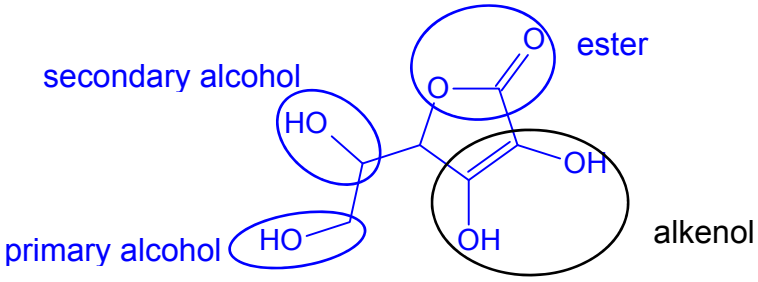
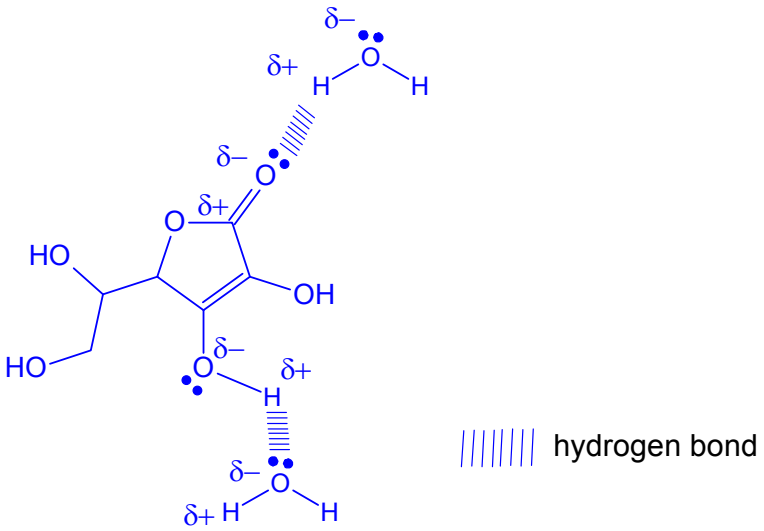
2016 MJC H1 Chemistry Prelim P2 Suggested Answers

1(a) **(i)**



(ii)



(iii) Ester functional group in ascorbic acid undergoes hydrolysis.

(b) **(i)** $C_6H_8O_6 + I_2 \longrightarrow C_6H_6O_6 + 2\ H^+ + 2\ I^-$

(ii) No. of moles of iodine that has reacted = $\frac{17.40}{1000} \times 0.015 = 2.61 \times 10^{-4}$

No. of moles of ascorbic acid that has reacted = 2.61×10^{-4}

(iii) No. of moles of ascorbic acid present in 500 cm^3 (in one tablet)

$= \frac{500}{25} \times 2.61 \times 10^{-4} = 5.22 \times 10^{-3}$ mol

Mass of ascorbic acid present in 500 cm^3 (in one tablet)

$= 5.22 \times 10^{-3} \times 176 = 0.919$ g $= 919$ mg

The information on the packaging is not accurate.

(iv) Add aqueous Br_2 to each compound separately in the dark.

Observation:

- For *ascorbic acid*, decolourisation of reddish–brown Br_2 will be observed.

Alternative viable chemical test also accepted

2 **(a)** It is the energy evolved when one mole of methanol is completely burnt in excess oxygen under standard conditions (or 298 K and 1 atm).

$$CH_3OH\,(l) + \frac{3}{2}O_2\,(g) \longrightarrow CO_2\,(g) + 2\,H_2O\,(l)$$

(b) $\Delta H_c^{\ominus}{}_{(CH_3OH)} = (2794) - (3320) = -526\ kJ\ mol^{-1}$

(c) The bond energy values given in the *Data Booklet* are average values.

