ZINC AND ITS COMPOUNDS

Atomic Number 30

Its electronic configuration is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$

Ores of Zinc

- Zinc Blend (ZnS)
- Zinc Calamite ($ZnCO_3$)

Extraction process from sulphide ores

These ores contains traces of lead sulphide and silica as impurities

Concentration

The ore is first crushed and mixed with water and oil (afrothing agent) so as to remove the unwanted earthly materials.

The oil wets the sulphide particles and the water wets the impurities

Air is then blown through the mixture producing froth. The oiled sulphide particles float on the surface while the impurities sink to the bottom. The ore is collected, washed and dried.

Roasting

The concentrated ore is then heated strongly in air to form zinc oxide

$$2ZnS\ (s) + 3O_2\ (g) \longrightarrow 2ZnO(s) + 2SO_2\ (g)$$

Reduction

Zinc oxide, limestone ($CaCO_3$) and excess coke are then heated in a blast furnace. Limestone decomposes in to cacium oxide and carbon dioxide.

$$CaCO_3\ (s) \longrightarrow CaO\ (s) + CO_2\ (g)$$

The calcium oxide reacts with silica, one of the impurities to form calcium silicate (slag)

$$CaO\ (s) + SiO_2\ (s) \longrightarrow CaSiO_3\ (l)$$

Coke burns to carbon dioxide which is reduced by burnt unburnt coke to carbon monoxide. The carbon monoxide reduces zinc oxide to zinc.

$$C(s) + O_2\ (g) \longrightarrow CO_{2\ (g)}$$

$$CO_2\ (g) + C\ (s) \longrightarrow 2CO\ (g)$$

$$ZnO\ (s) + CO\ (g) \longrightarrow Zn\ (s) + CO_2\ (g)$$

The slag sinks to the bottom and can be removed whereas Zinc produced leaves as vapour at the top of the blast furnace where its cooled and allowed to solidify.

Reactions of Zinc

(a) With Air

On exposure to air zinc develops a thin layer of zinc oxide. This layer prevents further reaction with the oxygen present in air. Zinc burns in oxygen to form zinc oxide.

$2Zn(s) + O_2\ (g) \longrightarrow 2ZnO\ (s)$

(*yellow when hot & white on cooling)*

(b) With water

Zinc (red hot) reacts with steam to form zinc oxide and hydrogen gas

$Zn(s) + H_2O\ (l) \longrightarrow ZnO\ (s) + H_2\ (g)$

(c) With acid

(i) *Hydrochloric acid*

Zinc reacts with dilute and conc. hydrochloric acid forming salt and hydrogen gas.

$Zn\ (s) + 2HCl\ (aq) \longrightarrow ZnCl_2\ (aq) + H_2\ (g)$

(ii) *Sulphuric acid*

Zinc reacts with dilute sulphuric acid to form salt and hydrogen gas

$Zn(s) + H_2SO_4\ (aq) \longrightarrow ZnSO_4\ (aq) + H_2\ (g)$

With concentrated sulphuric acid zinc forms zinc sulphate sulphur dioxide and water as the products.

$Zn\ (s) + 2H_2SO_4\ (aq) \longrightarrow ZnSO_4\ (aq) + SO_2\ (g) + 2H_2O\ (l)$

(d) With alkalis

Zinc reacts with aqueous alkalis to form zincates complex and hydrogen gas

$Zn\ (s) + 2\overline{O}H\ (aq) + 2H_2O\ (l) \longrightarrow Zn(OH)_4^{2-}\ (aq) + H_2\ (g)$

COMPOUNDS OF ZINC

(i) Zinc Oxide

Preparation

(i) Decomposing either zinc hydroxide, zinc carbonate and zinc nitrate

$Zn(OH)_2\ (s) \longrightarrow ZnO\ (s) + H_2O\ (l)$

$ZnCO_3\ (s) \longrightarrow ZnO\ (s) + CO_2\ (g)$

$2Zn(NO_3)_2\ (s) \longrightarrow 2ZnO\ (s) + 4NO_2(g) + O_2\ (g)$

(ii) By passing steam over strongly heated zinc metal

$Zn(s) + H_2O\ (l) \longrightarrow ZnO\ (s) + H_2\ (g)$

Chemical properties

(a) Is yellow when hot and white when cold.

(b) It is an amphoteric oxide that is yellow when hot and white when cold.

$ZnO\ (s) + 2H^+\ (aq) \longrightarrow Zn^{2+}(aq) + H_2O\ (l)$

$ZnO\ (s) + 2OH\ (aq) + H_2O\ (l) \longrightarrow [Zn(OH)_4]^{2+}(aq)$

(ii) Zinc Hydroxide

Preparation: By precipitation on addition of a little sodium hydroxide or aqueous ammonia to a solution containing zinc ions.

