attractions.

As the electron cloud of IBr is larger than ICl, dipoles are more easily induced for IBr and hence strength of id-id is greater for IBr. More energy is required to overcome the stronger intermolecular forces (id-id & pd-pd) in IBr, and hence a higher melting point for IBr.

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1 (c) (i) The ring of delocalised π electrons gives benzene additional aromatic stability. Addition reactions destroy the aromaticity and hence is not favorable. Benzene undergoes substitution reactions to preserve the aromaticity.

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1 (c) (ii) Cl is more electronegative than I. ICl reacts with $AlCl_3$ to form I^+ electrophile that reacts with the electron rich benzene to produce iodobenzene.

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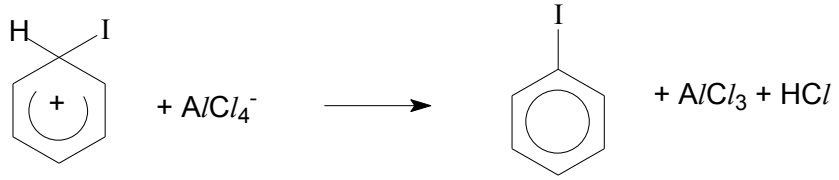
1 (c) (iii) $AlCl_3$ acts as a Lewis acid (electron acceptor) when it reacts with ICl

$$AlCl_3 + ICl \longrightarrow AlCl_4^- + I^+$$

$AlCl_3$ also acts as a catalyst as it is regenerated at the end of reaction.



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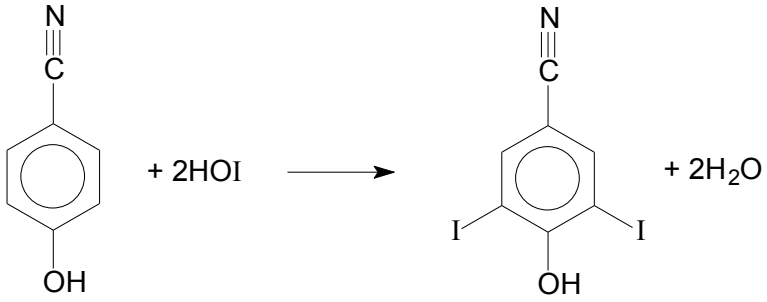
1 (d) (i) I^- is the reducing agent while IO_3^- is the oxidising agent.
I^- loses electron to IO_3^- to form HOI. Oxidation state of I increases from –1 (in NaI) to +1 (in HOI) while oxidation state of I decreases from +5 (in $NaIO_3$) to +1 (in HOI).

---

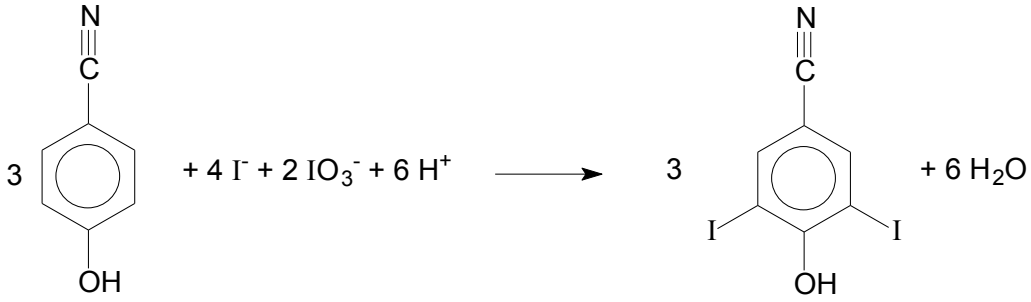
1 (d) (ii) **Note: This question is very time consuming.**

Thinking process:
[O] $I^- + H_2O \longrightarrow HOI + H^+ + 2e^-$
[R] $IO_3^- + 5H^+ + 4e^- \longrightarrow HOI + 2H_2O$
Overall reaction to form HOI: $2I^- + IO_3^- + 3H^+ \longrightarrow 3HOI$

Reaction of 4-hydroxybenzonitrile with HOI:



Overall ionic equation:



2 (a) (i) $CH_2(OH)COOH \rightleftharpoons CH_2(OH)COO^- + H^+$

Glycolic acid is a weak acid that dissociates partially.

$[H^+] = \sqrt{K_a \times [weak\ acid]}$

$= \sqrt{1.48 \times 10^{-4} \times 0.100}$
$= 0.003847$ mol dm^{-3}

pH = –lg $[H^+]$ = **2.41 (2 d.p.)**

2 (a) (ii) $NaOH \longrightarrow Na^+ + OH^-$

NaOH is a strong base that dissociates completely.

$[OH^-] = 0.100$ mol dm^{-3}

pOH = –lg$[OH^-]$ = 1

pH = 14 – pOH = **13.00 (2 d.p)**

2 (a) (iii) $CH_2(OH)COOH + NaOH \longrightarrow CH_2(OH)COO^- Na^+ + H_2O$

Amount of NaOH = $\frac{25.0}{1000} \times 0.100 = 0.00250$ mol

Amount of $CH_2(OH)COOH = \frac{25.0}{1000} \times 0.100 = 0.00250$ mol

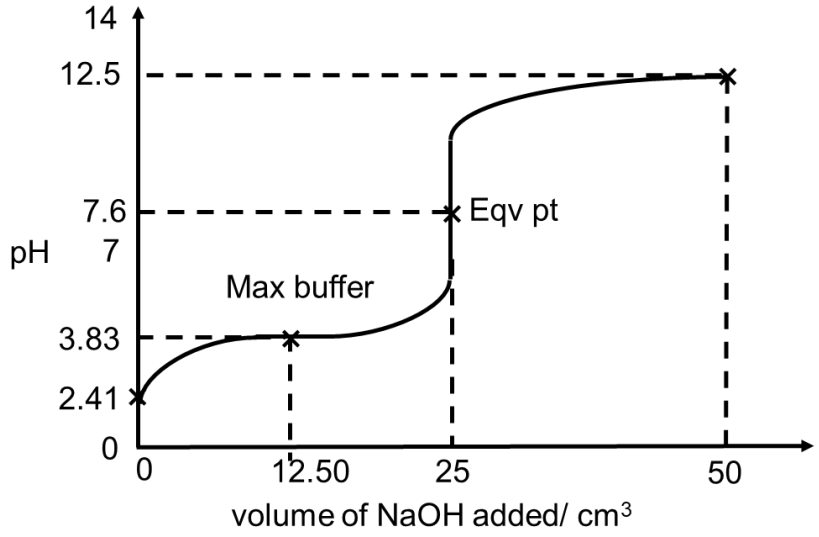
NaOH reacts completely with the $CH_2(OH)COOH$ and the resulting solution only contains the salt $CH_2(OH)COO^- Na^+$ and H_2O.

$CH_2(OH)COO^-$ is the conjugate base of the weak acid $CH_2(OH)COOH$.

$CH_2(OH)COO^-$ has a K_b value and **ionises partially** in water similar to a weak base to **produce some OH^-**, hence the resulting mixture has a **pH of slightly greater than 7**.

