

Suggested Solutions to N2010 H2 Chemistry Paper 1 (9746/01)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
B	B	B	D	B	C	A	A	D	A	B	D	C	B	C	B	C	C	B	C
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
D	B	B	D	D	A	B	C	C	D	A	B	A	B	C	B	C	A	A	C

Working for Suggested Solutions to N2010 H2 Chemistry Paper 1 (9746/01)

Q1

Element	Br	K	Kr	Sc
Covalent Radius/nm	0.114	0.196	0.117 (in KrF ₂)	0.144

Atomic radii should fall across the period with increasing effective nuclear charge. This is because across the period, nuclear charge increases but shielding effect does not increase as significantly. Thus K has the largest atomic radius.

Ans: B

Q2 Amt of CO₂ = $\frac{1.1 \times 10^7}{22.7} = 4.85 \times 10^5$ mol
 since 3 mol of CO₂ gives 2 mol of Na₂CO₃
 Amt of Na₂CO₃ = $\frac{4.85 \times 10^5}{3} \times 2 = 3.23 \times 10^5$ mol

Mass of Na₂CO₃ = $3.23 \times 10^5 \times 106.0$
 = 3.42×10^7 g

Ans: B

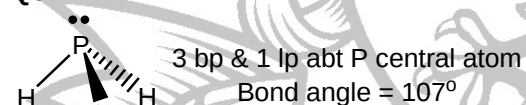
Q3

No of neutrons in $^{210}_{84}\text{Po}$ = 210 – 84 = 126
 He nucleus contains 2 neutrons & 2 protons
 No of neutrons in X = 126 – 2 = 124
 No of protons in X = 84 – 2 = 82
 Ans: B

Q4 The interaction between gecko's toe pads and the glass surface is van der Waals' forces, depends on surface area (millions of microscopic hairs) and is a reversible process.

Ans: D

Q5



Ans: B

Q6

MgO has similar ionic lattice structure to NaCl. Each ion is surrounded by six oppositely charge ions (co-ordination number = 6), held by electrostatic forces of attraction.

Ans: C

Q7

NH₃ has the more significant and strongest intermolecular interactions (hydrogen bonding) amongst the 4 gases of the 4 options. The other 3 gases are non-polar covalent simple molecules, thus they have van der Waals' forces of interactions.

Ans: A

Q8

- (A) Enthalpy change of atomisation, ΔH_{atm} , involves the liberation of gaseous atoms from elements in standard states. This means breaking of bonds between atoms and always be endothermic
- (B) Enthalpy change of combustion, ΔH_{c} , is the enthalpy change when one mole of substance undergoes complete combustion in excess oxygen. Combustion is usually exothermic, but occasionally endothermic, for example, in N₂.
- (C) Enthalpy change of formation, ΔH_{f} , is the enthalpy change when one of substance is formed from its constituent elements at their standard states. Whether ΔH_{f} is exothermic or not, it depends on the relative stability of the substance to be formed and its constituent elements in their standard states.
- (D) $\Delta H_{\text{soln}} = \Delta H_{\text{hyd}} - \text{L.E.}$ Whether ΔH_{soln} is exothermic or not, it depends on the relative magnitude of ΔH_{hyd} and L.E.

Ans: A

Q9 According to Arrhenius eqn, $k = A \exp(-E_a/RT)$, rate constant, k , increases in the presence of catalyst as the E_a is decreased. Energy profile should show lower E_a (energy difference between reactant & transition state). However, ΔH should be the same since reactants & products are the same, thus product level should be at 5, not lower than 5.

Ans: D

Q10

When steam condenses at its boiling point of 100°C (373 K), $\Delta G = 0$ since dynamic equilibrium exist when $\text{H}_2\text{O(g)} \rightleftharpoons \text{H}_2\text{O(l)}$

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

$$0 = -44 \text{ kJ mol}^{-1} \left(\frac{54}{18.0} \text{ mol} \right) - (373 \text{ K})(\Delta S)$$

$$\Delta S = \frac{-132}{373} = -0.354 \text{ kJ K}^{-1} = -354 \text{ J K}^{-1}$$

Ans: A

Q11

Strongest reducing agent has the greatest tendency to be oxidized, i.e. either Fe^{2+} or Br^- . Since *reduction potential* $E^\ominus_{\text{Fe}^{3+}/\text{Fe}^{2+}}$ is less positive than $E^\ominus_{\text{Br}_2/\text{Br}^-}$, Fe^{2+} is more likely to be oxidized ($\text{Fe}^{2+} \rightarrow \text{Fe}^{3+}$, -0.77V) than Br^- ($\text{Br}^- \rightarrow \text{Br}_2$, -1.07V), thus Fe^{2+} is the strongest reducing agent.

Ans: B

Q12

Overall Eqn:



Since H^+ is produced, $[\text{H}^+]$ increases, causing pH to decrease generally.

Ans: D

Q13

	$\text{N}_2\text{O}_4(\text{g})$	$\rightleftharpoons$	$2\text{NO}_2(\text{g})$
Initial P/atm	P		
Δ in P/atm	-0.5P		$+ \text{P}$
Eqm P/atm	0.5P		P
	$= \frac{1}{3}\text{atm}$		$= \frac{2}{3}\text{atm}$

Total P at eqm = 1 atm

$$1.5\text{P} = 1\text{atm}$$

$$\therefore \text{P} = \frac{2}{3}\text{atm}$$

$$K_p = \frac{(P_{\text{NO}_2})^2}{P_{\text{N}_2\text{O}_4}} = \frac{(\frac{2}{3}\text{atm})^2}{(\frac{1}{3}\text{atm})} = \frac{4}{3}\text{atm}$$

Ans: C

Q14

$$\text{Charge Density} \propto \frac{q^+}{r^+}$$

$$(A) \frac{q^+}{r^+} \text{ of } \text{Mg}^{2+} = \frac{+2}{0.065\text{nm}} = 30.8$$

$$(B) \frac{q^+}{r^+} \text{ of } \text{Al}^{3+} = \frac{+3}{0.050\text{nm}} = 60.0$$

$$(C) \frac{q^+}{r^+} \text{ of } \text{Fe}^{3+} = \frac{+3}{0.064\text{nm}} = 46.9$$

(D) SiCl_4 hydrolyses completely in water to give $\text{Si}(\text{OH})_4(\text{s})$ or $\text{SiO}_2 \cdot 2\text{H}_2\text{O}(\text{s})$, hence $\text{Si}^{4+}(\text{aq})$ will not exist in aqueous solution.

Ans: B

Q15

(A) Si, not P, has the highest melting pt in Period III.

(B) Like P, S can also form 2 acidic oxides, SO_2 and SO_3 .

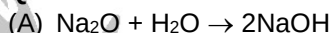
(C) P can form P_4 molecule. Other simple molecules in Period III are S_8 and Cl_2 .

(D) Like P, Si can also form chloride that hydrolyses completely in H_2O to form acidic soln.

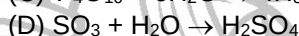


Ans: C

Q16



(B) SiO_2 is insoluble, with giant molecular structure and all atoms are linked by strong covalent bonds.



Ans: B

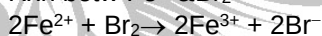
Q17 Examine if halogen can oxidize $\text{Fe}(\text{II})$ to $\text{Fe}(\text{III})$

Rxn betw Fe^{2+} & Cl_2



$$E^\ominus = +1.36 - (+0.77) = +0.59\text{V} > 0 \text{ (feasible)}$$

Rxn betw Fe^{2+} & Br_2



$$E^\ominus = +1.07 - (+0.77) = +0.30\text{V} > 0 \text{ (feasible)}$$

Rxn betw Fe^{2+} & I_2



$$E^\ominus = +0.54 - (+0.77) = -0.23\text{V} < 0 \text{ (not feasible)}$$

Ans: C

Q18

A **transition element** is defined as a d-block element which can form one or more stable ions with a partially filled d sub-shell. The rest of the 3 options are merely properties of transition elements.