(d) Mass of methanol combusted = 356.8 – 350.9 = 5.9 g

No. of moles of methanol combusted = $\frac{5.9}{32.0}$ = 0.1844

Quantity of heat released = 0.1844 x 715.0 = 131.8 kJ

Quantity of heat absorbed = 131.8 x $\frac{60}{100}$ = 79.10 kJ

Quantity of heat absorbed = m c ΔT

79.10 x 1000 = 800 x 4.18 x (T_f – 25.8)

T_f = 49.5°C

(e)

There are 2 bond pair and 1 lone pair around central atom. To minimise repulsion (and maximise stability), the 3 electron pairs are directed to the corners of an equilateral triangle.

Since lone pair–bond pair repulsion is stronger than bond pair–bond pair repulsion, SO_2 has a bent shape and the bond angle is 119°.

(f) S is a Period 3 element and can expand octet structure due to the availability of vacant and energetically accessible d orbitals.

3 **(a)** **(i)** $$K_c = \frac{[CuCl_4^{2-}]}{[\,[Cu(H_2O)_6]^{2+}\,]\,[Cl^-]^4}$$

(ii)

	$[Cu(H_2O)_6]^{2+}$ +	$4Cl^-$ ⇌	$[CuCl_4]^{2-}$ +	$6H_2O$
Initial [ ]	1.00	4.00	0	–
Change in [ ]	–0.925	–3.70	+0.925	–
Equilibrium [ ]	0.0750	0.300	0.925	–

$$K_c = \frac{0.925}{(0.0750)(0.300)^4} = 1520 \text{ mol}^{-4} \text{ dm}^{12}$$

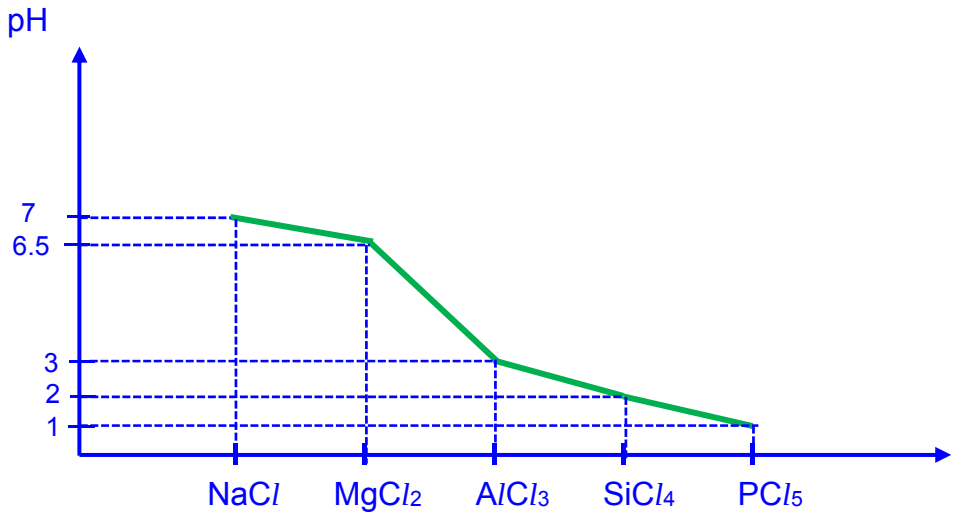
(iii) Yellow solution turns blue/ green.

$[Cu(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons [CuCl_4]^{2-}(aq) + 6H_2O(l)$ --- (1)

Position of equilibrium in (1) shifts left to increase $[[Cu(H_2O)_6]^{2+}]$ and $[Cl^-]$.

Concentration of $[Cu(H_2O)_6]^{2+}$ (blue) increases.

(b) **(i)**



(ii) $AlCl_3$ undergoes both hydration and hydrolysis to form a slightly acidic solution with pH = 3.0

Hydration of $AlCl_3$

$AlCl_3(s) + 6H_2O(l) \longrightarrow [Al(H_2O)_6]^{3+}(aq) + 3Cl^-(aq)$

Hydrolysis of $AlCl_3$

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

The high charge density of the Al^{3+} polarizes the electron cloud of one of its surrounding water molecules, weakening and breaking the O-H bond which results in the release of a proton.