$CH_2(OH)COO^- + H_2O \rightleftharpoons CH_2(OH)COOH + OH^-$

2 (a) (iv) Maximum buffering capacity (MBC) is when 12.50 cm^3 of NaOH is added to the mixture.
pH at MBC = pK_a = 3.83



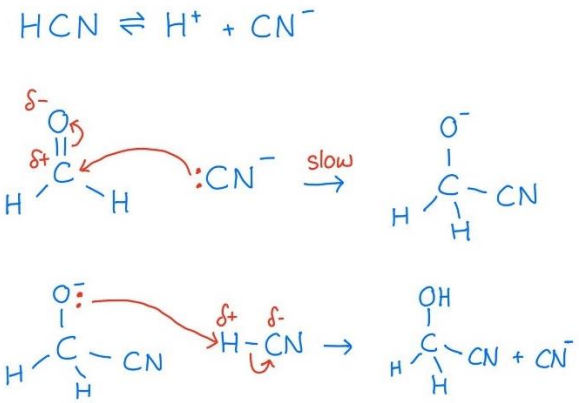
2 (b) Phenol red is the most suitable indicator as the indicator changes colour in the pH range of 6.8-8.4 and this coincides with the sharp change in pH at the equivalence point of this acid-base titration.

Note: Even though 7.6 also lies in the range of pH for colour change for litmus, litmus starts changing colour at pH 5, meaning it could change colour BEFORE equivalent point is reached (make reference to the pH graph).

2 (c) $HOCH_2COOH \rightleftharpoons HOCH_2COO^- + H^+$

When ammonium glycolate is added to glycolic acid, concentration of $HOCH_2COO^-$ increases. This causes the position of equilibrium to shift to the left, $[H^+]$ in the equilibrium mixture decreases.
Since pH = $-\lg[H^+]$, pH of the mixture increases.

2 (d) (i) Nucleophilic Addition



2 (d) (ii) Acid hydrolysis of nitrile group.

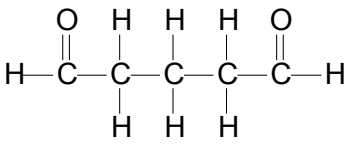
$HOCH_2CN + H^+ + 2H_2O \longrightarrow HOCH_2COOH + NH_4^+$

Note: It is easier to balance using ionic equation as the SO_4^{2-} ion is a spectator ion in the acid hydrolysis.

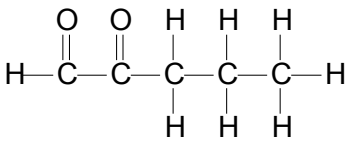
3 (a) (i) Thinking process:
A is **$C_5H_8O_2$, straight chain molecule**.
A does not react with Na(s), A **does not** contain alcohol nor carboxylic acid functional group.
A gives silver mirror with Tollens' reagent, A contains an **aldehyde** functional group.
A does not react with alkaline I_2(aq), A **does not** contain methyl carbinol nor methyl carbonyl group.
A does not react with Br_2(l), A **does not** contain alkene functional group.

Note: For displayed formula, must show ALL the bonds between the atoms.

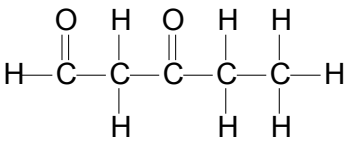
There are a few possible structures of A that agrees with the observations.



A1

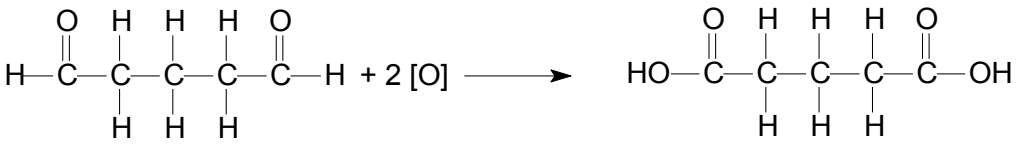


A2

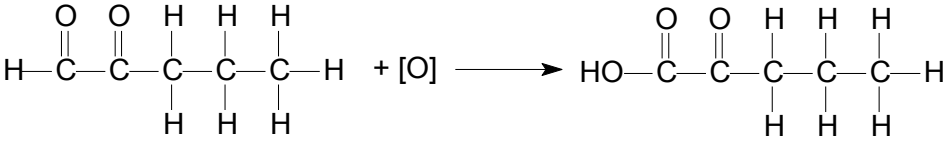


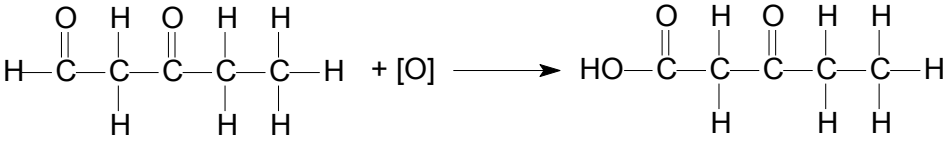
A3

3 (a) (ii) For structure A1 in (i), A contains 2 aldehyde functional group.

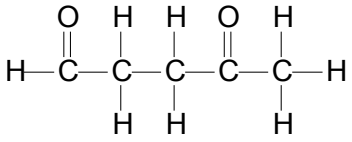


For structure A2 and A3 in (i), A contains 1 aldehyde functional group.





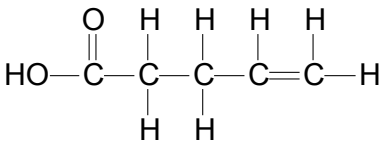
3 (a) (iii) Thinking process:
B is **$C_5H_8O_2$, straight chain molecule.**
B does not react with Na(s), B **does not** contain alcohol nor carboxylic acid functional group.
B gives silver mirror with Tollens' reagent, B contains an **aldehyde** functional group.
B reacts with alkaline I_2(aq), B contains **methyl carbinol or methyl carbonyl group**.
B does not react with Br_2(l), B **does not** contain alkene functional group.

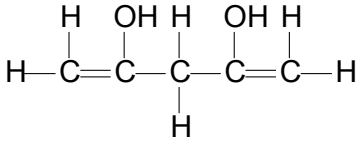


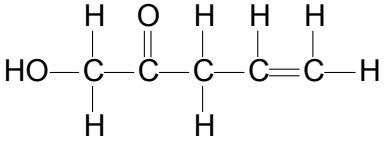
3 (a) (iv) CHI_3

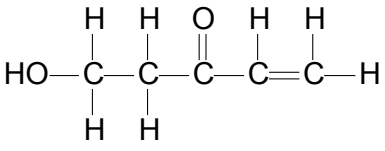
3 (a) (v) Thinking process:
C is **$C_5H_8O_2$, straight chain molecule.**
C reacts with Na(s), C **contains alcohol or carboxylic acid functional group**.
C does not give silver mirror with Tollens' reagent, C **does not** contain an aldehyde functional group.
C does not react with alkaline I_2(aq), C **does not** contain methyl carbinol nor methyl carbonyl group.
C reacts with Br_2(l), C contains **alkene** functional group.
C does not show stereoisomerism, C **does not** contain chiral C and cis-trans C=C.

