USES OF BORON, ALUMINIUM AND THEIR COMPOUNDS

Compounds of Aluminium

Aluminum Oxide (Al_2O_3)

It is also called alumina. It occurs in nature in the form of bauxite and corundum. It is also found in the form of gems. Some important aluminum oxide gems are:

(A) Oriental Topaz-yellow (Fe^{3+})

(B) Sapphire-blue ($Fe^{2+/3+}$ / Ti^{4+})

(C) Ruby-red (Cr^{3+})

(D) Oriental Emerald-green (Cr^{3+} / V^{3+})

Preparation

Pure Al_2O_3 is obtained by igniting $Al_2(SO_4)_3$, $Al(OH)_3$ or ammonium alum.

$$Al_2(SO_4)_3 \xrightarrow{\Delta} Al_2O_3 + 3SO_3 \quad ; 2Al(OH)_3 \xrightarrow{\Delta} Al_2O_3 + 3H_2O$$

$$(NH_4)_2SO_4.Al_2(SO_4)_3.24H_2O \xrightarrow{\Delta} 2NH_3 + Al_2O_3 + 4SO_2 + 25H_2O$$

Properties

It is a white amorphous powder insoluble in water but soluble in acids (forming e.g., $AlCl_3$) as well as alkali's (forming e.g., $NaAlO_2$), Thus amphoteric in nature. It is a polar covalent compound. Exists in two forms a-Al_2O_3 or corundum and g-Al_2O_3.

Addition of Cr_2O_3 or Fe_2O_3 makes alumina coloured.

$$g\text{-}Al_2O_3 \xrightarrow[\Delta]{1000^\circ C} a\text{-}Al_2O_3$$

Uses

(i) It is used for the extraction of aluminum.

(ii) It is used for making artificial gems.

(iii) It is used for the preparation of compounds of aluminum.

(iv) a-Al_2O_3 is used in making furnace linings. It is a refractory material.

(v) It is used as a catalyst in organic reactions.

(vi) Corundum is extremely hard and is used as 'Jewelers rouge' to polish glass.

(vii) g-Al_2O_3 dissolves in acids absorbs moisture and is used in chromatography.

Aluminum Chloride ($AlCl_3.6H_2O$)

It is a colourless crystalline solid, soluble in water. It is covalent. Anhydrous $AlCl_3$ is a deliquescent white solid.

Preparation:

(i) By dissolving aluminum, Al_2O_3, or Al $(OH)_3$ in dilute HCl:

$2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$; $Al_2O_3 + 6HCl \longrightarrow 2AlCl_3 + 3H_2O$; $Al(OH)_3 + 3HCl \longrightarrow AlCl_3 + 3H_2O$

The solution obtained is filtered and crystallized when the crystals of $AlCl_3.6H_2O$ are obtained.

(ii) Anhydrous $AlCl_3$ is obtained by the action of Cl_2 on heated aluminum.

(iii) By heating a mixture of Al_2O_3 and coke and passing chlorine over it.

$$Al_2O_3 + 3C + 3Cl_2 \longrightarrow 2AlCl_3 \text{ (anhidros)} + 3CO$$

Properties:

(i) Action of heat: Hydrated salt when heated strongly is converted to Al_2O_3.

$$2AlCl_3.6H_2O \xrightarrow{\Delta} Al_2O_3 + 6HCl + 3H_2O$$

(ii) Action of moisture on anhydrous $AlCl_3$: When exposed to air, anhydrous $AlCl_3$ produces white fumes of HCl.

$$AlCl_3 + 3H_2O \rightleftharpoons Al(OH)_3 + 3HCl$$

(iii) Action of NH_3: Anhydrous $AlCl_3$ absorbs NH_3 since the former is a Lewis acid.

$$AlCl_3 + 6NH_3 \longrightarrow AlCl_3.6NH_3 \text{ (white solid)}$$

(iv) Action of NaOH solution: When NaOH solution is added dropwise to an aqueous $AlCl_3$ solution, a gelatinous precipitate of $Al(OH)_3$ is first formed which dissolves in excess of NaOH solution to give a colourless solution of sodium meta-aluminate.

$$AlCl_3 + 3NaOH \longrightarrow Al(OH)_3^- + 3NaCl;\ Al(OH)_3 + NaOH \longrightarrow NaAlO_2 + 2H_2O$$

This reaction is important as a test to distinguish between an aluminum salt from salts of Mg, Ca, Sr, and Ba. (When NaOH solution is added to their salt solutions, a white precipitate of hydroxide forms which does not dissolve in excess of NaOH).