(iii) $MgCl_2$ has giant ionic lattice structure. Large amount of energy is required to overcome strong electrostatic force of attraction between oppositely charged ions.

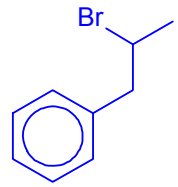
$SiCl_4$ has simple molecular structure. Small amount of energy is required to overcome weak intermolecular van der Waals' attraction between molecules.

[Total: 11]

4 **(a)** Benzene is a planar molecule containing a hexagonal ring of six carbon atoms, each with a hydrogen atom attached. Each carbon in the benzene ring forms two σ bonds with 2 other carbon atoms and one σ bond with a hydrogen atom. This involves the head-on overlap of orbitals.

The remaining electron is in a 2*p* orbital perpendicular to the plane of C atoms. Each 2*p* orbital overlaps sideway equally with the 2*p* orbital of its neighbours so that the six unbonded p electrons are completely delocalised in the π electron cloud above and below the plane of the ring.

(b) **(i)**

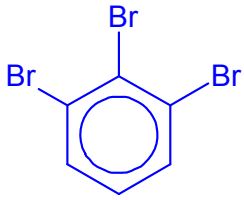


Compound **P**

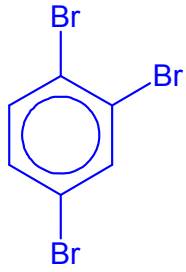
(ii)

	Type of reaction	Reagents and conditions
Step **II**	Substitution	Br_2 with $FeBr_3$, in the dark
Step **III**	Elimination	Ethanolic KOH, heat

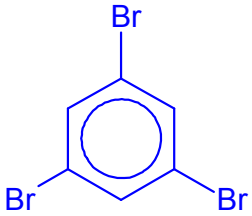
(c) **(i)**



1,2,3–tribromobenzene



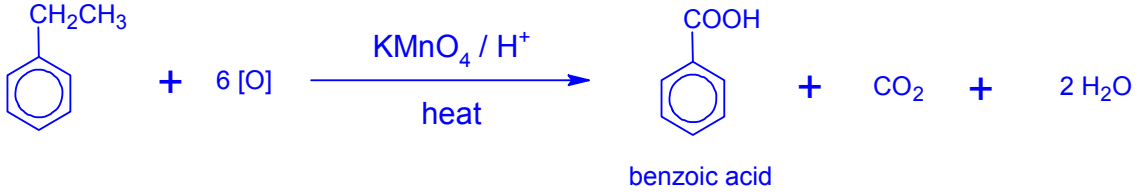
1,2,4–tribromobenzene



1,3,5–tribromobenzene

Any 2 of the 3 structures.

(ii) Compound S: No decolourisation of purple $KMnO_4$.
Ethylbenzene: Decolourisation of purple $KMnO_4$ with (effervescence of colourless CO_2 gas which forms white ppt with $Ca(OH)_2$).