There are a few possible structures of C that agrees with the observations.







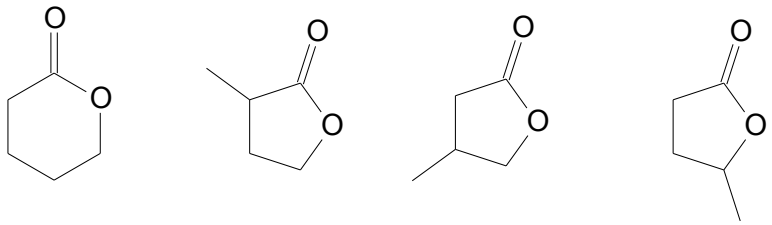


3 (b) (i) Constitutional isomers are molecules with the same molecular formula but different structural formula.

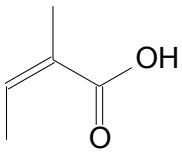
3 (b) (ii) Thinking process:
D is **$C_5H_8O_2$**
D does not react with Na(s), D **does not** contain alcohol or carboxylic acid functional group.
D does not give silver mirror with Tollens' reagent, D **does not** contain an aldehyde functional group.
D does not react with alkaline I_2(aq), D **does not** contain methyl carbinol nor methyl carbonyl group.
D does not react with Br_2(l), D **does not** contain alkene functional group.

D **undergoes hydrolysis** with dilute sulfuric acid to give a single organic molecule. D **contains an ester group in a cyclic structure**.
(Note: straight chain ester would produce 2 organic molecules after hydrolysis.)

There are a few possible structures of D that agrees with the observations.



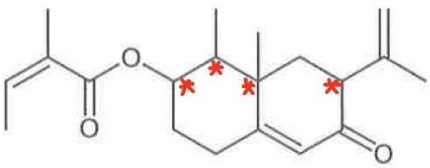
3 (c) (i) Note: Question states that angelic acid reacts to form petasin, which contains the ester functional group.
Hence angelic acid should have the following structure.



Functional groups: alkene and carboxylic acid.

3 (c) (ii) Stereoisomers have the same molecular and structural formulae. The bonding of atoms differs in the spatial (3 dimensional) arrangements of their bonds.

3 (c) (iii)

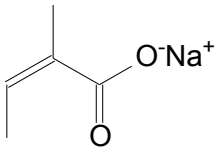


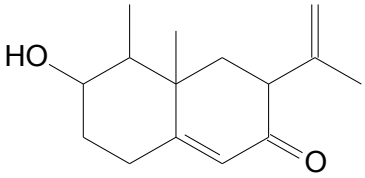
petasin

3 (c) (iv) There are a total of 4 chiral C and 1 cis-trans C=C (note: C=C in the cyclic ring is not able to exhibit cis-trans isomerism.

Total number of stereoisomers = 2^5 = 32

3 (c) (v) Note: Alkaline hydrolysis of ester functional group produces R–COO^- and alcohol. Alcohol group is neutral and have no further acid-base reaction with NaOH.





4 (a) 1) Pressure of 1 bar.

2) Concentration of 1 mol dm^{-3} for aq solution (similar to $E^{\ominus}$ definition).

(Note: The temperature of 298 K is already stated in the question,)

4 (b) (i) $\Delta G = \Delta H - T\Delta S$

4 (b) (ii) $\Delta G_{rxn\ 3} = \Delta G_{f(trans\ isomer)} - \Delta G_{f(cis\ isomer)}$

From Fig. 4.1,
When mol fraction of trans-but-2-ene = 1.0, the mixture only contains trans isomer, hence $\Delta G_{f(trans\ isomer)} = 62.9\ kJ\ mol^{-1}$

When mol fraction of trans-but-2-ene = 0.0, the mixture only contains cis isomer, hence $\Delta G_{f(cis\ isomer)} = 65.9\ kJ\ mol^{-1}$

$\Delta G_{rxn\ 3} = \Delta G_{f(trans\ isomer)} - \Delta G_{f(cis\ isomer)}$
$= 62.9 - 65.9 = -3.0\ kJ\ mol^{-1}$

Similarly, for ΔH, $\Delta H_{rxn\ 3} = \Delta H_{f(trans\ isomer)} - \Delta H_{f(cis\ isomer)}$

From Fig. 4.2,
When mol fraction of trans-but-2-ene = 1.0, the mixture only contains trans isomer, hence $\Delta H_{f(trans\ isomer)} = -12.2\ kJ\ mol^{-1}$

When mol fraction of trans-but-2-ene = 0.0, the mixture only contains cis isomer, hence $\Delta H_{f(cis\ isomer)} = -7.8\ kJ\ mol^{-1}$
$\Delta H_{rxn\ 3} = \Delta H_{f(trans\ isomer)} - \Delta H_{f(cis\ isomer)}$
$= -12.2 - (-7.8) = -4.4\ kJ\ mol^{-1}$

At 298K, using $\Delta G = \Delta H - T\Delta S$,
$-3.0 = -4.4 - 298\Delta S$
$\Delta S = \dfrac{-4.4 + 3.0}{298} = -0.00407\ kJ\ mol^{-1}\ K^{-1}$

4 (b) (iii) $\Delta G = \Delta H - T\Delta S$

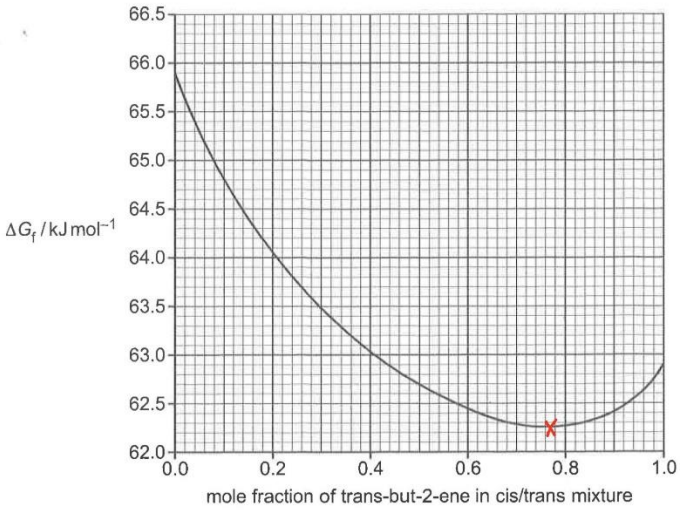
T is kept constant at 298K, and Fig. 4.2 shows that ΔH decreases linearly as the mole fraction of trans-but-2-ene increases. Theoretically, if ΔH decreases linearly, ΔG should decrease linearly. However, the linear relationship is not observed in Fig 4.1.

Hence it is likely that the ΔS does not remain constant for the various mixtures containing different proportions of the isomers. (E.g. mixture containing both cis- and trans- isomer has a higher ΔS than pure cis- or pure trans- isomer).

4 (c) (i) A dynamic equilibrium occurs when the **rates of forward and backward reaction are equal** and there is **no net change in concentration of reactants and products in a closed system**.