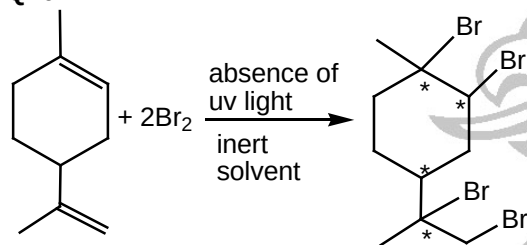
Ans: C

Q19

C_1 and C_2 are sp^1 hybridised and C_3 is sp^3 hybridised. sp orbitals have higher "s character" than sp^2 and sp^3 hybrid orbitals. Thus electrons in sp orbitals are more strongly attracted to the nucleus than sp^2 or sp^3 orbitals. Hence bonds formed via sp orbitals are stronger than sp^2 or sp^3 orbitals

Ans: B

Q20



Ans: C

Q21

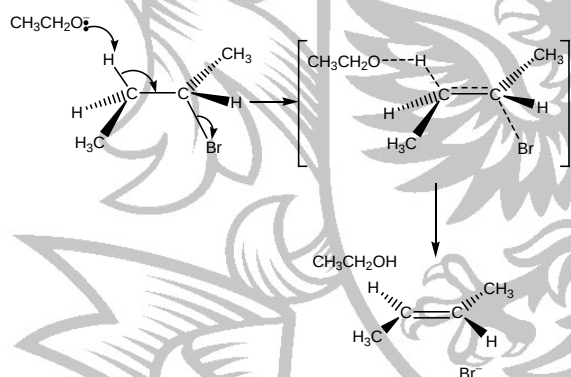
- (A) The C=C is unlikely to remain intact upon free radical substitution.
- (B) C-F bond is extremely strong due to small atomic size of F atom which leads to effective overlapping of orbitals. Thus F⁻ is not readily replaced by NH₃ to undergo nucleophilic substitution.
- (C) CH₃ is 2,4-directing, thus NO₂⁺ is unlikely to be substituted in position 3 in the benzene ring.
- (D) CH₃CH₂ is 2,4-directing, thus Br⁺ is likely to be substituted in position 4 in the benzene ring as the major product.

Ans: D

Q22

- (A) HI in aqueous medium implies large excess of H₂O which can be added across C=C bond to form CH₃CH₂CH(OH)CH₃ as major product instead.
- (B) Sodium ethoxide in alcoholic medium acts as base, favours elimination of HBr to form but-2-ene by Elimination mechanism. (This is the "active species" in the use of alcoholic KOH or NaOH, the detailed mechanism is not in syllabus.)

Elimination (E2) mechanism (Not in syllabus)



- (C) AlCl₃ is rapidly hydrolysed by water. The hydrated Al³⁺ ion will not be able to generate Cl⁺ electrophile (not electron deficient to function as a Lewis acid to extract Cl⁻ from Cl₂).
- (D) Cl₂ in aqueous medium cannot undergo homolytic fission to generate Cl[•] radicals. Both Cl₂ and cyclohexane must be in same physical

state (gaseous state) to undergo free radical substitution.

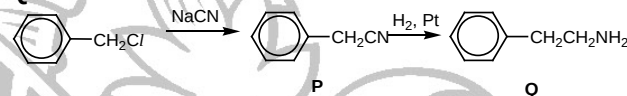
Ans: B

Q23

X only undergoes nucleophilic substitution only when heated, thus X must be a halogenoalkane and not acyl halide, as heating is required to break C-X bond. X is Cl as white ppt of AgCl is formed upon addition of AgNO₃(aq). Chlorobenzene is not possible as the C-Cl bond has double bond character and cannot undergo nucleophilic substitution.

Ans: B

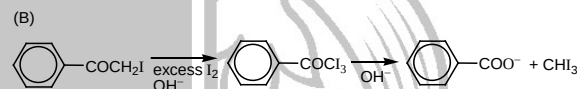
Q24



Ans: D

Q25

CH₃CH(OH)R and CH₃COR give CHI₃ from tri-iodomethane test (hot NaOH(aq) and I₂(aq)). Option D (Cl₃CO₂CH₃) is an ester, thus it does not give positive tri-iodomethane test. In the iodoform test, the 3 hydrogen atoms of the methyl ketones being replaced by 3 iodine atoms, then loses -CI₃ to give tri-iodomethane.

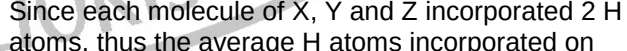
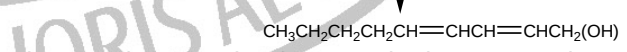
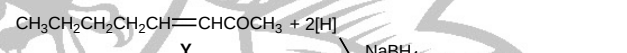
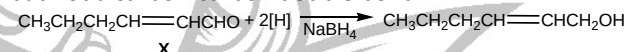


Iodine is an oxidising agent and an alcohol can give positive tri-iodomethane test if it oxidises to methyl ketone.



Ans: D

Q26 NaBH₄ can only reduce aldehydes and ketones, but not a carbon-carbon double bond.



Since each molecule of X, Y and Z incorporated 2 H atoms, thus the average H atoms incorporated on average per molecule is also 2.0. Ans : A

Q27

Only the phenol and carboxylic acid functional groups can react with NaOH(aq) to form phenoxide and carboxylate salt. The alcohol is not acidic enough to react with NaOH(aq), thus it does not react with NaOH(aq).

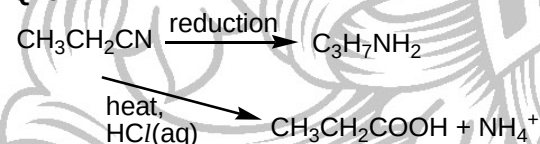
Ans: B

Q28

The question was not only about correct methods of preparing an ester; it was also a test of the knowledge of nomenclature

- (A) ester formed is ethyl 3-methylbutanoate
 (B) ester formed is methyl 4-methylpentanoate
 (C) ester formed is 3-methylbutyl ethanoate
 (D) ester formed is 2-methylbutyl ethanoate

Ans: C

Q29

Ans: C

Q30

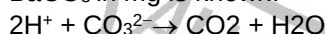
The conversion of proteins into peptides and amino acids involves the hydrolysis of the amide(peptide) groups. Proteins can be hydrolysed by heating with strong acids (acidic hydrolysis), heat with strong alkali (alkali hydrolysis) or by action of enzymes such as trypsin.

Ans: D

Q31

- Back titration involving use of excess acid enables the total amt of carbonate to be known as both MgCO_3 and BaCO_3 will react with HCl.
- As both MgCO_3 and BaCO_3 will react with HCl to give CO_2 , H_2O and salt. The total amt of CO_2 (based on volume of CO_2 obtained) determines the total amt of MgCO_3 and BaCO_3 .

For options 1 & 2, since total mass of mixture is known and let it be m g. Let the mass of MgCO_3 be x g and mass of BaCO_3 be (m - x)g. From options 1 & 2, total amt of MgCO_3 and BaCO_3 in mg is known.



Total amt of $\text{CO}_3^{2-} =$

$$\left(\frac{x}{\text{Mr of MgCO}_3} \right) + \left(\frac{m-x}{\text{Mr of BaCO}_3} \right)$$

- Back titration involving use of excess acid enables the total amt of carbonate to be known as both MgCO_3 and BaCO_3 will react with HCl. Addition of H_2SO_4 will precipitate Ba^{2+} as BaSO_4 , a white ppt, thus amt of BaCO_3 can be determined.

Ans: A

Q32

Two of the bonds are dative from nitrogen atoms (lone pair of electrons donated from N to Mg). Dative bond is σ bonding as bonding electrons are overlapped along the axis joining the two nuclei. Option 3 is incorrect, sp^3 hybridization requires a tetrahedral, not square planar geometry.

Ans: B

Q33

- Dissolving solute in solvent involves mixing of 2 different types of chemical substances, leading to more ways of arrangement of particles, thus leading to greater disorderliness.
- Evaporation of solvent from solution involves change of physical state from liquid to vapour state, thus leading to greater disorderliness.
- When solvent pass through a semi-permeable membrane, it is diffusing to a region where the solvent concentration is lower (where the solute is more concentrated). This clearly would lead to an increased dispersion of the solute in its solution and an increase in entropy.