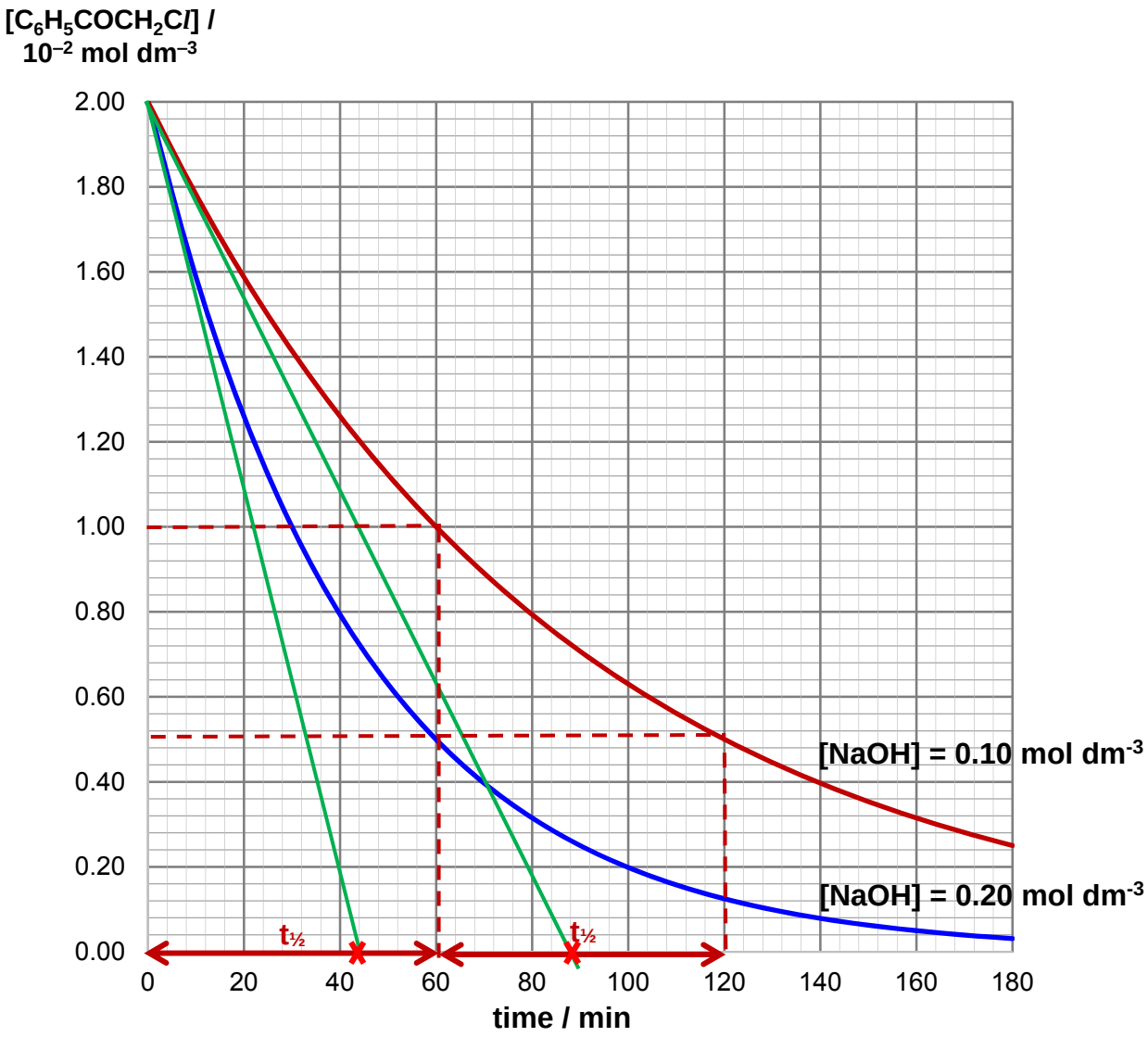
benzoic acid

[Total: 9]

END OF SECTION A

5 **(a)** $C_6H_5COCH_2Cl + NaOH \longrightarrow C_6H_5COCH_2OH + NaCl$

(b)



(i) From graph of [NaOH] = 0.10 / 0.20 mol dm^{-3},
$t_{½}$ is constant at 60 / 30 min.