$Zn^{2+}\ (aq) + 2\bar{O}H\ (aq) \longrightarrow Zn(OH)_2\ (s)$
(*white ppt)*

Properties:

- The hydroxide is amphoteric; dissolves in excess sodium hydroxide to form zincates complex ion
  $Zn(OH)_2\ (s) + 2\bar{O}H\ (aq) \longrightarrow Zn(OH)_4^{2-}\ (aq)$
- In aqueous ammonia zinc hydroxide dissolves forming a colourless of tetraamine zinc (II)ion.
  $Zn(OH)_2\ (s) + 4NH_3\ (aq) \rightleftharpoons Zn(NH_3)_4^{2-}\ (aq)$

(iii) Zinc sulphide

Preparation: By passing hydrogen sulphide through a solution of zinc ions. A metallic sulphide salt is formed. However if H_2S is passed through an acidic solution of a metallic salt the sulphide may not be formed.

Explanation

If before bubbling the Hydrogen sulphide the solution is acidified, the excess H^+ ion present in the solution suppresses the formation of sulphide ions in the equation:

$H_2S\ (g) + (aq) \rightleftharpoons 2H^+\ (aq) + S^{2-}\ (aq)$

Thus the concentration of the sulphide ions will be low to precipitate zinc sulphide.

$Zn^{2+}\ (aq) + S^{2-}\ (aq) \longrightarrow ZnS$

Note:

Aqueous solution of zinc chloride is acidic due to hydrolysis of $[Zn\ (H_2O)_6]^{2+}$

$ZnCl_2\ (aq) + 6H_2O\ (l) \longrightarrow [Zn\ (H_2O)_6]^{2+}\ (aq) + 2Cl^-\ (aq)$

$[Zn\ (H_2O)_6]^{2+}\ (aq) + H_2O\ (l) \longrightarrow [Zn\ (H_2O)_5\ OH]^+\ (aq) + H_3O^+\ (aq)$

Test for Zinc Ions

(i) *Addition of sodium hydroxide solution*

Sodium hydroxide is added drop wise to a solution of zinc (II) ions produces a white precipitate which dissolves in excess alkali to form a colourless solution.

$Zn^{2+} (aq) + 2\bar{O}H (aq) \longrightarrow Zn(OH)_2 (s)$ *white ppt*

$Zn(OH)_2 (s) + 2\bar{O}H (aq) \longrightarrow [Zn(OH)_4]^{2+} (aq)$

(ii) *Addition of ammonia*

Addition of ammonia solution drop wise to a solution of zinc ions produces a precipitate soluble in excess to form a colourless solution

$Zn^{2+}(aq) + 2\bar{O}H(aq) \longrightarrow Zn(OH)_2(s)$

$2Zn(OH)_2 (s) + 4NH_3 (aq) \longrightarrow [Zn(NH_3)_4]^{2+} (aq) + \bar{2}OH(aq)$

(iii) *Addition of ammonium sulphide*

A white precipitate soluble in dilute hydrochloric acid

(iv) *Addition of potassium ferrocyanide* (confirmatory test)

A white precipitate soluble in sodium hydroxide

(v) *Using disodium hydrogen phosphate* (confirmatory test)

White precipitate is formed with zinc ions

Uses of Zinc

- Making alloys e.g. Brass is alloy of zinc and copper
- Galvanizing iron

Zinc is higher than iron in electrochemical series, if a galvanized piece of iron developed a small scratch and the iron is exposed, iron does not rust.

This is because the zinc in the neighborhood of the exposed iron undergoes oxidation in preference to iron forming a thin layer of Zinc oxide which prevents further attack.

Questions

(a) Write the electronic configuration of zinc (atomic number 30)

(b) State

(i) Two reasons why zinc is not considered a typical transition element

(ii) One property in which zinc behaves as a transition element

(c) (i) Name one ore from which zinc can be extracted and write its formula

(ii) Briefly describe how pure zinc can be obtained from the ore you have named in (c)(i)

(d) Describe the reactions of zinc with

(i) Air

(ii) Sodium hydroxide

(Your answer should include equations for the reactions)

Solution

(a) Electronic configuration of zinc is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$

(b) (i) Zinc is not considered as a typical transition element because

- Zinc atoms or ions have completely filled 3d sub energy level
- Zinc does not form coloured compounds

(ii) Zinc forms complex compounds similar to transition elements

(c) (i) Zinc can be extracted from zinc blend

(ii) Extraction of Zinc from Zinc blende.

The ore is crushed and agitated with water mixed with a frothing agent. Air is passed through the mixture. The impurities sink to the bottom and the ore with frothing agent float, which are skimmed off or removed. Dilute acid is added to break it down. It is filtered and dried. The purified ore is roasted in air to form zinc oxide and sulphur-dioxide.

$$2ZnS\ (s) + 3O_2\ (g) \longrightarrow 2ZnO\ (s) + 2SO_2\ (g)$$

A mixture of zinc oxide, limestone and coke is put in the blast furnace and hot air blown in to the furnace. Zinc oxide is reduced to zinc by carbon.

$$ZnO\ (s) + C\ (s) \longrightarrow Zn\ (g) + CO\ (g)$$

Zinc vapour distills off from the furnace, it is cooled by a spray of molten lead. It is then purified by re-distillation.