Ans: A

Q34

- Rate eqn for 1st rxn is inversely proportional to $[\text{HBr}]$. When HBr is formed, $[\text{HBr}]$ increases, rate of forward rxn decreases.
- Orders of rxn wrt to H_2 and I_2 are the same as the stoichiometric coefficients of H_2 and I_2 in the overall chemical equation.
- Insufficient information is conclusive about the generation of radicals in the mechanistic steps.

Ans: B

Q35

- SrSO_4 are insoluble, thus they cannot be absorbed or dissolved, thus not easily incorporated into human metabolism.
- Half life of 29 years means that a significant amount of radioactivity still remains after a long time (considering the lifespan of a human), with only half the activity lost after 29 years. This means that Sr that has been assimilated into the human body can continually irradiate surrounding cells for a long time and cause damage.
- Sr is below Ca, thus it can easily replace Ca compounds in human metabolism, and most importantly, be incorporated into the body in

bones. This means Sr will be absorbed and accumulated, causing great damage to the cells, in particular, cell in the bone marrow.

Ans: C

Q36

1. Silver ethanoate is the white ppt formed when sodium ethanoate and silver nitrate are mixed.
2. AgBr, the cream ppt, remains despite addition of sodium ethanoate to AgBr. This implies that formation of AgBr is more likely than silver ethanoate since AgBr is less soluble than silver ethanoate.
3. There is no redox reaction involved.

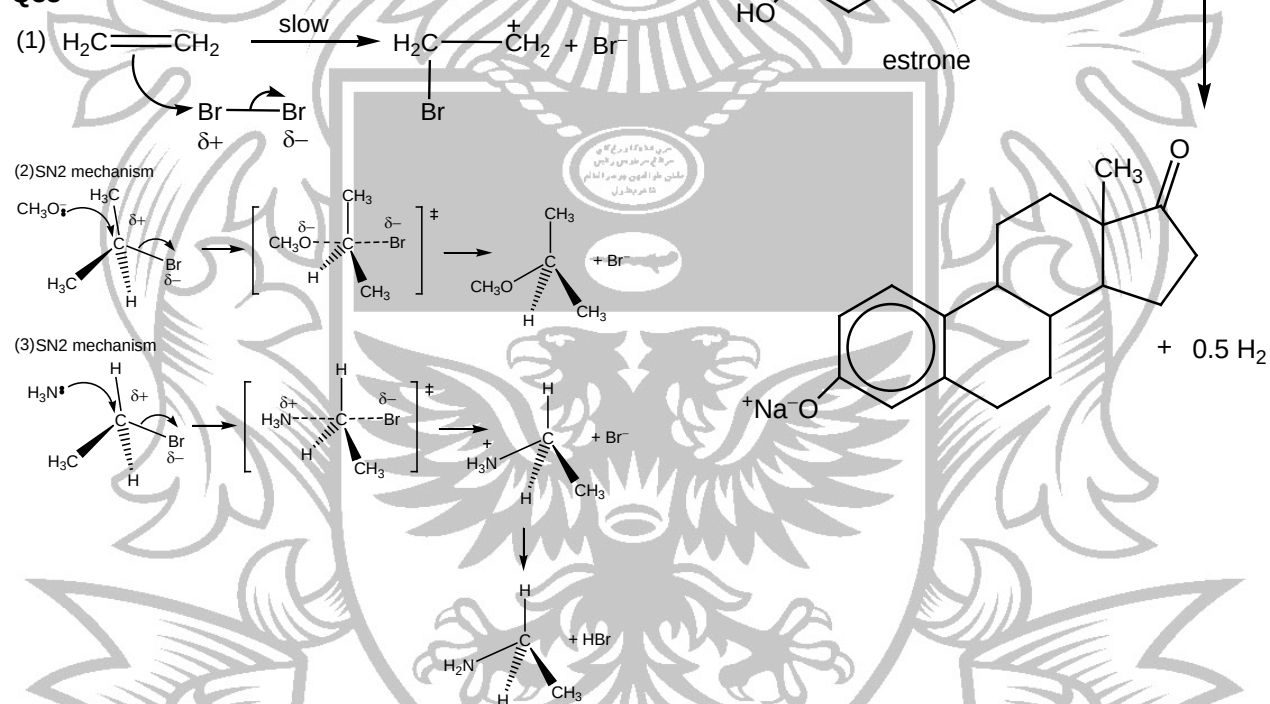
Ans: B

Q37

1. Electrophilic substitution where NO_2^+ is the electrophile that is substituted at the benzene ring.
2. Nucleophilic substitution where Br^- is replaced by OH^- .
3. Nucleophilic substitution where Cl^- is replaced by NH_3 .

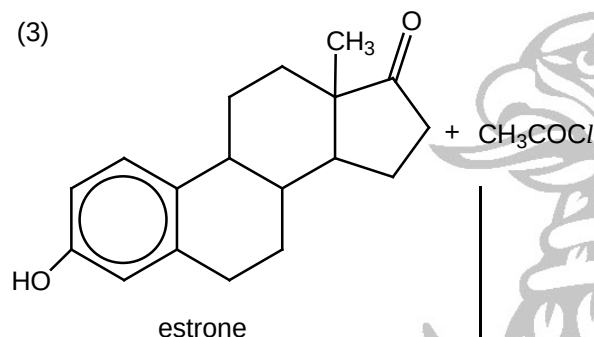
Ans: C

Q38



Ans: A

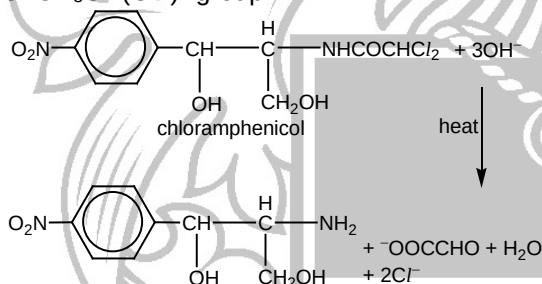
(3)



Ans: A

Q40

1. It does not give positive tri-iodomethane test due to absence of $\text{CH}_3\text{CO}-$ group (in ketone or ethanal) or $\text{CH}_3\text{CH}(\text{OH})-$ group.

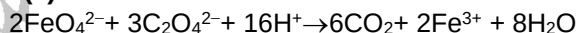


2.
3. Due to presence of alkyl side chain or presence of primary alcohol and secondary alcohol, chloramphenicol can be oxidised by H^+/KMnO_4 on warming.

Ans: C

Suggested Solns for N2010 H2 Chemistry Paper 2 (9746/02)

Experimental Planning

1(a)**1(b)**

For titration of FA1 ($\text{K}_2\text{FeO}_4(\text{aq})$) in conical flask against FA2 ($\text{Na}_2\text{C}_2\text{O}_4(\text{aq})$) burette)

With the given concentration of $0.100 \text{ mol dm}^{-3}$, the titre volume (of FA2) will exceed 50 cm^3 which is the maximum capacity of a laboratory burette. Hence, careful refilling of the burette is required.

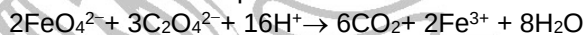
OR

For titration of FA2 ($\text{Na}_2\text{C}_2\text{O}_4(\text{aq})$) in conical flask against in FA1 ($\text{K}_2\text{FeO}_4(\text{aq})$) in burette)

With the given concentration of $0.100 \text{ mol dm}^{-3}$, the titre volume (of FA1) will be approximately 7 cm^3 which will result in inaccuracy in terms of volume measurements.

1(c)**Pre-calculations**

Let volume of 1 drop be $x \text{ dm}^3$.