4 (c) (ii) Note: Fig 4.1 shows the ΔG_f for various mixtures containing different proportions of the cis- and trans- isomers.

For a reversible reaction, the reaction mixture will adjust its composition such that its Gibbs free energy (ΔG_f) is at a minimum.



4 (c) (iii) Let the mole fraction of cis-but-2-ene be "c"
Mole fraction of trans-but-2-ene = 1 – c

For gases, partial pressure of A = mole fraction of A × P_{total}
P_{cis} = c × P_{total}
P_{trans} = (1–c) × P_{total}

$$K_p = \frac{P_{trans}}{P_{cis}} = \frac{(1-c) \times P_{total}}{c \times P_{total}}$$

$$3.36 = \frac{(1-c)}{c}$$

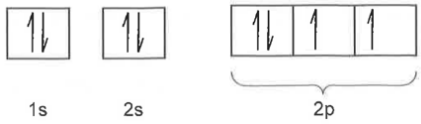
3.36 c = 1 – c
4.36 c = 1
c = 0.23 (2 s.f.) = mole fraction of cis-but-2-ene

mole fraction of trans-but-2-ene = 1 – 0.23 = 0.77 (2 s.f.)

Note: Qn requires answer to be presented in 2 s.f.

4 (d) Trans isomer is more stable (as it is present in higher mole fraction at equilibrium). Trans isomer is more stable than cis isomer as the two methyl groups are further apart, and this minimises the steric repulsion between the electron cloud of the methyl groups.

5 (a) Oxygen atom has electronic configuration of $1s^2\ 2s^2\ 2p^4$.



It contains **<u>two unpair electrons</u>** in its p orbitals and hence it is a free radical.

5 (b) (i) **M** is N_2 as it has the highest % abundance in the ozone layer and it also has strong N≡N bond, allowing it to remain unreacted during the reactions described in Table 5.1.

5 (b) (ii) Reaction 3 occurs at a slower rate.

1) The concentration of O_3 is much lower than that of O_2 in the ozone layer (from Table 5.2). The frequency of effective collision is lower and hence the rate of reaction is slower.

OR

2) Reaction 3 involves the breaking of O–O bond in O_3 while reaction 2 involves the formation of O–O bond. The activation energy of reaction 3 would be larger and hence there would be lower frequency of effective collision and hence rate of reaction is slower.

5 (c) (i) Note: wavelength needs to be converted from nm to m

Energy of a photon with wavelength 254 nm $= \frac{hc}{\lambda}$

$$= \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{254 \times 10^{-9}}$$

$$= 7.831 \times 10^{-19}\ \text{J}$$

Energy of 1 mol of photons $= 7.831 \times 10^{-19} \times 6.02 \times 10^{23}$

$= 4.714 \times 10^{5}$ J

$= 471$ kJ mol^{-1} (in kJ mol^{-1})

5 (c) (ii) Photolysis of O_2(g) (reaction 1) requires the absorption of light with 220 nm wavelength. However, Table 5.1 states that photolysis of O_2 occurs above the ozone layer, and light with wavelength 220nm is mostly absorbed by O_2 **<u>above</u>** the ozone layer. The light that reaches the ozone layer is less likely to contain this wavelength (or energy), hence the rate of photolysis of O_2 is slower in the ozone layer.

5 (d) (i) Note : Reaction 3 shows the decomposition of O_3: $O_3 + O \longrightarrow 2O_2$, C*l* free radical can catalyse this reaction. The two-step reaction should give the same overall equation and show the regeneration of the catalyst.

Step 1: $O_3 + Cl \longrightarrow O_2 + ClO$

Step 2: $ClO + O \longrightarrow O_2 + Cl$

5 (d) (ii) Chlorofluorocarbons (CFCs).

5 (d) (iii) NO produced on the Earth's surface would react with other compounds such as O_2 and SO_2 before it reaches the stratosphere.

NO produced by aircraft in the stratosphere would be able to react readily with the ozone in the stratosphere due to proximity.

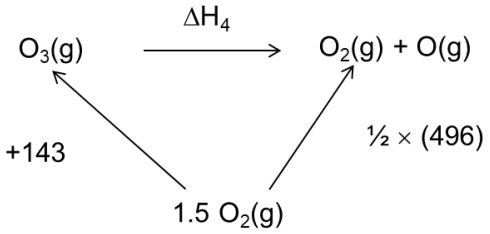
5 (e) (i) Fig. 5.1 shows that O_3 contains a O=O bond and O–O (similar to H_2O_2). However, the information in Table 5.4 shows that the bond length in O_3 is neither that of O=O (in O_2) and O–O (in H_2O_2), but an intermediate value between the two. Hence Fig. 5.1. does not represent O_3.

5 (e) (ii) Mixing of one 2s orbital with two 2p orbitals to give three sp^2 hybrid orbitals. For each O atom, there is one unhybridised 2p orbital.

The sp^2 hybrid orbital of O overlap head-on with sp^2 hybrid orbital of another O atom to form sigma bond.

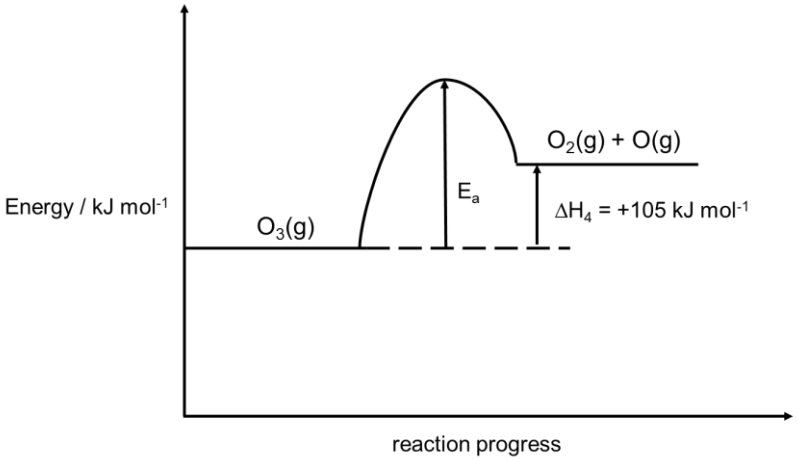
The continuous sideway overlap of the unhybridised 2p orbitals of the 3 O atoms allow the pi electrons to be delocalised across the 3 atoms, giving rise to a resonance structure with partial double bond character. Hence the bond length is in between of a single bond and double bond.

5 (e) (iii)

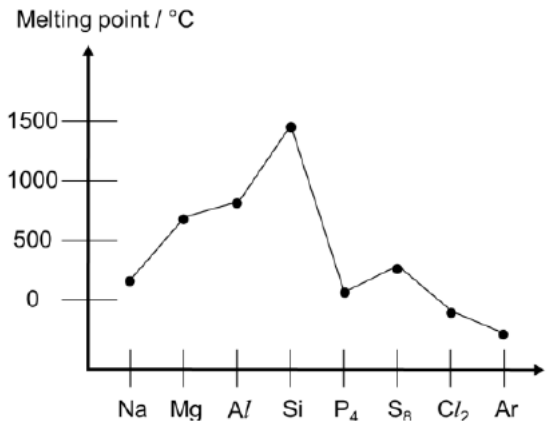


By Hess's Law,
$\Delta H_4 = -143 + ½ \times 496 =$ **$+105$ kJ mol^{-1}**

5 (e) (iv)



1 (a)



Na, Mg and A*l* exist as giant metallic lattice structure. Melting point increases from Na to A*l* because of ***stronger metallic bond strength*** between cations and sea of delocalized electrons as the charge of cations increases and number of delocalised electrons increase.

