(iii) Molar mass $= \frac{\text{Mass}}{\text{Moles}}$

$= \frac{5.8\text{ g}}{0.021\text{ moles}} = 276.19$ g/mole (1 *mk*)

d(i) Average bond energy per mole of a particular covalent bond in a range of compounds

(iv) $FeSO_4.xH_2O$

$56 + 32 + 64 + 18x = 276.19$ (1 *mk*)

$18x = 124.19 \Rightarrow x = 6.9 \approx 7.0$ (1 *mk*)

(ii)

E(C-C) + 6E(C-H) = 2824 ...*Eqn* 1

2E(C-C) + 8E(C-H) = 3996 ...*Eqn* 2

*Eqn*1×2 ⇒ 2E(C-C) + 12E(C-H) = 5648 ...*Eqn* 3

*Eqn*2×1 ⇒ 2E(C-C) + 8E(C-H) − 3996 ...*Eqn* 4

Eqn 3 - *Eqn* 4

4E(C-H) = 1654

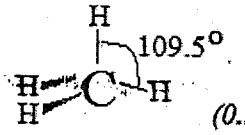
⇒ E(C-H) = 413 KJ/mol (1*mk*)

*Substitute*E(C-H) in *Eqn* 1

E(C-C) + 6(413) = 2824

⇒ E(C-C) = 346 KJ/mol (1 *mk*)

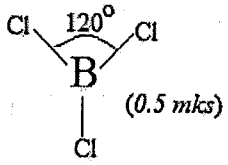
c(i) A: Methane



(0.5 mks)

Others: CCl_4, SO_4^{2-}, NH_4^+ and etc

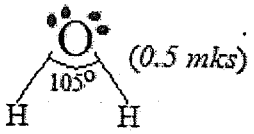
B: Boron triflouride



(0.5 mks)

Others: C_2H_4, SO_3, CO_3^{2-}, NO_3^- and etc

C: Water



(0.5 mks)

Others: H_2S, H_2Se, Cl_2O, ClO_2^- and etc

(ii) There are four electron pairs around carbon which repel each other equally leading to a tetrahedral shape while only three around Boron which also repel each other equally leading to a trigonal planar shape

f. -Presence of a lone pair of electrons on an atom of one of the participating species

-Presence of an available empty orbital on an atom of the other participating species

---

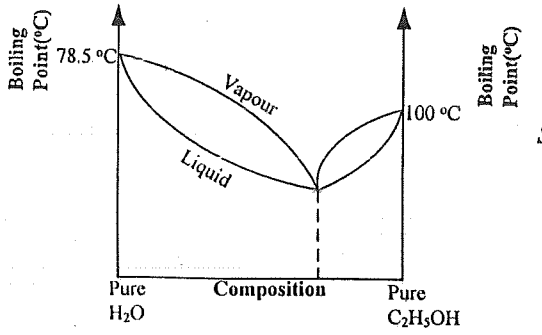
2a(i) For a mixture of miscible liquids, the partial vapour pressure of a component is directly proportional to its mole fraction in the mixture at a given temperature.

Or F or an ideal mixture, the partial vapour pressure of a component is equal to the vapour pressure of the pure component multiplied by its mole fraction at a given temperature.

Or At constant temperature, the total vapour pressure above the mixture of two miscible liquids varies linearly with composition expressed in mole fractions.

(ii) A constant boiling point mixture whose composition does not change on boiling

iii)



Shape = 1 mk

Axes = 1 mk

b(i) One which resists changes in pH on addition of small amounts of an acid or alkali.

(ii)A: $CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$ and $CH_3COONa(aq) \longrightarrow CH_3COO^-(aq) + Na^+(aq)$

$CH_3COOH(aq) + OH^-(aq) \longrightarrow CH_3COO^-(aq) + H_2O(l)$

Or $(H^+ + OH^- \longrightarrow H_2O$ $\qquad CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

B: $CH_3COO^-(aq) + H^+(aq) \longrightarrow CH_3COOH$

(iii) $pH = pK_a + \log\frac{[Salt]}{[Acid]}$ $\quad (1mk)$

$5.5 = (-\log K_a) + \log\frac{[Salt]}{[Acid]}$

$5.5 = (-\log 1.8\times10^{-5}) + \log\frac{[Salt]}{[Acid]}$

$0.76 = \log\frac{[Salt]}{[Acid]}$

$\text{Antilog}(0.76) = \frac{[Salt]}{[Acid]}$

$5.75 = \frac{[Salt]}{[Acid]}$

$5.75 \times 0.1 = [Salt]$

$[Salt] = 0.575$ $\quad (1\ mk)$

RMMof salt = 82

$\therefore$ Mass of salt $= 0.575 \times 82$

$= 47.15$ g $\quad (1\ mk)$

c (i) -Volume of oxygen gas produced
-Increase in pressure at constant volume
-Decrease in mass of reaction mixture

(ii) Volume of oxygen gas produced

(iii) Fit a graduated syringe into the reaction vessel and then record the volume after a regular time interval

d (i) Average mass of one atom of an element compared to one twelfth the mass of one atom of carbon-12 isotope.