10 drops 32 drops

Amt of $\text{C}_2\text{O}_4^{2-}$ in 32 drops = $0.100 \times x \times 32 = 3.2x \text{ mol}$

Amt of FeO_4^{2-} in 10 drops = $\frac{2}{3} \times 3.2x = 2.13x \text{ mol}$

Approx conc of $\text{FeO}_4^{2-} = \frac{2.13x}{10x} = 0.213 \text{ mol dm}^{-3}$

Amt of FeO_4^{2-} in $25 \text{ cm}^3 = \frac{25}{1000} \text{ dm}^3 \times 0.213 \text{ mol dm}^{-3} = 5.33 \times 10^{-3} \text{ mol}$

Assuming suitable titre vol to be 25.00 cm^3 ,

Suitable conc of $\text{C}_2\text{O}_4^{2-} = \left(\frac{5.33 \times 10^{-3}}{2} \times 3 \right) \div \frac{25}{1000} = 0.320 \text{ mol dm}^{-3}$

Molar mass of $\text{Na}_2\text{C}_2\text{O}_4 = 2(23.0) + 2(16.0) = 134.0 \text{ g mol}^{-1}$

Mass of $\text{Na}_2\text{C}_2\text{O}_4$ to be weighed for 250 cm^3 soln
 $= 134.0 \text{ g mol}^{-1} \times 0.320 \text{ mol dm}^{-3} \times \frac{250}{1000} \text{ dm}^3 = 10.7 \text{ g}$

OR

From the micro-titration, the ethanedioate needs to be $32/10 = 3.2$ times more concentrated, so that 25 cm^3 of FA1 will require 25 cm^3 of FA2

Thus the desired concentration of the $\text{Na}_2\text{C}_2\text{O}_4$ solution is $0.100 \times 3.2 = 0.32 \text{ mol dm}^{-3}$

The total volume of solution prepared is 250 cm³

Hence the mass of Na₂C₂O₄ required = 250/1000 x 0.32 x 134.0 = 10.72g

Procedures

For titration of FA2 (K₂FeO₄(aq) in conical flask) against in FA1(Na₂C₂O₄(aq) burette)

- Weigh 10.7 g of Na₂C₂O₄ in a clean and dry weighing bottle using a weighing balance.
- Transfer the Na₂C₂O₄ to a 250 cm³ beaker.
- Weigh the weighing bottle and the residual Na₂C₂O₄(s) to determine the mass of Na₂C₂O₄(s) dissolved by finding the difference the weighings in (i) and (iii).
- Add 100 cm³ of 1mol dm⁻³ of sulfuric acid to the Na₂C₂O₄ in the 250 cm³ beaker. Note that hydrochloric acid is not acceptable here as FeO₄²⁻ will oxidize the Cl⁻ ions from HCl(aq), resulting in inaccurate titre readings.
- Use a glass stirrer to stir the solution in the 100 cm³ beaker to ensure a homogeneous solution is obtained.
- Transfer the homogeneous solution carefully to a 250 cm³ volumetric flask.
- Using 100 cm³ of distilled water, rinse the beaker and the stirrer and transfer the washings carefully to the solution in the 250 cm³ volumetric flask.
- Top up to the mark with distilled water, stopper the bottle and shake this solution to obtain a homogeneous solution. Label this solution obtained as FA 2.
- Fill up the burette with FA 1(ferrate), noting the initial volume reading.
- Pipette 25.0 cm³ of FA 2 to a 250 cm³ conical flask.
- Carry out the titration until permanent pink colour is obtained. (Colour change is from pale yellow to pink due of 1 drop of dark red K₂FeO₄(aq) in excess)
- Repeat titration until at least 2 consistent titre readings are obtained (titre volume differ not more than 0.10 cm³). Use the average of these 2 consistent titres for subsequent calculations.

1(d) Amt of C₂O₄²⁻ in FA2 reacted = $\left(\frac{y}{1000} \times M\right)$ mol

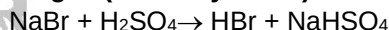
Amt of FeO₄²⁻ in FA1 reacted = $\left(\frac{yM}{1000} \times \frac{2}{3}\right)$ mol

Conc of FeO₄²⁻ in FA1 = $\frac{\left(\frac{yM}{1000} \times \frac{2}{3}\right) \text{mol}}{\frac{x}{1000} \text{dm}^3}$
 $= \frac{2yM}{3x} \text{mol dm}^{-3}$

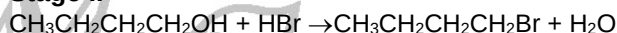
1(e) One potential safety hazard is the corrosive nature of the chemicals like sulfuric acid or toxicity of compounds containing FeO₄²⁻ or C₂O₄²⁻ that have high concentration. One way to minimize this risk is to wear gloves and lab-coats to avoid direct contact with these chemicals.

2(a)

Stage I (Not in syllabus)



Stage II



2(b)

$$\text{Amt of NaBr} = \frac{35\text{g}}{(23.0 + 79.9)\text{g mol}^{-1}} = 0.340 \text{ mol}$$

$$\text{Amt of butan-1-ol} = \frac{(25 \times 0.81)\text{g}}{(4 \times 12.0 + 10.0 + 16.0)\text{g mol}^{-1}} = 0.274 \text{ mol}$$

NaBr is in excess.

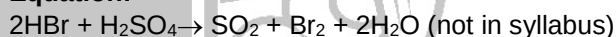
2(c)(i) Enthalpy change of reaction of solution of concentrated sulfuric acid is highly exothermic. Dilution of concentrated sulfuric acid liberates a lot of heat that can be sufficient to form steam, resulting in dangerous splashing of chemicals if cooling is not provided.

******Merely stating that the reaction is exothermic will not get any credit as it is just restating the question.

2(c)(ii)

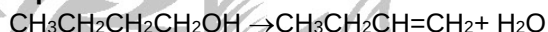
Inorganic By-product: Bromine, Br₂ (not in syllabus)

Equation:



Organic By-product: But-1-ene, CH₃CH₂CH=CH₂

Equation:



******Note that butene or but-2-ene is not acceptable.

Equation that is not balanced (eg. H₂SO₄ being included only on left hand side of arrow) is also not acceptable.

2(d)

Most organic reactions are slow as it involves breaking of strong covalent bonds. Also, most organic compounds have low boiling point and being hydrocarbon-based, are highly flammable, thus refluxing is recommended.

******Descriptions of the need to break intermolecular forces for reactions to occur are incorrect.

2(e)

Compounds are H₂O and butan-1-ol.

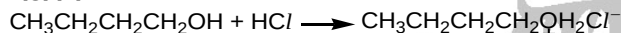
Reason: Their boiling points are very close to that of 1-bromobutane.

2(f)

1-bromobutane will be found in the lower layer.
This is because its density (1.35 g cm^{-3}) is higher than that of water (1.00 g cm^{-3}).
**Reference to M_r of 1-bromobutane is incorrect here.

2(g)(i) Concentrated HCl reacts with butan-1-ol

2(g)(ii) Protonation of alcohol has occurred.

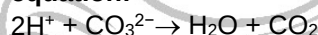


2(g)(iii)

The product in (ii) is an ionic salt that can form ion-dipole interaction with water molecules which is a stronger interaction than the hydrogen bonds that the original reactant can form with water molecules. ion-dipole interaction being a stronger interaction is more likely to overcome solute-solute interactions and solvent-solvent interactions, enabling the product to be soluble in water.

2(h)

impurity: excess concentrated HCl
equation:



2(i)

Water is removed when treated with anhydrous CaCl_2 .

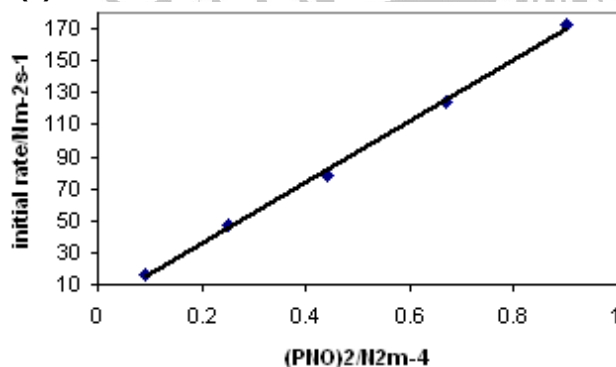
2(j)

Suitable range of temperature is from 99°C to 102°C .

** Wide temperature ranges like from 99°C to 1390°C will cause the glass apparatus used to crack or melt.

3(a) NO is a radical (as it has one odd electron on the nitrogen atom) that reacts with ozone, O_3 , in the stratosphere, giving O_2 gas, thus causing ozone depletion, resulting in increased surface UV radiation. NO causing acid rain is not acceptable here.

3(b)



Graph is expected to pass through origin.

3(c)

From the graph in **3(b)**, the initial rate of reaction is directly proportion to the square of the partial pressure of NO (p_{NO})², thus the order of reaction with respect to NO is 2.