Si exist as giant covalent lattice structure. ***Much higher energy*** is required to break the strong covalent bonds between Si atoms. Hence, it has the highest melting point.

P_4 to Ar exist as simple covalent molecules. ***Little energy*** is required to overcome the weaker instantaneous dipole – induced dipole (id-id) interaction between molecules.
As strength of id-id ∝ no. of electrons in a molecule/atom,
Melting point decrease in order: **S_8 > P_4 > Cl_2 > Ar**

---

1 (b) $Na_2O(s) + H_2O(l) \rightarrow 2\ NaOH(aq)$
NaOH(aq) is a strong base that dissociates completely to give strongly alkaline solution (pH 13–14)

Al_2O_3 has no reaction with water due to strong ionic bonds between Al^{3+} and O^{2-} in the giant ionic lattice.
Resultant solution has pH 7

$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$
$H_3PO_4(aq) \rightleftharpoons H^+(aq) + H_2PO_4^-(aq)$

$H_3PO_4(aq)$ is a *weak acid* that *dissociates partially* to produce some $H^+(aq)$, giving a weakly acidic solution (pH 2–3)

---

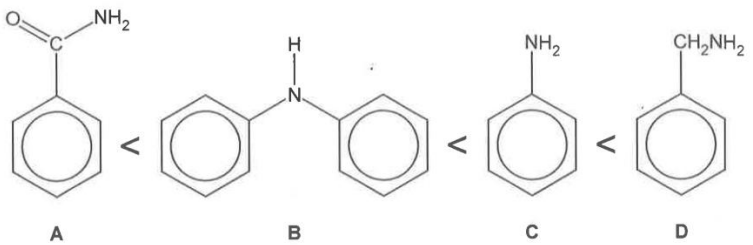
1 (c) Ethylamine behaves as a Bronsted base by being a proton acceptor.

$CH_3CH_2NH_2 + HCl \rightarrow CH_3CH_2NH_3^+Cl^-$

Ethylamine behaves as a nucleophile by donating an electron pair to an electron deficient carbon.

$CH_3CH_2NH_2 + CH_3Br \rightarrow CH_3CH_2NH(CH_3) + HBr$

1 (d)



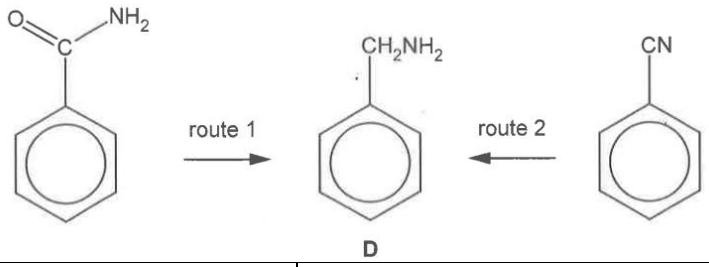
A is an amide: lone pair electron on N is delocalised significantly into the adjacent C=O with highlight electronegative O atom, hence it is **un**available for **donation to a H^+.** A is least basic.

B is less basic than C due to a greater extent of delocalisation (the lone pair on N is delocalised into 2 benzene rings compared to C where electrons only delocalised into 1 benzene ring). Hence lone pair electron on N of B is less unavailable for donation to a H^+.

D is most basic due to the presence of electron donating alkyl group which increases the availability of the lone pair electron on N for donation to H^+.

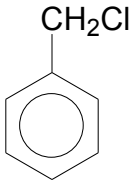
Note: must relate basicity to the ability of N to bond to a H^+.

1 (e) (i)



	Type of reaction	Reagents and conditions
Route 1	Reduction	$LiAlH_4$ in dry ether
Route 2	Reduction	H_2, Pt or $LiAlH_4$ in dry ether

1 (e) (ii)



React

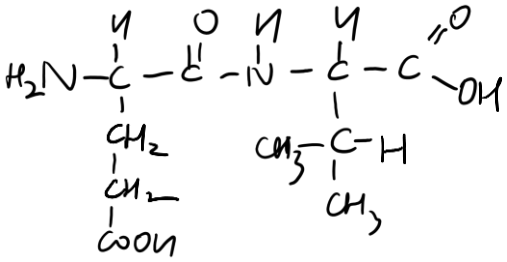
Excess ethanolic NH_3, heat in sealed tube

1 (f) (i) Note: R-group –COOH of glutamic acid is not able to undergo condensation with another amino acid.

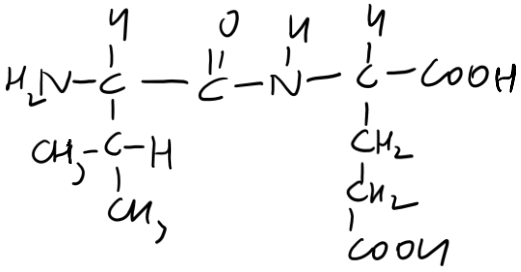
2 constitutional isomers
Condensation between the α–COOH of glutamic acid with the α–NH_2 of the valine and
Condensation between the α–COOH of valine with the α–NH_2 of the glutamic acid

(ii)

Glu–Val

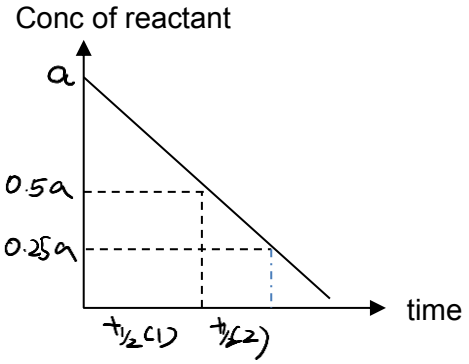


Val–Glu



2 (a) (i) Half-life of a reaction is the time taken for the concentration of a reactant to drop to half of its initial concentration.

2 (a) (ii)



From the graph successive half-lives decreases.

2 (b) Since each half-life is 220min, 660min = 3 half-lives.

75kPa ⟶ 37.5kPa ⟶ 18.75kPa ⟶ 9.38kPa

Pressure after 660minutes: 9.38 kPa

2 (c) **Note: The equations shown in the question are not balanced!**

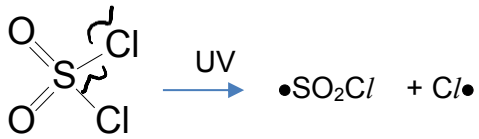
E: H_2SO_4 (oxidation state of S remains at +6 as in SO_2Cl_2)

F: H_2SO_3 (oxidation state of S remains at +4 as in $SOCl_2$)

Hint: replace C*l* in the reactant with OH.