Hence order of reaction w.r.t $C_6H_5COCH_2Cl$ = 1

From graph of [NaOH] = 0.10 mol dm^{-3},

Rate = $\left|\frac{(2.00-0.00)\times10^{-2}}{0-88}\right| = 2.27\times10^{-4}$ mol dm^{-3} min^{-1}

From graph of [NaOH] = 0.20 mol dm^{-3},

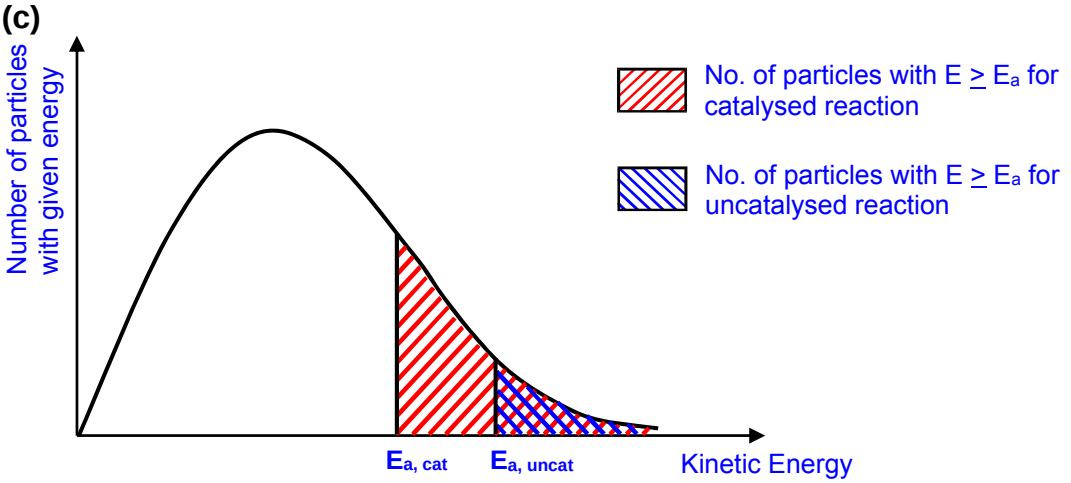
Rate = $\left|\frac{(2.00-0.00)\times10^{-2}}{0-44}\right| = 4.55\times10^{-4}$ mol dm^{-3} min^{-1}

When [NaOH] doubles, rate is approximately doubled.
Hence order of reaction w.r.t NaOH = 1

(ii) Rate = k [$C_6H_5COCH_2Cl$] [NaOH]

(iii) k $= \dfrac{4.64 \times 10^{-3}}{0.200 \times 0.200} = 0.116$ mol^{-1} dm^3 min^{-1}

(c)



- The catalyst increases the rate of reaction by providing an alternative reaction pathway of lower activation energy.
- Number of reactant particles with E ≥ E_a increases,
- Frequency of effective collisions increases.
- Since rate of reaction is proportional to the frequency of effective collisions, rate of reaction increases.

(d)

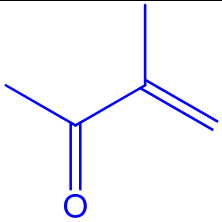
Compound	Precipitate
2–chloro–1–phenylethanone	White AgCl ppt
2–bromo–1–phenylethanone	Cream AgBr ppt

- Strength of C–X bond hence ease of breaking: C–Cl > C–Br
- Order of reactivity of R-X: R-Cl < R-Br

(e) **(i)**

Steps	Reagents and conditions
I	ethanolic NaOH , heat
II	H_2(g), Pd or Pt, r.t.p

(ii)



(iii) Both compounds have simple molecular structures.

4–chloro–3–methylbutan–2–one has a higher boiling point than 3–methylbutan–2–ol. The extensive van der Waals forces of attraction between 4–chloro–3–methylbutan–2–one molecules is stronger than the hydrogen bonding between 3–methylbutan–2–ol molecules. (due to difference in the size of the electron cloud)

(iv) The formation of ion–dipole results in the release of energy that causes the detachment of ions from the lattice for solvation.