(ii) High speed electrons are fired from the electron gun to collide with the gaseous sample of the element thus ionizing it.

(iii) -Only charged particles can be detected by the detector
- To enable them be accelerated
To enable them be deflected

SET 10: SECTION A (CGCEB 2018)
Physical chemistry

1. *(a)* Mole: the amount of substance which contains as many elementary particles (atoms, molecules, protons, ions etc) as there are carbon atoms in exactly 12 grams of carbon-12 isotope. (1mk)

$$\frac{25\ x\ 0.005}{1000}$$

(b) (i) moles of $S_2O_3^{2-} = 0.000125\ (1.25 \times 10^{-4})$ mol.

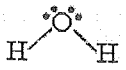
Moles of $I_2 = 0.00125\ (1.25 \times 10^{-3})$ mol.

$$\frac{25\ x\ 0.05}{1000}$$

2 mol $S_2O_3^{2-}$ $\rightarrow$ 1 mol I_2. $\Rightarrow x = (1.25 \times 10^{-4})/2 = 6.25 \times 10^{-5}$ mol.

1.25×10^{-4} mol $S_2O_3^{2-}$ → x mol I_2. Thus $S_2O_3^{2-}$ is the limiting reagent.

(iii) Starch

(c) (i) 

(ii) The mutual repulsion between the two lone pairs is greater than the mutual repulsion between the two bonded pairs. Thus, the lone pairs push the bonded pairs closer giving the molecule a V-shape with a bond angle of 104.5°.

(d) (i) An acid is an electron pair acceptor.

A base is an electron pair donor.

(ii) NH_3 is a base since it donates the lone pair of electrons on N-atom to the empty orbital in the outermost shell of B-atom in the acid BF_3.

$$H_3N + BF_3 \rightarrow H_3N \rightarrow BF_3.$$

(e) (i) A solution in which the pH does not change significantly when small quantities of acid or base (alkaline) are added. OR a solution that can resist changes in pH on addition of small amounts of strong acid or base.

(ii) A: $CH_3COO^-_{(aq)} + H^+_{(aq)} \rightarrow CH_3COOH_{(aq)}$.

B: $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$.

$CH_3COOH_{(aq)} \rightleftharpoons H^+_{(aq)} + CH_3COO^-_{(aq)}$.

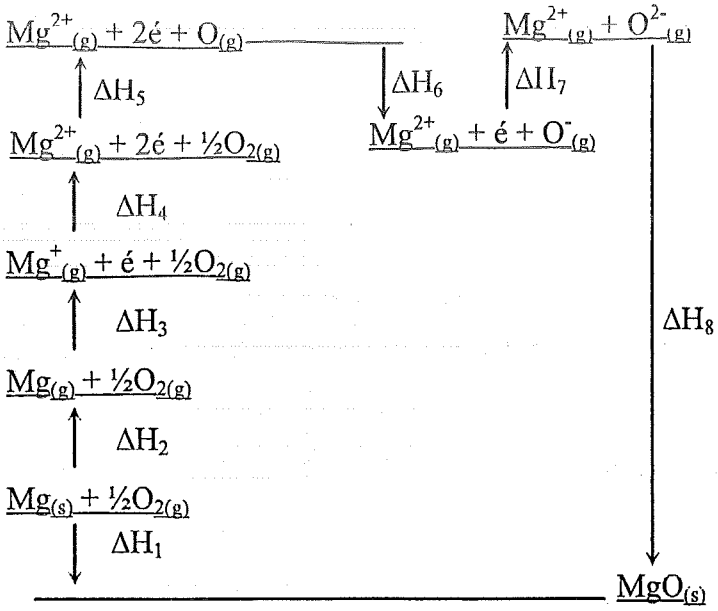
OR $CH_3COOH_{(aq)} + OH^-_{(aq)} \rightarrow CH_3COO^-_{(aq)} + H_2O_{(l)}$.