2 (d) Free Radical substitution

Initiation:



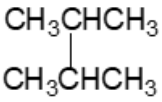
Propagation:

$CH_3CH_2CH_3 + Cl\bullet \longrightarrow CH_3\dot{C}HCH_3 + HCl$

$CH_3\dot{C}HCH_3 + SO_2Cl_2 \longrightarrow CH_3CHClCH_3 + \bullet SO_2Cl$

Termination:

$CH_3\dot{C}HCH_3 + Cl\bullet \longrightarrow CH_3CHClCH_3$

$CH_3\dot{C}HCH_3 + CH_3\dot{C}HCH_3 \longrightarrow$ 

2 (e) (i) Ratio of 1-bromobutane : 2-bromobutane = 3:2

Assuming substitution of H by Br is random, there 6 H atoms (on the $-CH_3$ at both ends) that can be substituted by Br to give 1-bromobutane.
There are 4 H atoms (on the $-CH_2-$) that can be substituted by Br to give 2-bromobutane.

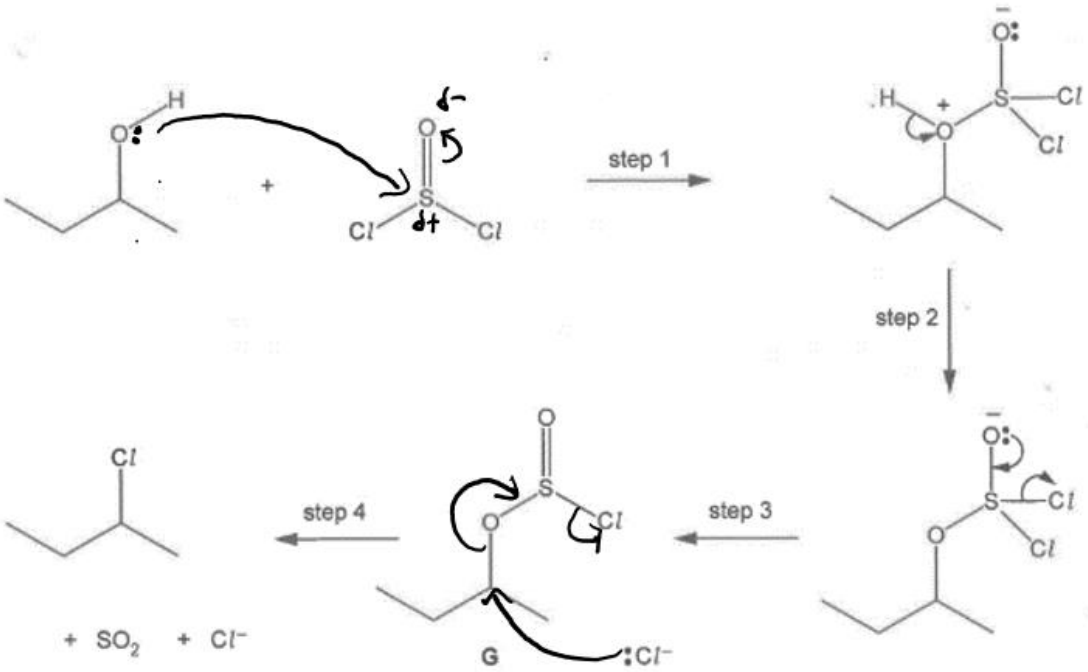
2 (e) (ii) The radical forming 1-bromobutane is a primary radical while the radical forming 2-bromobutane is a secondary radical. There are more electron-donating alkyl group which reduces the electron-deficiency of the secondary radical, making it more stable. Therefore, secondary radical is preferentially formed, resulting in greater than expected amount of 2-bromobutane, and hence the observed ratio.

2 (f) Nitrobenzene < benzene < phenylamine

The NH_2 group on phenylamine is an activating group, the lone pair electron of N delocalised into the benzene ring and increases the electron density of the benzene ring, making it more susceptible to electrophilic substitution with bromine as compared to benzene.

The NO_2 group on nitrobenzene is a deactivating group, it is electron withdrawing, and hence it reduces electron density of the benzene ring and make it less susceptible to electrophilic substitution with bromine as compared to benzene.

2 (g) (i)



(ii)

Fig. 2.2

Note: Full arrow pointing to S–O bond represents the formation of the new π bond in S=O of SO_2

2 (g) (iii) Single enantiomer. S_N2 mechanism occurs via a rearside attack in step 4, where the Cl^- attacks the electron deficient carbon in **G** from the opposite side of the leaving group, thus producing a single enantiomer with an inverse stereochemistry.

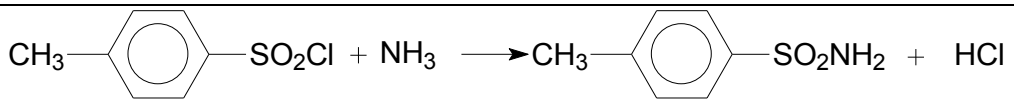
2 (h) (i) $CH_3SO_2OH + H_2O \rightleftharpoons CH_3SO_2O^- + H_3O^+$

	Acid	Conjugate base
1st pair	CH_3SO_2OH	$CH_3SO_2O^-$
2nd pair	H_3O^+	H_2O

2 (h) (ii) Sulfonic acid **H**: CF_3SO_2OH

alcohol **J**: CH_3OH

2 (h) (iii)



3 (a) (i) Cu^{2+}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9$

3 (a) (ii) Copper is a d-block element which forms one or more stable ions with a ***partially filled d subshell.***

3 (b) In the presence of ligands, electronic repulsion between lone pair electrons of ligands and the electrons in d orbitals causes the degenerate d-orbitals of the transition metal ion to split into two different energy levels with a small energy gap, ΔE. (d splitting)

As the 3d subshell is partially filled, electrons in the lower energy d-orbitals can absorb light of a certain wavelength in the visible light spectrum with energy corresponding to the energy gap, ΔE, and be promoted to the higher energy d-orbitals (d−d transition).

The colour observed is the complement of the colour absorbed.

3 (c) (i)

- Dilute sulfuric acid

Observation: blue solid dissolves in sulfuric acid to give a pale blue solution containing $[Cu(H_2O)_6]^{2+}$

Type of reaction: acid base reaction

Equation: $Cu(H_2O)_4(OH)_2 + H_2SO_4 \rightarrow [Cu(H_2O)_6]SO_4$
or
$Cu(H_2O)_4(OH)_2 + H_2SO_4 \rightarrow CuSO_4 + 6H_2O$

- Excess ammonia

Observation: blue solid dissolves in excess to give a deep blue solution containing $[Cu(NH_3)_4(H_2O)_2]^{2+}$ or $[Cu(NH_3)_4]^{2+}$

Type of reaction: Ligand exchange reaction

Equation: $Cu(H_2O)_4(OH)_2 + 4NH_3 \rightleftharpoons [Cu(NH_3)_4(H_2O)_2]^{2+} + 2OH^- + 2H_2O$
Or
$Cu(H_2O)_4(OH)_2 + 4NH_3 \rightleftharpoons [Cu(NH_3)_4]^{2+} + 2OH^- + 4H_2O$