**Answers such as 'Since the graphs is not a straight line, the reaction must be second order with respect to p_{NO} ' are not acceptable.

3(d) Gradient at each point on the graph is directly proportional to the instantaneous rate of reaction. When the partial pressure of O_2 is halved, the initial rate of reaction is halved. Thus, the rate of reaction is directly proportional to the partial pressure of O_2 , p_{O_2} . The order of reaction with respect to O_2 is 1.

3(e)(i) rate = $k(p_{\text{O}_2})(p_{\text{NO}})^2$

**Note that rate equation is expected to be written in terms of partial pressures rather than concentrations.

3(e)(ii) Units of rate constant, $k = \frac{\text{Nm}^{-2}\text{s}^{-1}}{(\text{Nm}^{-2})^3}$

$$= \frac{\text{Nm}^{-2}\text{s}^{-1}}{\text{N}^3\text{m}^{-6}} = \text{N}^{-2}\text{m}^4\text{s}^{-1}$$

4(a)(i) Magnitude of lattice energy, L.E., decreases from MgSO_4 to BaSO_4 .

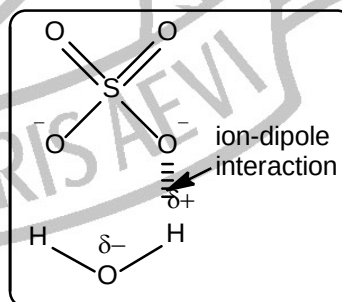
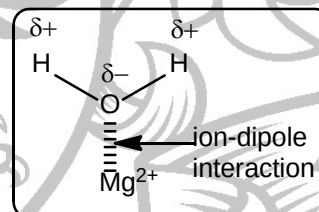
4(a)(ii) $|L.E.|\propto \left| \frac{q^+q^-}{r^+ + r^-} \right|$

From Data Booklet,

Group 2 Ion	Mg^{2+}	Ca^{2+}	Sr^{2+}	Ba^{2+}
Ionic radius/nm	0.065	0.099	0.113	0.135

The cationic radii of the Group metal cations increases from Mg^{2+} to Ba^{2+} while the other variables like the charges of the ions and the anionic radius of SO_4^{2-} remain constant. This results in the decreasing magnitude of L.E..

4(b)(i)



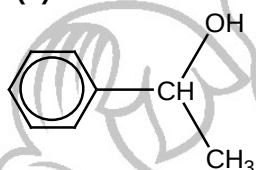
$$4(b)(ii) \Delta H_{\text{hydration}} \propto \frac{q^+}{r^+}$$

The higher the charge density of M^{2+} , the stronger polarizing power of the M^{2+} , the more exothermic $\Delta H_{\text{hydration}}$ is. As the charge of M^{2+} is the same (being +2) and the ionic radius of M^{2+} increases from Mg^{2+} to Ba^{2+} , thus charge density decreases Mg^{2+} to Ba^{2+} . Hence $\Delta H_{\text{hydration}}$ becomes less exothermic from Mg^{2+} to Ba^{2+} .

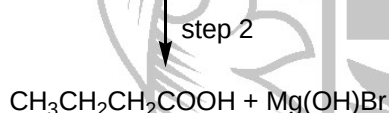
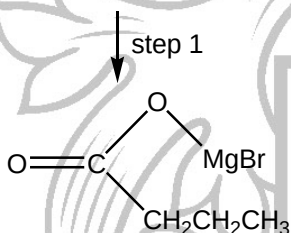
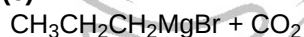
4(c)(i) Nucleophilic Addition
Note that addition is not acceptable.

4(c)(ii) Hydrolysis

4(d)



4(e)



5(a)(i)

The disruption of tertiary or quaternary structure of proteins by breaking the non-covalent interactions (but including disulfide links) that hold these structures in their native conformations.

5(a)(ii)

Any one method below will suffice

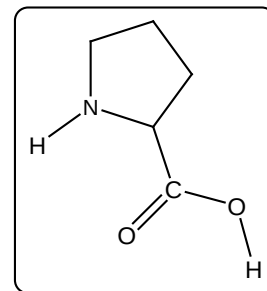
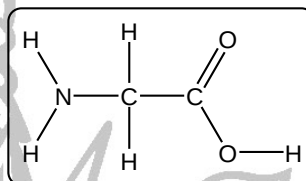
- Heat
- Changes in pH by addition of strong acids or strong alkali
- Addition of aqueous heavy metal ions such as Ag^+ or Pb^{2+}
- Mechanical agitation
- Organic solvents, detergents etc

** Note that conditions for the hydrolysis of collagen is not acceptable.

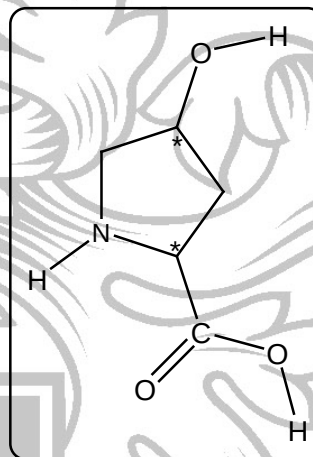
5(b)

6 different amino acids

5(c)(i)



5(c)(ii)

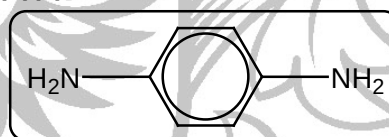


5(d)(i)

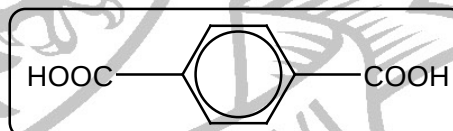
Any one method below will suffice

- Heat with strong acid for several hours
- Heat with strong alkali for several hours
- Enzymatic hydrolysis for several hours

5(d)(ii)



and

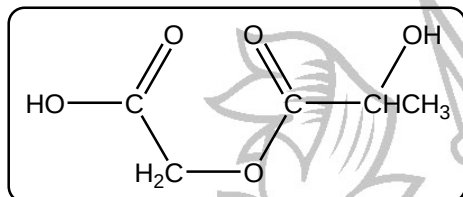
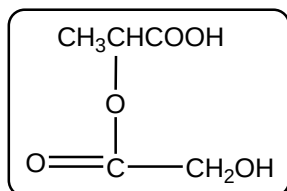


5(d)(iii)

The monomers of proteins are amino acids that generally have the same general formula of $H_2NCH(R)COOH$ which are naturally occurring while

the monomers of Kevlar® are dicarboxylic acids and diamines which are synthetic or man-made.

5(e)



5(f)(i)

Hydrolysis reaction

5(f)(ii)

The products of hydrolysis are hydroxyacids that are able to form extensive intermolecular hydrogen bonds with water molecules, enabling them to be soluble in water.

Suggested Solns for N2010 H2 Chemistry Paper 3 (9746/03)

1(a)(i)

Entropy (S) is a measure of the randomness or disorderliness of matter and energy of a system.

1(a)(ii)

- Entropy increases or change in entropy is positive ($\Delta S > 0$) as mixing of 1 mol of $\text{Cl}_2(\text{g})$ and 1 mol of $\text{N}_2(\text{g})$ occurs and the number of ways of arrangement of particles increases, increase in disorderliness occurs.
- Entropy increases as the increase in temperature causes the broadening of the Maxwell-Boltzmann energy distribution of the particle. Thus there are more ways of arranging "energy quanta" or more ways of distributing energy.
- Entropy decreases due to the decrease in amount of **gaseous** particles from 1 mol to 0 mol, causing decrease in disorderliness.
- Entropy increases due to the increase in amount of gaseous particles from 1 mol to 2 mol, causing increase in disorderliness.

1(b)(i)

Chlorine reacts **more quickly and explosively** with hydrogen gas than the reaction between bromine and hydrogen gas in the presence of ultraviolet light.

1(b)(ii)

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Fluorine reacts **more quickly and vigorously** with hydrogen gas under room temperature and pressure in the dark but hydrogen does not react with chlorine in the dark.