(ii) Moles of $CH_3COONa = {}^{75}/_{82} = 0.914$ mol

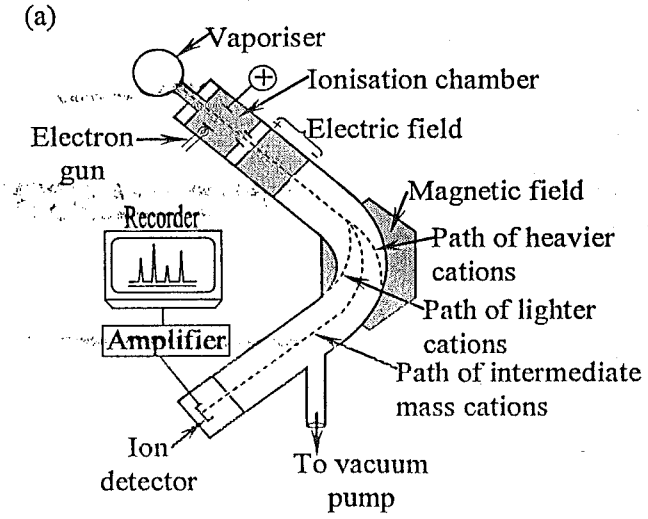
$[CH_3COONa] = {}^{0.914}/_{0.5} = 1.83$ moldm^{-3}.

$$pH = 4.8 + \log_{10}\left(\frac{1.83}{0.64}\right) = 5.26$$

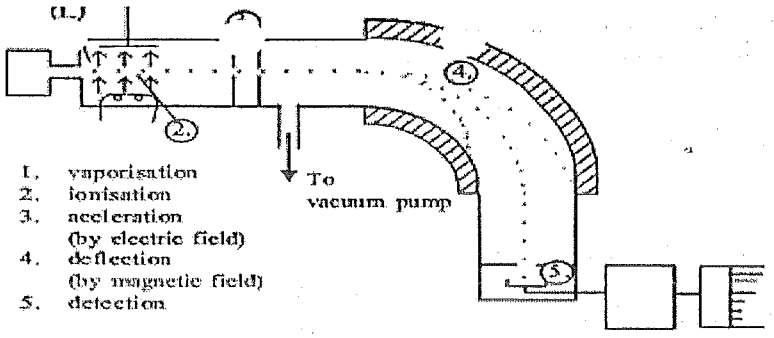
(iii) Energy released when one mole of an ionic compound is formed from its gaseous ions under standard conditions (298K, 1 atm). OR It is the heat absorbed when one mole of an ionic crystal separates into its constituent gaseous ions under standard conditions


$Mg^{2+}_{(g)} + 2é + O_{(g)}$
$Mg^{2+}_{(g)} + O^{2-}_{(g)}$
ΔH_5
ΔH_6
ΔH_7
$Mg^{2+}_{(g)} + 2é + ½O_{2(g)}$
$Mg^{2+}_{(g)} + é + O^{-}_{(g)}$
ΔH_4
$Mg^{+}_{(g)} + é + ½O_{2(g)}$
ΔH_3
ΔH_8
$Mg_{(g)} + ½O_{2(g)}$
ΔH_2
$Mg_{(s)} + ½O_{2(g)}$
ΔH_1
$MgO_{(s)}$

2. (a)


Vaporiser
Ionisation chamber
Electron gun
Electric field
Magnetic field
Recorder
Path of heavier cations
Path of lighter cations
Amplifier
Path of intermediate mass cations
Ion detector
To vacuum pump

OR


1. vaporisation
2. ionisation
3. acceleration (by electric field)
4. deflection (by magnetic field)
5. detection
To vacuum pump

(b) (i) Sum of detector current = 6.83 + 9.13 + 2.60 + 12.17 + 2.6 = 33.33.

Isotope	Detector current/ arbitrary units	Relative abundance
70	6.83	2.63
72	9.13	3.51
73	2.60	1.0
74	12.17	4.66
76	2.60	1.0

Any one correctly calculated = ½mk rounded up

(ii) $\text{RAM} = \frac{(70\ X\ 6.83)+ (72\ X\ 9.13)+ (73\ X\ 2.60)+ (74\ X\ 12.17)+ (76\ X\ 2.60)}{33.33} = 72.71$

OR USING RELATIVE ABUNDANCE

(c) (i) It is a type of equilibrium in which substances in equilibrium process are not in the different phases

(ii) It is a three phase and one component system.