- Concentrated HC*l*

Observation: Blue solid dissolves in excess to give a yellow solution of $[CuCl_4]^{2-}$

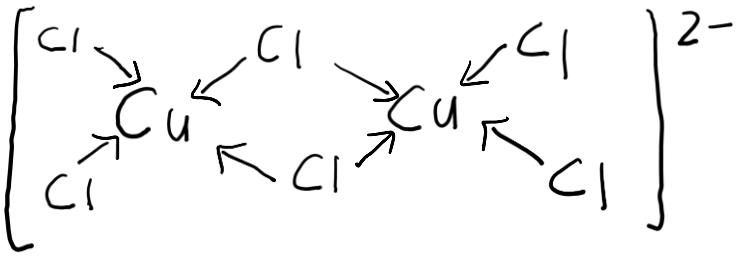
Type of reaction: Ligand exchange reaction

Equation: $Cu(H_2O)_4(OH)_2 + 4Cl^- \rightleftharpoons [CuCl_4]^{2-} + 2OH^- + 4H_2O$

3 (c) (ii) Black solid: CuO

Type of reaction: Thermal decomposition

3 (d)



3 (e) (i) $K_{sp} = [Cu^{2+}][OH^-]^2$

3 (e) (ii) Let s be the solubility of $Cu(OH)_2$
$2.00 \times 10^{-19} = (s)(2s)^2 = 4s^3$
$s = 3.68 \times 10^{-7}$

$[OH^-] = 2s = 7.368 \times 10^{-7}$

$pOH = -\lg (7.368 \times 10^{-7}) = 6.13$

pH = **7.87**

4 (a) (i) High Temperature and low pressure

4 (a) (ii) M is a ideal gas. Since pV= nRT for an ideal gas, $\frac{pV}{RT} = n$. Since there is negligible intermolecular forces of attraction and n is a constant value, the graph is a horizontal line (remains unchanged) as p increases.

L is a gas with significant intermolecular forces. At low pressure, gas particles are further apart and the intermolecular forces are negligible, hence L behave closely as an ideal gas. However, as pressure increases, gas particles are closer, and the intermolecular forces are more significant. This causes $\frac{pV}{RT}$ value of L to deviate from idea gas.

4 (b) $pV = nRT$
$pV = \frac{mRT}{M_r}$
$M_r = \frac{0.16 \times 8.31 \times (250+273)}{(150 \times 1000 \times 50.4 \times 10^{-6})}$ = 92.0 (no unit)

4 (c) (i)

	Anode (Anion/water) (Ox)	Cathode (Cation/water) (Red)
Aq $AgNO_3$	O_2	Ag
Conc. $CaBr_2$	Br_2	H_2

Thinking process
Recall: species with less positive E_{red} undergo oxidation at anode
Species with more positive E_{red} undergo reduction at cathode

For $AgNO_3$:

Anode: NO_3^-, H_2O
Relevant half equations:
NO_3^- do not undergo oxidation as O.S. of N is +5 (its maximum oxidation state).
$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$
Oxidation of H_2O occurs.

Cathode: Ag^+, H_2O
Relevant half equations:
$Ag^+ + e^- \rightleftharpoons Ag$ **$E^\ominus = +0.80$ V**
$2H_2O + 2e^- \rightleftharpoons H_2 + 2OH^-$ $E^\ominus = -0.83$ V
Reduction of Ag^+ occurs

For Conc. $CaBr_2$

Anode: H_2O, Br^-
Relevant half equations:
$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$ $E^\ominus = +1.23$ V
$Br_2 + 2e^- \rightleftharpoons 2Br^-$ $E^\ominus = +1.07$ V
Oxidation of Br^- occurs.

Cathode: Ca^{2+}, H_2O
Relevant half equations:
$2H_2O + 2e^- \rightleftharpoons H_2 + 2OH^-$ **$E^\ominus = -0.83$ V**
$Ca^{2+} + 2e^- \rightleftharpoons Ca$ $E^\ominus = -2.87$ V
Reduction of H_2O occurs even though high concentration of Ca^{2+} is present.

4 (c) (ii) At cathode: [R] $Cu^{2+} + 2e^- \rightarrow Cu$

Amount of Cu = $\frac{0.35}{63.5} = 0.0055$

$n_e = 2 \times 0.0055 = 0.0110$

Using $Q = I \times t$ and $Q = n_eF$ and $F = L \times e$

$I \times t = n_e \times L \times e$

$(0.500)(45 \times 60) = (0.0110) \times L \times (1.622 \times 10^{-19})$

$L = 7.66 \times 10^{23}$

---

4 (d) (i) The standard cell potential is the **potential difference between** the **two half-cells** measured at standard conditions (298 K, 1 bar for gases, and 1 mol dm^{-3} for aqueous ions).

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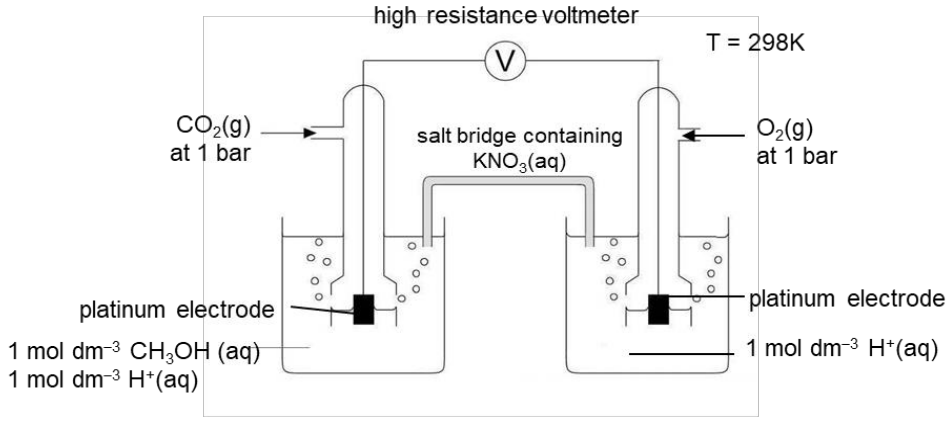
4 (d) (ii)



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4 (d) (iii) n = 6 (1 mol of CH_3OH loses 6 mol of electron)

$\Delta G^\ominus = -nFE^\ominus_{cell}$

$= (-6 \times 96500 \times 1.61)$

$= -9.32 \times 10^5$ J mol^{-1} or -932 kJ mol^{-1}

---

4 (e) $E^\ominus(MnO_4^-/Mn^{2+}) = +1.52$ V

$E^\ominus(Sn^{4+}/Sn^{2+}) = +0.15$ V

$E^\ominus(Pb^{4+}/Pb^{2+}) = +1.69$ V

For reaction between MnO_4^- and Sn^{2+}, MnO_4^- undergoes reduction and Sn^{2+} undergoes oxidation.

$E^\ominus_{cell} = E^\ominus(MnO_4^-/Mn^{2+}) - E^\ominus(Sn^{4+}/Sn^{2+}) = +1.52 - 0.15 = +1.37$ V > 0

Hence reaction will take place.