****Note that comparison in terms of rates of the reactions, and not the extent of reactions, are required for 1(b)(i) and 1(b)(ii).**

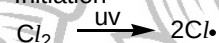
1(c)(i)

Ultraviolet light or heat

1(c)(ii)

Name of mechanism: Free Radical Substitution

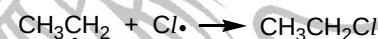
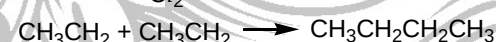
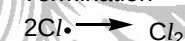
Initiation



Propagation



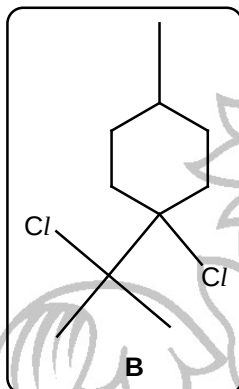
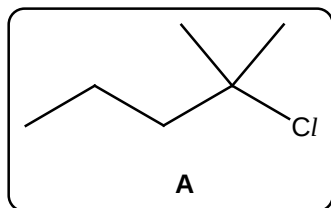
Termination



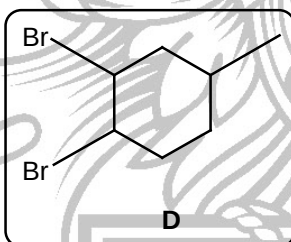
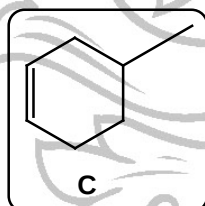
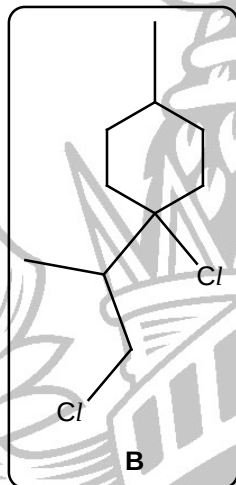
1(c)(iii)

The first propagation step is endothermic due to the relatively weaker H-I bond formed, thus it is energetically unfavourable to occur.

1(d)



OR



1(e)(i)

CFCs were used because they are normally chemically inert and non-toxic (making them safe and easy to use). They are also compounds that are liquefied under pressure and therefore volatilise readily when that pressure is released (making them useful as propellants and refrigerants, applications which require the vaporization of compounds).

1(e)(ii)

Ultraviolet radiation from the sun in the stratosphere photolyses the CFC molecules and this forms chlorine radicals (not fluorine radicals). This initiates a chain of reaction of destruction of ozone molecules.



Repeat (1) & (2).....

1(e)(iii)

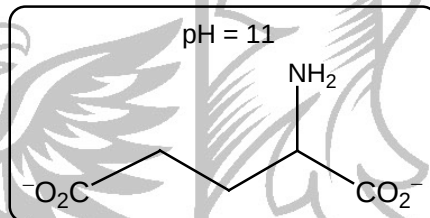
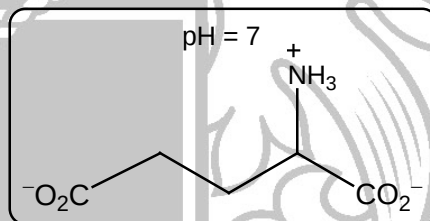
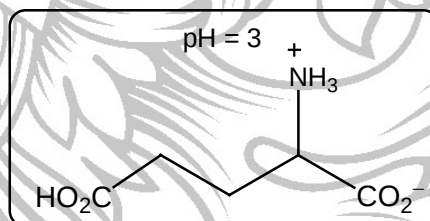
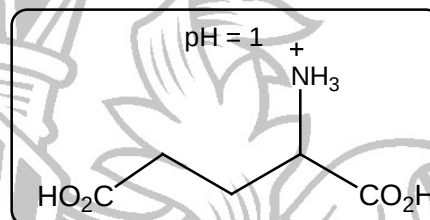
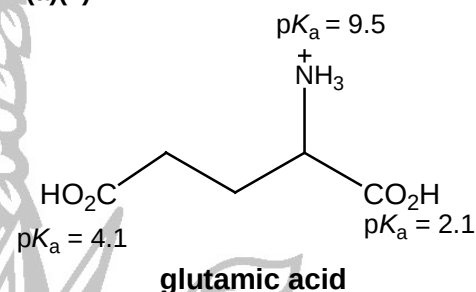
One potential hazard of the use of alkanes is that alkanes are highly flammable, catching fire easily.

2(a)(i)

pK_a is the negative logarithm to the base of 10 of the acid dissociation constant, K_a , of a weak acid. Given that $HA \rightleftharpoons H^+ + A^-$

$$pK_a = -\lg K_a \quad \text{where } K_a = \frac{[H^+][A^-]}{[HA]}$$

2(a)(ii)

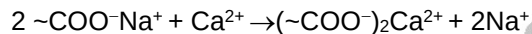


2(b)(i)

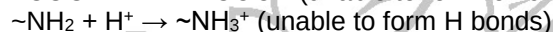
The tertiary structure or 3D arrangement due to folding of the protein, the quaternary structure and the secondary structure of the protein are altered. The folding or native conformation of the protein is held by side-chain interactions. During denaturation, these side-chain interactions that maintain the native conformation (hydrogen bonds, van der Waals interactions, ionic interactions and disulfide bonds) are broken or disrupted.

2(b)(ii)

$\text{Ca}^{2+}(\text{aq})$ cations compete with positively charged groups for attraction to negatively charged groups e.g. COO^- , hence disrupting the original ionic bonds. Resident metal ions in certain proteins may be displaced. This will cause the coagulation and precipitation of the protein.

**2(b)(iii)**

Weak acid disrupt ionic interactions by protonating either carboxylic anionic groups or amino groups in lysine by decreasing pH, thus causing the coagulation and precipitation of the protein.

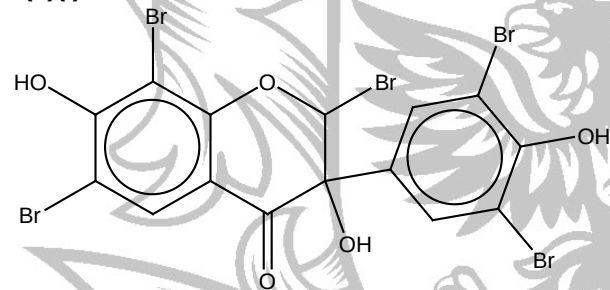
**2(b)(iv)**

GDL	+	H_2O	$\rightleftharpoons$	Gluconic acid
Initial conc/ mol dm^{-3}	1.00	50	55.5	0
	$\div$	178		
	$\div$	1000		
Δ in conc/ mol dm^{-3}	-0.0670			+ 0.0670
Eqm conc/ mol dm^{-3}	0.112 - 0.0670		55.5	0.0670
	= 0.0454			

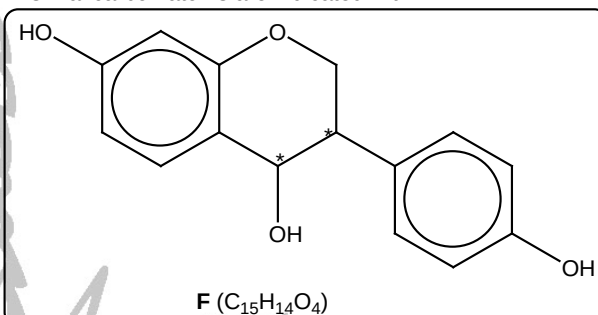
$$K_C = \frac{[\text{gluconic acid}]}{[\text{H}_2\text{O}][\text{GDL}]}$$

$$\therefore K_C = \frac{0.0670}{(0.0454)(55.5)} = 0.0266 \text{ mol}^{-1} \text{ dm}^3$$

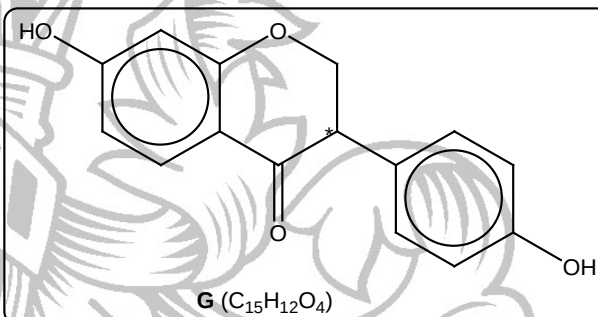
** Note that water is to be included in K_C expression.