(d) (i) Order of a reaction is the sum of the powers to which the concentrations of the reactants are raised in the experimentally determined rate law are raised.

The order of a reaction with respect to a reactant is the power to which the concentration of that reactant appearing in the experimentally determined rate law is raised.

(ii) Colorimetry, conductivity, gas syringe, titration, dilatometry

(iii) A: Order with respect to A; doubling the concentration of reactant A in experiments 4 and 1 or 3 and 2 while keeping the concentration of reactant B constant, rate doubles. This implies that reaction is 1st order with respect to reactant A.

Order with respect to B; doubling the concentration of reactant B in experiments 1 and 2 or 4 and 3 while keeping the concentration of reactant A constant, rate quadruples. This implies that reaction is 2nd order with respect to reactant B.

OR

$$\frac{\text{Rate 1}}{\text{Rate 4}} = \frac{K(0.130)^m(0.20)^n}{K(0.065)^m(0.20)^n} = \frac{1.50 \times 10^{-5}}{0.75 \times 10^{-5}} \Rightarrow m = 1$$

. Same for Exp'ts 3 & 2.

Thus 1st with respect to reactant A

$$\frac{\text{Rate 2}}{\text{Rate 1}} = \frac{K(0.130)^m(0.40)^n}{K(0.130)^m(0.20)^n} = \frac{6.50 \times 10^{-5}}{1.50 \times 10^{-5}} \Rightarrow n \approx 2$$

. Samc for Exp'ts 4 & 3.

Thus 2nd with respect to reactant B

B: Rate = $K[A][B]^2 \Rightarrow$ $K = \frac{Rate}{[A][B]^2} = \frac{1.50 \times 10^{-5}}{(0.130)(0.20)^2} = 2.885 \times 10^{-3}$ $mol^{-2}dm^6s^{-1}$.

SET 1 SECTION B: CGCEB 2009

Inorganic (Mineral) Chemistry

4. (a) It increases across with a slight drop in Mg and Al, P and S in the period

Explanation: Because of increase in effective nuclear charge, decrease in atomic radius. The drop is due to stability achieved by half filed and completely filled orbital.

(b) (i)

Na	Mg	Al	Si	P	S	Cl	Ar
N_2O	MgO	Al_2O_3	SiO_2	P_4O_{10} P_4O_6	SO_2 SO_3		
basic	basic	Amp-hoteric	Acidic ⟷				

(ii) P_4O_{10} and P_4O_6 are solids because of increase in the strength of van der waal force due to increase in number of electrons and molecular weight. SiO_2 is a solid with a giant molecular structure with strong covalent bond holding the Si-O atoms.

(iii) $Na_2O_{(s)} + H_2O \rightarrow 2NaOH(aq)$

$Cl_2O_{7(g)} + H_2O \rightarrow 2HClO_{4(aq)}$

$Cl_2O + H_2O \rightarrow 2HClO(aq)$

(c) (i) $AlCl_3, SiCl_4, PCl_3, PCl_5, SCl_2, S_2Cl_2$

(ii) $SiCl_{4(l)} + H_2O_{(l)} \rightarrow SiO_{2(s)} + 4HCl(aq)$

$PCl_{5(s)} + 4H_2O_{(l)} \rightarrow 5HCl_{(aq)} + H_3PO_{4(aq)}$

$PCl_{3(s)} + 3H_2O_{(l)} \rightarrow 3HCl_{(aq)} + H_3PO_{3(aq)}$

(d) (i) The hydride are strong reducing agent in water.

(ii) $SiH_{4(g)} + H_2O_{(l)} + 2OH^- \rightarrow SiO_2.H_2O + 3H_{2(g)}$

5. (a) The structure changes from giant molecular in C, Si and Ge to giant metallic structure in Sn and Pb.

(b) (i) +2 and +4 oxidation state.

(ii) The +2 oxidation state increases down the group due to the reluctance of the ns^2 electron to take part in bonding while the np^2 electrons are used up in bonding (inert pair effect)

(c) (i) CO (ii) $SnCl_2$ or $GeCl_2$ (iii) CCl_4

(d) (i) $SiCl_{4(l)} + 2H_2O_{(l)} \rightarrow SiO_{2(s)} + 4HCl_{(aq)}$

(ii) Due to the presence of a low lying d-orbital which accept electrons from water molecules. Or because the Si-Cl bond far more polar, it is longer and weaker and can easily be hydrolysed by water molecules.