For reaction between MnO_4^- and Pb^{2+}, MnO_4^- undergoes reduction and Pb^{2+} undergoes oxidation.

$E^\ominus_{cell} = E^\ominus(MnO_4\text{-}/Mn^{2+}) - E^\ominus(Pb^{4+}/Pb^{2+}) = +1.52 - 1.69 = -0.17$ V < 0

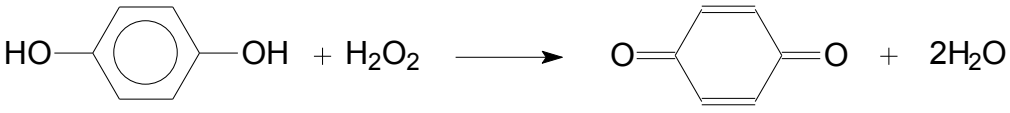
Hence reaction will not take place.

Cannot use $E^\ominus(Sn^{2+}/Sn)$ or $E^\ominus(Pb^{2+}/Pb)$ as $KMnO_4$ undergo reduction and hence the other reactants in the reaction (ie Sn^{2+} or Pb^{2+}) has to undergo oxidation.

4 (f) (i) $H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O \quad E^\ominus(H_2O_2/H_2O) = +1.77\ V$

$E^\ominus_{cell} = +1.77 - 0.70 = +1.07\ V$

Equation:



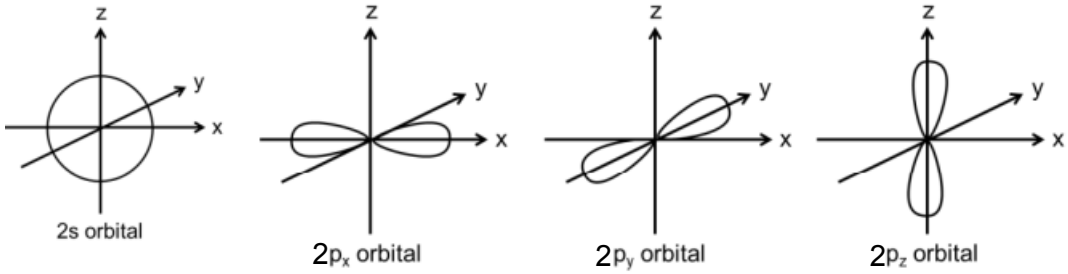
4 (f) (ii)

$$pH = (E^\ominus - E) \times \frac{nF}{2.303\,RT}$$

$$pH = (0.70 - 0.51) \times \frac{2 \times 96500}{2.303 \times 8.31 \times 298}$$
$$= 6.43$$

4 (g) 4-chloro-3,5-dimethylphenol

5 (a)



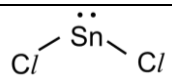
Any one of the 2p orbitals

Note: electronic configuration of B is $1s^2\ 2s^2\ 2p^1$. Occupied orbitals in outer shell are 2s and 2p

5 (b) (i) VSEPR theory states that electron regions (bond pairs and lone pairs) around the central atom arrange themselves to be as far apart as possible to minimise mutual repulsion.

Ther are 3 bond pairs regions in BCl_3, hence the shape is trigonal planar and the bond angle is 120°.

5 (b) (ii)

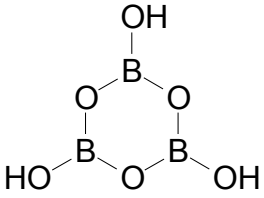


$SnCl_2$ has 2 bond pair regions and 1 lone pair region.
Since lone pair-bond pair repulsion is greater than bond pair-bond pair repulsion, $SnCl_2$ has a smaller bond angle of 118 ° and is bent in shape.

5 (c) (i) $BCl_3 + 3H_2O \rightarrow H_3BO_3 + 3HCl$

5 (c) (ii) Note: $3H_3BO_3 \rightarrow H_3B_3O_6 + 3H_2O$

Condensation reaction



5 (d) (i) A buffer solution is a solution that resists changes in pH when small amounts of an acid or a base are added.

5 (d) (ii) Amount of $H_3BO_3 = \frac{75}{1000} \times 0.02 = 0.0015$

Let the amount of NaOH used be x mol

	H_3BO_3	$+ OH^-$	$\rightarrow$	$H_2BO_3^-$	$+ H_2O$ (*l*)
Initial / mol	0.0015	x (L.R.)		0	–
Change / mol	–x	–x		+x	–
Final / mol	0.0015 – x	0		x	–

$$pH = pK_a + \lg \frac{[H_2BO_3^-]}{[H_2BO_3]}$$

$$8.8 = 9.27 + \lg \frac{[H_2BO_3^-]}{[H_2BO_3]}$$

$$\frac{[H_2BO_3^-]}{[H_2BO_3]} = 0.338$$

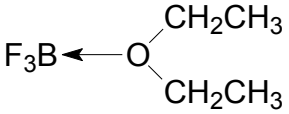
$$\frac{\frac{x}{V}}{\frac{0.0015 - x}{V}} = 0.338$$

$x = 0.000507 - 0.338x$
$1.338\ x = 0.000507$
$x = 0.0003789$ mol

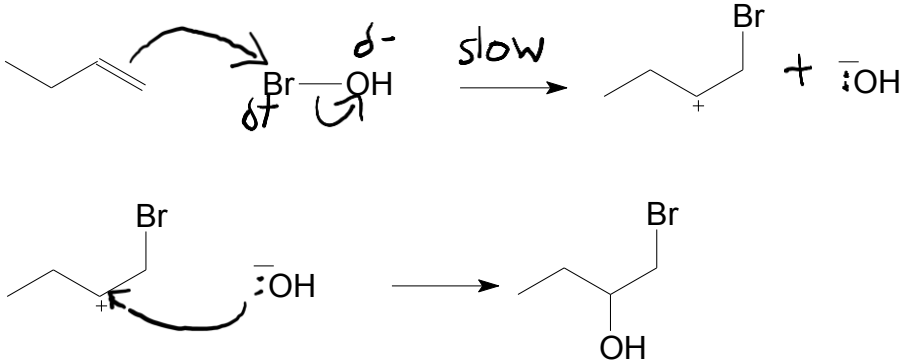
Volume of NaOH used $= \frac{0.0003789}{0.0300} = 12.6\ cm^3$

5 (e) (i) There are only 6 electrons in the valence shell of BF_3 after bonding. There is presence of an energetically accessible p orbital in its valence shell to accept an electron pair from ethoxyethane.

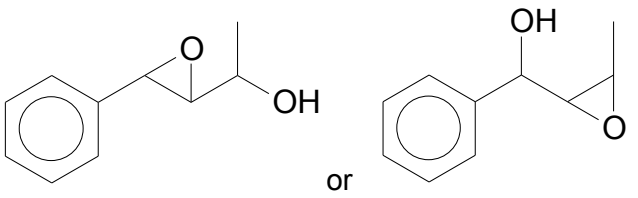
5 (e) (ii)



5 (f) (i)



5 (f) (ii)



5 (f) (iii) Nucleophilic substitution

Note: O^- acts as the nucleophile to attack the electron deficient C in C–Br via intramolecular reaction.