2(c)(i)**2(c)(ii)**

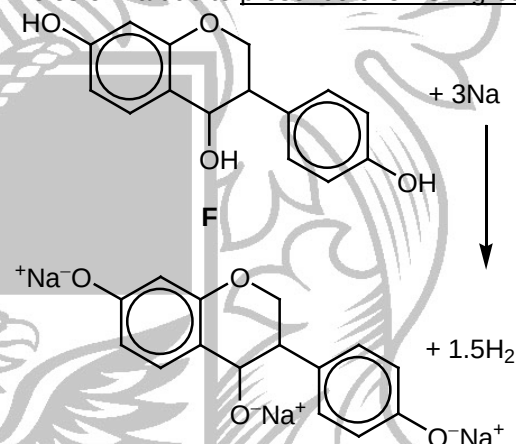
Chiral carbon atoms are indicated with *.



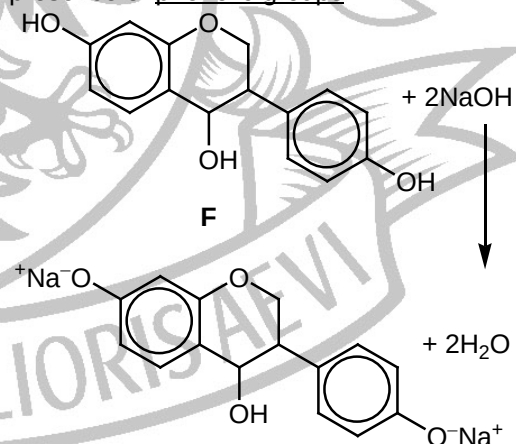
Chiral carbon atoms are indicated with *.



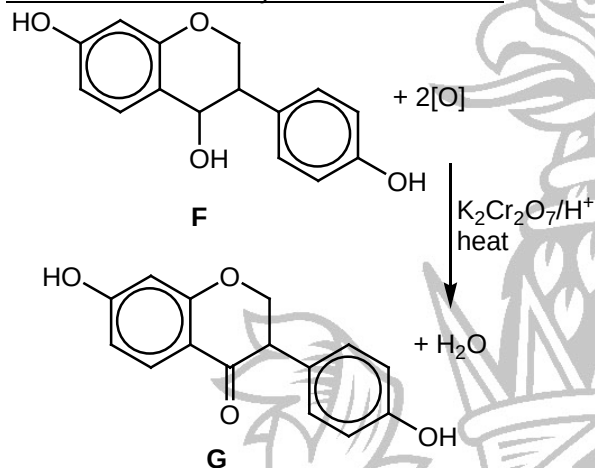
F undergoes redox rxn (or displacement rxn) with 3 moles of Na due to presence of 3 -OH groups.



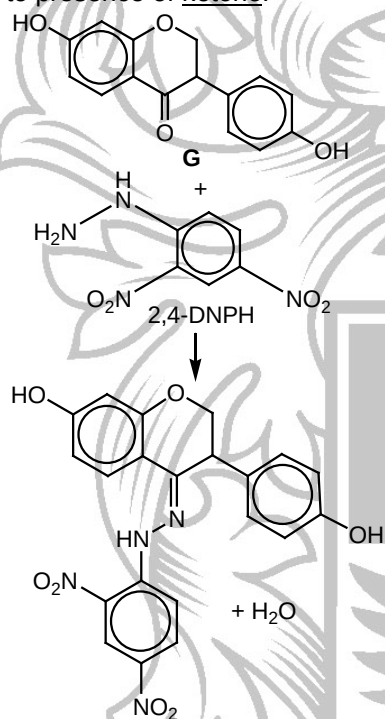
F undergoes acid-base rxn with NaOH(aq) due to presence of phenolic groups.



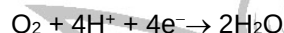
When heated with acidified $K_2Cr_2O_7$, **F** undergoes oxidation of secondary alcohol to a ketone in **G**.



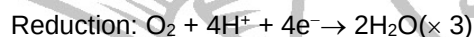
G undergoes condensation rxn with 2,4-DNPH due to presence of ketone.



3(a)(i)



3(a)(ii)



3(a)(iii)

$$+1.18 = +1.23 - E_{CO_2/CH_3OH}$$

$$E_{CO_2/CH_3OH} = +1.23 - (+1.18) = +0.05V$$

3(a)(iv)

Any one below will suffice.

- Methanol has a more efficient storage (by volume or by weight since it is a liquid) compared to compressed hydrogen gas.
- Hydrogen gas is volatile and explosive, thus requires high pressure storage system but not methanol.

3(b)(i)



3(b)(ii)

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

$$\Delta G = (-1367 \times 10^3) - (298)(-140)$$

$$= -1.33 \times 10^6 \text{ Jmol}^{-1} = -1330 \text{ kJmol}^{-1}$$

3(b)(iii)

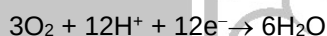
$$E^\ominus_{\text{cell}} = E^\ominus_{\text{red}} - E^\ominus_{\text{oxid}}$$

$$+1.18 = +1.23 - E^\ominus_{\text{oxid}}$$

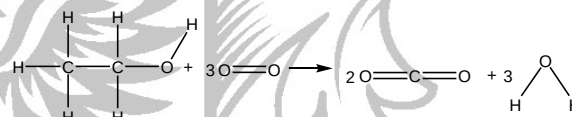
$$E^\ominus_{\text{oxid}} = E^\ominus_{CO_2/CH_3OH} = +1.23 - (+1.18) = +0.05V$$

$$E^\ominus_{\text{cell}} = \frac{-(-1.33 \times 10^6 \text{ Jmol}^{-1})}{12(96500 \text{ Cmol}^{-1})} = +1.15V$$

$Z = 12$ since complete combustion of 1 mol of CH_3CH_2OH uses 3 moles of $O_2(g)$ which is twice the amount of $O_2(g)$ used by complete combustion of 1 mol of CH_3OH .



3(c)(i)



$$\Delta H_r = \Sigma B.E. \text{ of bonds broken} - \Sigma B.E. \text{ of bonds formed}$$

$$= (5(410) + 360 + 460 + 3(496) + 350) - (4(805) + 6(460))$$

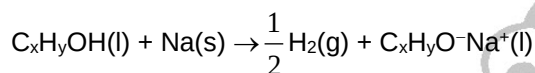
$$= -1272 \text{ kJmol}^{-1} \approx -1270 \text{ kJmol}^{-1}$$

3(c)(ii)

Any one below will suffice.

- Bond energies are average values.
- Enthalpy change of vaporization is not included in the calculations in **(c)(i)** as the physical state of ethanol, CH_3CH_2OH , is liquid at standard conditions.

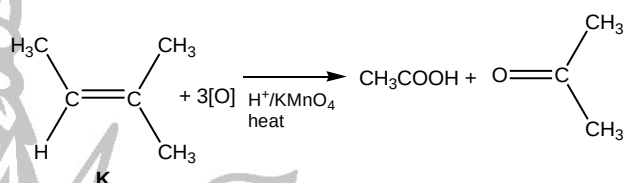
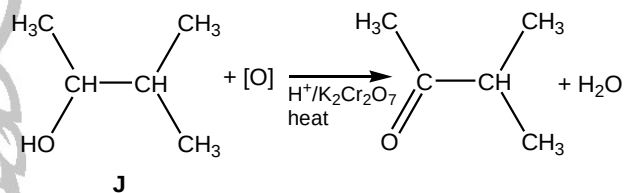
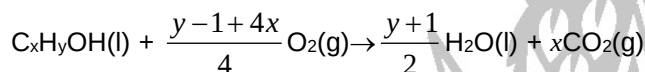
3(d)(i)



Amt of C_xH_yOH in $0.10\text{cm}^3 = 2 \times \text{Amt of } H_2$

$$= 2 \times \frac{10.9}{24000}$$

$$= 9.08 \times 10^{-4} \text{ mol}$$



Initial vol/ cm^3 –

A

Δ in vol/ cm^3 –

$$(21.8)\left(\frac{y-1+4x}{4}\right)$$

$$+21.8x$$

Final vol/ cm^3 –

$$(21.8)\left(\frac{y-1+4x}{4}\right)$$

109

$$\text{Vol of } CO_2 = 21.8x = 109 \Rightarrow x = 5$$

1st contraction in vol = Total initial vol – Total final vol

$$54.4 = A - (A - (21.8)\left(\frac{y-1+4x}{4}\right) + 109)$$

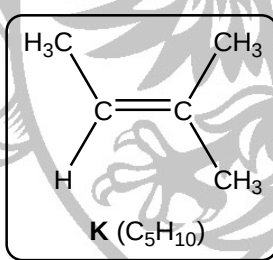
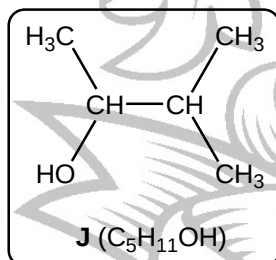
$$54.4 = A - (A - (21.8)\left(\frac{y-1+4(5)}{4}\right) + 109)$$

$$54.4 = (21.8)\left(\frac{y-1}{4}\right) - 109 + 109$$

$$54.4 = 5.45y - 5.45$$

$$y = \frac{54.4 + 5.45}{5.45} = 11$$

3(d)(ii)



J is a secondary alcohol that can be oxidised to a ketone by hot acidified $K_2Cr_2O_7$.