(e) All the hydrides are simple molecular in structure. All are gasses at room temperature.

(f) (i) Their valence electrons enter the s-subshell

(ii) Na reacts vigorously with water,

Mg does not react with cold water but it reacts with steam

Be does not react with cold water nor steam

(g) (i) The similarity in properties between a pair of elements on top left to bottom right on a leading diagonal on the periodic table.
Or the similarity in properties between pairs of elements in nearest group and period on the periodic table.

(ii) $4LiNO_3 \xrightarrow[\Delta]{} 2Li_2O_{(s)} + 2NO_{2(g)} + O_{2(g)}$

$2Mg(NO_3)_2 \xrightarrow[\Delta]{} 2MgO_{(s)} + 4NO_{2(g)} + O_{2(g)}$

$Li_2CO_3 \xrightarrow[\Delta]{} Li_2O_{(s)} + CO_{2(g)}$

$MgCO_3 \xrightarrow[\Delta]{} MgO_{(s)} + 2CO_{2(g)}$

(h) It increases down the group because the hydration energy is increasing faster than the lattice energy as the size of the cation is increasing.

(i) The nitrates of group I except lithium nitrate decompose on heating to metallic nitrite and oxygen while those of group II and lithium decompose to metallic oxide, nitrogen dioxide and oxygen. E.g.

$4LiNO_3 \xrightarrow[\Delta]{} 2Li_2O_{(s)} + 2NO_{2(g)} + O_{2(g)}$

$2NaNO_3 \xrightarrow[\Delta]{} 2NaNO_{2(s)} + O_{2(g)}$

$2Mg(NO_3)_2 \xrightarrow[\Delta]{} 2MgO_{(s)} + 4NO_{2(g)} + O_{2(g)}$

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6. (a) (i) Elements that form at least one stable ion or compound with a partially filled d-orbital.

(ii) Sc^{3+} has empty d-orbital hence no electron for d-d-transition to take place. Zn^{2+} has completely filled d-orbital with paired electrons thus no empty orbital in the higher or lower energy level for d-d transition to occur. V^{3+} has unpaired electrons in the d-orbital thus d-d electron transition is possible.

(iii) It decreases across the period because of increase in effective nuclear charge. The decrease is only sliglit since electrons are entering the inner d-subshell which screens the 4s-electrons more effectively from nuclear charge.

(iv) The formation of coloured compounds and the formation of complex.

(b) (i) An anion or a neutral molecule with at least a lone pair of electron to be donated to the vacant d-orbital of the central metal ion or atom to form a complex through dative bond.

(ii) Oxalate, ethylenediamine, 1,2-dihydroxyl benzene

(c) (i)

Dichlorobis(ethylenediamine)cobalt(III) ion

Potassiumhexacyanoferrate(II)

(ii) Optical and Geometric isomerism (cis-trans isomerism)

(d) The state changes from gas to liquid to solid because of increase in the strength of the van der waal force which increases in number of electrons and the molar weight.

(e) (i) It is a reaction in which a species simultaneously reduces and oxidise.

(iii)

dil. $2NaOH_{(aq)} + I_{2(aq)} \rightarrow NaOI_{3(aq)} + NaI_{(aq)} + H_2O_{(aq)}$

conc. $6NaOH_{(aq)} + I_{2(aq)} \rightarrow NaIO_{2(aq)} + 5NaI_{(aq)} + H_2O_{(aq)}$

(f) (i)

$$2NaI_{(aq)} + H_3PO_{4(aq)} \rightarrow Na_2HPO_4 + 2HI_{(g)}$$
$$PI_{3(s)} + 3H_2O_{(l)} \rightarrow H_3PO_{3(aq)} + 3HI_{(g)}$$

(ii) HI> HBr > HCl >HF

The bond length is longer and weaker down the group thus can easily be hydrolyse by water. HF forms H-bond with waters this preventing easy hydrolysis.

SET 2: SECTION B (CGCEB 2010)
Inorganic (Mineral) Chemistry

4. (a) (i) The stability of +2 oxidation state increases down the group while the +4 oxidation state decrease down the group. This is due to the reluctant of the ns^2 electron to take part in covalent bonding while the np^2 electrons are used up (inert pair effect) down the group.

(ii) This is the ability of an element to form ring, and chains with itself and other elements.
$Pb < Sn < Ge < Si < C$

(iii) (A) Carbon and other elements of the group form hydride in the +4 state, they also form Oxide in the +4 state

(B) *The chlorides and the hydride of carbon are not hydrolysed by water while those of other elements hydrolysis in water.