(v) Action of NH_4OH solution: When NH_4OH solution is added to a solution of $AlCl_3$, a white precipitate of $Al(OH)_3$ is formed which does not dissolve in excess of NH_4OH.

$$AlCl_3 + 3NH_4OH \longrightarrow Al(OH)_3^- \text{ (white gelatinous)} + 3NH_4Cl$$

This reaction is important as a test to distinguish an Al salt from a Zn salt. (With a Zn salt a white precipitate of $Zn(OH)_2$ is formed which dissolves in excess of NH_4OH solution).

(vi) Hydrolysis with water: When $AlCl_3$ is dissolved in water, it undergoes hydrolysis rapidly to produce $Al(OH)_3$ which is a weak base and HCl which is a strong acid. Hence the solution is acidic to litmus.

$$[Al(H_2O)_6]^{3+} \rightleftharpoons [Al(H_2O)_5OH]^{+2} + H^+$$

The complex cation has a high tendency to get dimerized.

$$2[Al(H_2O)_5OH]^{2+} \rightarrow [(H_2O)_4\ Al(OH)_2\ Al\ (H_2O)_4]^{+4} + 2H_2O$$

(vii) $$4LiH + AlCl_3 \longrightarrow LiAlH_4 + 3LiCl$$

Uses:

(i) As catalyst for cracking of petroleum.

(ii) As catalyst in Friedel-Crafts reactions.

(iii) For preparing aluminum compounds.

Alums; $M_2SO_4.M'_2(SO_4)_3.24H_2O$ or $MM'(SO_4)_2.12H_2O$

Alums are transparent crystalline solids having the above general formula where M is almost any univalent positive cation (except Li^+ because this ion is too small to meet the structural requirements of the crystal) and M' is a trivalent positive cation (Al^{3+}, Ti^{3+}, V^{3+}, Cr^{3+}, Fe^{3+}, Mn^{3+}, Co^{3+}, Ga^{3+} etc.). Alums contain the ions $[M(H_2O)_6]^+$, $[M'(H_2O)_6]^{3+}$ and SO_4^{2-} in the ratio 1: 1: 2. Some important alums are:

(i) Potash alum $K_2SO_4.Al_2(SO_4)_3.24H_2O$

(ii) Chrome alum $K_2SO_4.Cr_2(SO_4)_3.24H_2O$

(iii) Ferric alum $K_2SO_4.Fe_2(SO_4)_3.24H_2O$

(iv) Ammonium alum $(NH_4)_2SO_4.Al_2(SO_4)_3.24H_2O$

Alums are double salts which when dissolved in water produce metal ions (or ammonium ions) and the sulphate ions.

Preparation:

A mixture containing solutions of M_2SO_4 and $M_2(SO_4)_3$ in 1 : 1 molar ratio is fused & then the resulting mass is dissolved into water. From the solution thus obtained, alums are crystallized.

Uses:

(i) As a mordant in dye industry. The fabric which is to be dyed is dipped in a solution of the alum and heated with steam. $Al(OH)_3$ obtained as hydrolysis product of $[Al(H_2O)_6]^{3+}$ deposits into the fibres and then the dye is absorbed on $Al(OH)_3$.

(ii) As a germicide for water purification

(iii) As a coagulating agent for precipitating colloidal impurities from water.

Uses of Boron Compounds

(i) Boron finds application in the fabrication of high-strength steel designed to withstand high-impact forces, and its neutron-absorbing properties make it valuable in reactor rods for regulating nuclear reactions.

(ii) Boron carbide serves as an abrasive material in various applications.

Uses of Aluminium Compounds

It is extensively used

(i) In the production of cooking and domestic utensils.

(ii) As a coating of aluminum on tanks, pipes, iron bars, and various steel items to protect against corrosion.

(iii) In the fabrication of aluminum cables.

(iv) For crafting precision instruments, surgical equipment, aircraft structures, railcar bodies, motorboats, and automobiles.

(v) Aluminates play a vital role as components of Portland cement.