3(d)(iii)

Excess concentrated H_2SO_4 , $170^\circ C$

3(d)(iv)

K cannot exhibit cis-trans isomerism due to two identical CH_3 groups that are bonded to one of the doubly-bonded carbon atom.

4(a)

Nucleon number is the total number of protons and neutrons in the atomic nucleus.

4(b)

Electrons will be deflected towards the positively charged electrode (anode) and protons will be attracted towards the negatively charged electrode (cathode).

Due to its relative smaller mass, electrons will have a greater angle of deflection than protons.

4(c)(i)



4(c)(ii)

For O_3 2 bp and 1 lp about central O atom, thus the basic angle is 120° . However, a lone pair is closer to the oxygen (or occupy a larger volume) than a bond pair. Hence the bond angle is diminished to something less than 120° .

$\therefore$ Bond angle in O_3 = approximately $110^\circ - 117^\circ$

For NO_2 2 bp and 1 odd unpaired electron about central N atom, a single unpaired electron will be less effective in diminishing the basic angle (of 120°). Hence, the bond angle for NO_2 should be greater than that for O_3 . $\therefore$ Bond angle in NO_2 = approximately $121^\circ - 130^\circ$

4(c)(iii)

Reason 1

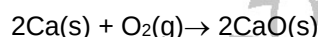
Fluorine is a Period II element that cannot expand its octet configuration while chlorine can expand its octet due to availability of vacant low-lying 3d-orbital.

Reason 2

Fluorine is more electronegative than oxygen, thus it is too electronegative to donate its lone pair of electrons to form dative covalent bonds with oxygen atom.

4(d)(i)

Heat calcium metal in a jar of oxygen gas.

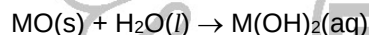


Red (or brick-red) flame is observed *during* the reaction.

****Note** that white precipitate of CaO is observed only *after* the reaction.

4(d)(ii)

This is due to increased solubility of Group 2 hydroxides in water down the group, resulting in increased concentration of hydroxide ions.

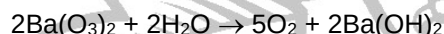


Solubility of Group 2 hydroxides depends on how exothermic enthalpy change of solution is. Since $\Delta H_{\text{soln}} = \Delta H_{\text{hyd}} - \Delta H_{\text{LE}}$ and cationic radius of M^{2+} increases down the group, $|\Delta H_{\text{hyd}}|$ and $|\Delta H_{\text{LE}}|$

decrease down the group. $\Delta H_{\text{hyd}} \propto \frac{q^+}{r^+} + \frac{q^-}{r^-}$

$\Delta H_{\text{LE}} \propto \frac{q^+ q^-}{r^+ + r^-}$ Since anionic radius of OH^- is much smaller than the cationic radius of M^{2+} , the decrease in the magnitude of ΔH_{LE} is smaller than the decrease in magnitude of ΔH_{hyd} . Hence, ΔH_{soln} of M(OH)_2 becomes more exothermic down the group.

4(e)



4(f)(i)

$$\text{Amt of I}_2 = \frac{1}{2} \times \text{Amt of Na}_2\text{S}_2\text{O}_3$$

$$= \frac{1}{2} \times \frac{15}{1000} \times 0.100 = 7.50 \times 10^{-4} \text{ mol}$$

4(f)(ii)

$$\begin{aligned} \text{Amt of I}_2 &= \text{Amt of O}_3 \\ &= 7.50 \times 10^{-4} \text{ mol} \end{aligned}$$

$$\text{Amt of O}_3 = 7.50 \times 10^{-4} \times 22400 = 16.8 \text{ cm}^3$$

$$\text{Percentage of O}_3 = \frac{16.8}{500} \times 100\% = 3.36\%$$

4(g)(i)

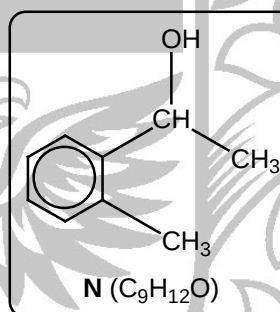
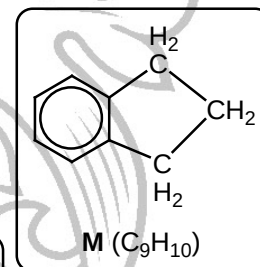
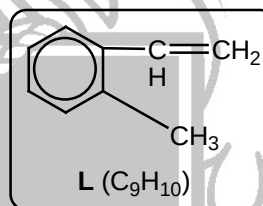
To ensure that only aldehyde is formed

Heat primary alcohol in $\text{H}_2\text{SO}_4\text{(aq)}$, $\text{K}_2\text{Cr}_2\text{O}_7$, with immediate distillation. The aldehyde formed distills out and thus further oxidation is prevented.

To ensure that only carboxylic acid is formed

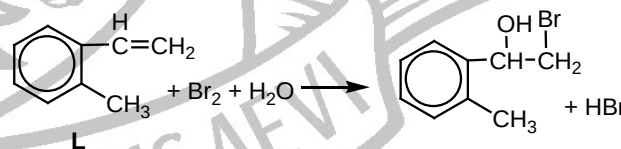
Heat primary alcohol with $\text{H}_2\text{SO}_4\text{(aq)}$, K_2CrO_7 , (note: dichromate must be used, as specified by the question, the difference is distil vs reflux) under reflux for a few hours. Refluxing prevents the loss of the aldehyde; any aldehyde which vaporizes due to the heating will be condensed and returned to the reaction vessel. This ensures further oxidation to the carboxylic acid

4(g)(ii)



*Explanation not required.

L undergoes electrophilic addition with $\text{Br}_2\text{(aq)}$ but not M.



Both L and M undergo oxidation of side-chains with hot concentrated alkaline KMnO_4 .

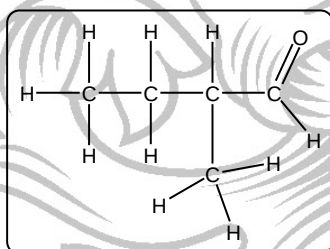
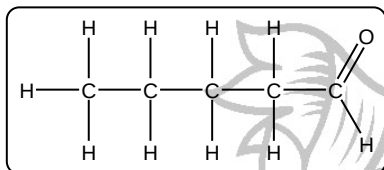
concentration of $\text{Cu}^+(\text{aq})$ ions, causing equilibrium position in $\text{Cu}^{2+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Cu}^+(\text{aq})$ to shift to the right.

5(f)(i)

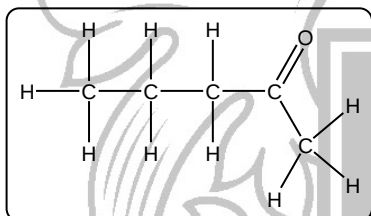
Appearance of reddish brown ppt of Cu_2O . (Fehling's Test)

5(f)(ii)

Two compounds that give positive results in this test.



One compound that does not give positive result.



Or pentan-3-one, cyclopentanol, penten-2-ol, etc