(f)

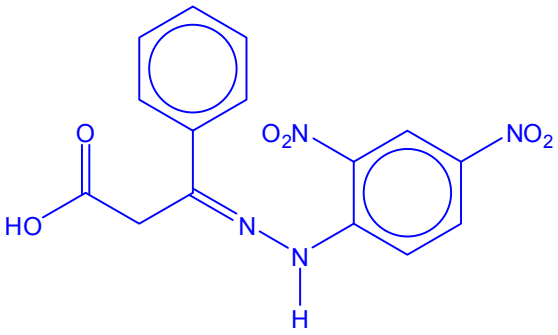
- Cationic radius: Cl^- (0.181 nm) > F^- (0.136 nm)
- Lattice energy of NaF is more exothermic than NaCl
- Since lattice energy is a measure of ionic bond strength, melting point of NaF is higher than NaCl

[Total: 20]

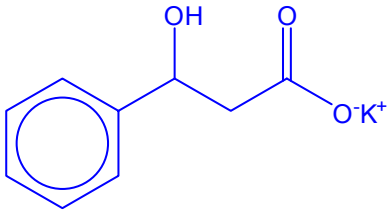
6 (a)

Reaction **I**	Reagents and Conditions:	$NaBH_4$ in ethanol, r.t.p.
	Type of Reaction:	Reduction
Reaction **II**	Reagents and Conditions:	Excess conc H_2SO_4, 170°C
	Type of Reaction:	Elimination

(b)

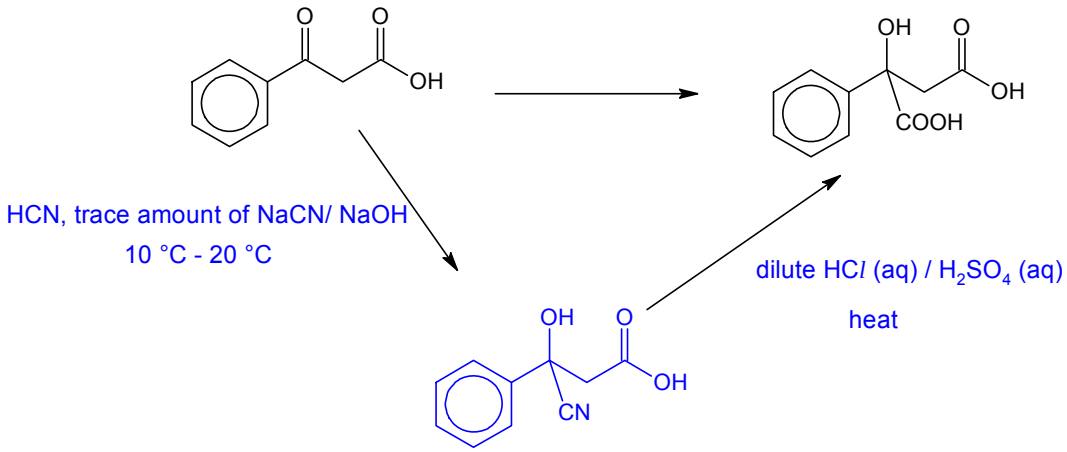


A



B

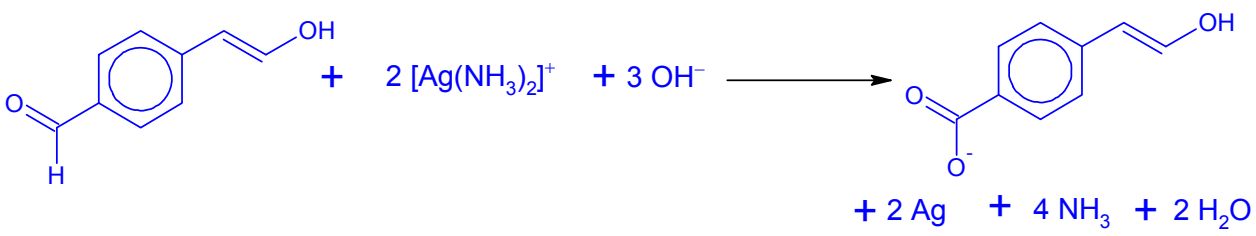
(c)



(d) (i) Test: Tollens' reagent,heat.

Observation: Silver mirror obtained for D but not for E.