*All the oxides of carbon are gases; oxides of other elements are solid.

*Carbon has the ability to form extensive covalent bonds (catenation)

*Carbon forms compound with pi-bonds

(b) (i) Elements whose valence electrons enters the inner d-sub-shell

(ii) (A) The availability of low-lying d-orbitals of similar energy; The existence of small and highly charge ions

(B) The existence of variable oxidation state is because the 3d and the 4s electrons are of similar energy and so are readily used for bonding

(c) (i) H_2O

(ii)

Isomers	Name
$[Cr(H_2O)_5Cl]Cl_2.H_2O$	Pentaaquachlorochromium(III)chloride hydrate
$[Cr(H_2O)_4Cl_2]Cl.2H_2O$	Tetraaquadichlorochromium(III)Chloride dehydrate
$[Cr(H_2O)_3Cl_3]3H_2O$	Triaquatrichlorochromium(III) trihydrate

(iii) The coordination number is 6 and the oxidation state is +3

(iv) $[Ar]3d^34s^0$ Or $1s^22s^22p^63s^23p^63d^3$

(d) (i)

Elements	Physical state at 25°C
Fluorine	Gas

Chlorine	Gas
Bromine	Liquid
Iodine	Solid

(ii) Increase in the strength of the van der waal forces down the group which increases with increase molecular weight and number of electrons.

(iii)

$2NaCl_{(s)} + H_2SO_{4(aq)} \xrightarrow{\Delta} Na_2SO_4 + 2HCl_{(g)}$

$2NaI_{(s)} + H_3PO_{4(aq)} \rightarrow Na_2HPO_4 + 2HI_{(g)}$

Or $PI_{3(s)} + 3H_2O_{(l)} \rightarrow H_3PO_{3(aq)} + 3HI_{(g)}$

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5. (i)

Element	Na	P	S	Al
Oxides	Na_2O	P_4O_{10}, P_4O_6	SO_2, SO_3	Al_2O_3

(b) (i) $Na_2O_{(s)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

(ii) $P_4O_{10(s)} + 12NaOH_{(aq)} \rightarrow 4Na_3PO_{4(aq)} + 6H_2O_{(l)}$

$P_4O_{6(s)} + 12NaOH_{(aq)} \rightarrow 4Na_3PO_{3(aq)} + 6H_2O_{(l)}$

(iii) (A) $Al_2O_{3(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_2O_{(l)}$

(B) $Al_2O_{3(s)} + 2NaOH_{(aq)} + 3H_2O_{(l)} \rightarrow 2Na[Al(OH)_4]$

(c) (i) $PCl_{5(s)} + 4H_2O_{(l)} \rightarrow H_3PO_{4(aq)} + 5HCl_{(aq)}$

(ii) $MgCl_{2(s)} + H_2O_{(l)} \rightarrow Mg^{2+}_{(aq)} + 2Cl^-_{(aq)}$

(iii) $AlCl_{3(s)} + 6H_2O_{(l)} \rightarrow [Al(H_2O)_3(OH)_3]_{(aq)} + 3HCl_{(aq)}$

Or $AlCl_{3(s)} + 3H_2O_{(l)} \rightarrow Al(OH)_{3(aq)} + 3HCl_{(aq)}$

(d) (i) K (ii) Li (iii) Ca or Mg

(e) (i)

$4LiNO_{3(s)} \xrightarrow{\Delta} 2Li_2O_{(s)} + 4NO_{2(g)} + O_{2(g)}$

$2Mg(NO_3)_{2(s)} \xrightarrow{\Delta} 2MgO_{(s)_{(s)}} + 4NO_{2(g)} + O_{2(g)}$

$Li_2CO_{3(s)} \xrightarrow{\Delta} Li_2O_{(s)} + CO_{2(g)}$

$MgCO_{3(s)} \xrightarrow{\Delta} MgO_{(s)} + CO_{2(g)}$

$6Li_{(s)} + N_{2(g)} \xrightarrow{\Delta} 2Li_3N_{(s)}$

(ii) $Li_2O_{(s)} + H_2O_{(l)} \rightarrow 2Li(OH)_{(aq)}$

$Na_2O_{(s)} + H_2O_{(l)} \rightarrow 2Na(OH)_{(aq)}$

(f) Pure dried chlorine is passed over heated aluminium powder in a desiccator's tube to obtain aluminium chloride and collected in the cooler sides of the container.