(ii)



(e) (i) $K_a = \dfrac{[C_8H_7COO^-][H^+]}{[C_8H_7COOH]}$

(ii) No. of moles of NaOH = $\dfrac{20.50}{1000}$ × 0.015 = 3.075 x 10^{-4}

[cinnamic acid] = $\dfrac{3.075 \times 10^{-4}}{\frac{25}{1000}}$ = 0.0123 mol dm^{-3}

(iii) $[H^+] = \sqrt{0.0123 \times 3.63 \times 10^{-5}}$ = 6.682 x 10^{-4} mol dm^{-3}

x = –lg (6.682 x 10^{-4}) = 3.18

(iv) Some of the energy evolved from the neutralisation process is used to further dissociate the weak acid, cinnamic acid completely.

Thus the enthalpy change of neutralisation between sodium hydroxide and hydrochloric acid will be more exothermic than that between sodium hydroxide and cinnamic acid.

(f) **(i)** A buffer solution is one which is capable of maintaining a fairly constant pH when small amounts of acid or base are added to it.

(ii) $C_8H_7COOH + OH^- \longrightarrow C_8H_7COO^- + H_2O$

(iii) $4.3 = -\lg (3.63 \times 10^{-5}) + \lg \dfrac{[salt]}{[acid]}$

$\dfrac{[salt]}{[acid]} = 0.724$

[Total: 20]

7 **(a)** Atomic radius decreases from sodium to agron across the period as effective nuclear charge increases.

(b) Melting point generally increases from sodium to aluminium (through the metals) until a maximum / highest at silicon (giant molecular) and then decreases from phosphorus to argon (simple molecular).

(c) Gaseous $AlCl_3$ has a simple molecular structure, with weak van der Waals' forces of attraction between molecules and covalent bonds between atoms.

Solid Al_2O_3 has a giant ionic lattice structure, with strong electrostatic forces of attraction between oppositely charged ions.

(d) Sodium burns very vigorously with a bright yellow flame to form white solid.
$4Na + O_2 \longrightarrow 2Na_2O$

Sulfur burns slowly with blue flame.
$S + O_2 \longrightarrow SO_2$

(e) **(i)** Sulfur has a larger nuclear charge than phosphorus but shielding effect is relatively constant since the inner quantum shell of electrons remain the same. Sulfur has a larger effective nuclear charge. There is stronger electrostatic attraction between the nucleus and the valence electrons. More energy is required to remove the valence electron.

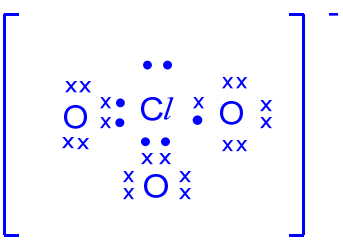
Inter-electron repulsion is present in the doubly-filled 3p orbital of Cl^+ . Hence less energy is required.

(ii) 2nd IE of Si involves removal of 3p valence electron which is further away from the nucleus hence 3p electron experience weaker electrostatic attraction with the nucleus and thus less energy is required.

(iii) Group VII

(f) **(i)** Disproportionation is a redox reaction in which atoms of an element in a single substance (i.e. Cl_2) undergoes oxidation (from 0 in Cl_2 to +5 in ClO_3^-) and reduction (from 0 in Cl_2 to -1 in Cl^-) simultaneously.

(ii)



There are 3 bond pairs and 1 lone pair around central Cl atom in ClO_3^-.
Hence ClO_3^- is trigonal pyramidal.

(iii) *Enthalpy change of formation of* $NaClO_3$ (aq) is the energy change when one mole of $NaClO_3$ (aq) is formed from its constituent elements (Na, Cl_2 and O_2).

(g) **(i)**

cis *trans*

Cis isomeric product is polar as the dipole moments do not cancel out in the molecule.

(ii) $(C_2H_2Cl_2)^{2+}$ due to the largest charge-to-mass ratio

[Total: 20]

END OF SECTION B