(d) Reactions of Zinc

(i) Air: Heated zinc reacts with dry air to form zinc oxide

$$2Zn(s) + O_2\ (g) \longrightarrow 2ZnO\ (s)$$

Zinc reacts slowly with moist air to form hydrated zinc carbonate

$$Zn\ (s) + H_2O\ (l) + O_2\ (g) + CO_2\ (g) \longrightarrow ZnCO_3.Zn(OH)_2(s)$$

(ii) Sodium hydroxide

Zinc reacts with hot concentrated sodium hydroxide solution to form sodium zincate and hydrogen gas

$$Zn\ (s) + 2OH^-\ (aq) + 2H_2O\ (l) \longrightarrow [Zn(OH)_4]^{2-}\ (aq) + H_2(g)$$

Compare the chemistry of Zinc and lead

(a) Reaction with air

Zinc when heated in air forms its oxide.

$$2Zn(s) + O_2(g) \longrightarrow 2ZnO\ (s)$$

Lead also reacts with air when heated strongly to form Lead(II)oxide

$2Pb(s) + O_2(g) \longrightarrow 2PbO(s)$

(b) With water

Heated zinc reacts with steam to form zinc oxide and hydrogen

$Zn(s) + H_2O(l) \longrightarrow ZnO(s) + H_2(g)$

Lead however reacts with water in the presence of dissolved oxygen to form lead (II) hydroxide

$2Pb(s) + 2H_2O(l) + O_2(g) \longrightarrow 2Pb(OH)_2(s)$

(c) With dilute acids

Both lead and zinc react with dilute acids liberating hydrogen gas and forming respective salts. However lead forms precipitates with dilute hydrochloric acid and sulpuric acid

$Pb(s) + 2HCl(aq) \longrightarrow PbCl_2(aq) + H_2(g)$

$Pb(s) + H_2SO_4(aq) \longrightarrow PbSO_4(aq) + H_2(g)$

$Zn(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2(g)$

(d) With conc. acids

(i) *concentrated sulphuric acid*

Zinc reacts with hot concentrated sulphuric acid as follows

$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + SO_2(g) + 2H_2O(l)$

Lead only slightly dissolves in concentrated sulphuric acid

(ii) *Concentrated nitric acid*

Zinc reacts with conc. Hot nitric acid to form zinc nitrate, nitrogen dioxide and water.

$Zn(s) + 4HNO_3(aq) \longrightarrow Zn(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$

Lead reacts with hot conc nitric acid and its oxidized to lead (II) nitrate and itself reduced to nitrogen monoxide and water

$3Pb(s) + 8HNO_3(aq) \longrightarrow 3Pb(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$

(iii) *Concentrated hydrochloric acid*

Zinc reacts with concentrated hydrochloric acid with evolution of hydrogen gas

$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + 2H(g)$

Lead reacts with concentrated hydrochloric acid to form a white precipitate which dissolves in excess acid to form a colourless solution

$Pb(s) + 2HCl(aq) \longrightarrow PbCl_2(s) + H_2(g)$

$PbCl_2(s) + 2HCl(aq) \longrightarrow PbCl_4(l) + H_2(g)$

(e) Properties of oxides

Both of the oxides of lead and zinc are amphoteric in nature

$ZnO(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2(g)$

$PbO(s) + 2H^{2+}(aq) \longrightarrow Al^{3+}(aq) + H_2(g)$

$ZnO(s) + 2\bar{O}H(aq) + H_2O(l) \longrightarrow [Zn(OH)_4]^{2-}(aq)$

$PbO(s) + 2\bar{O}H(aq) + H_2O(l) \longrightarrow [Pb(OH)_4]^{2-}(aq)$

(f) Properties of hydroxides

Both hydroxides of lead and zinc are amphoteric in nature

$Zn(OH)_2 (s) + 2\overline{O}H (aq) \longrightarrow [Zn(OH)_4]^{2-}$

$Pb(OH)_2 (s) + 2\overline{O}H (aq) \longrightarrow [Pb(OH)_4]^{2-}$

Their hydroxides, like their oxides, also react with dilute acids to form salt and water

$PbO (s) + 2HNO_3 (aq) \longrightarrow Pb(NO_3)_2 (aq) + H_2O (l)$

$ZnO (s) + 2HNO_3 (aq) \longrightarrow Zn(NO_3)_2 (aq) + H_2O (l)$

Similarities between Zn and Pb

(i) Zinc nitrate like lead nitrate when heated in air decompose to form nitrogen dioxide gas and their respective oxides.

$2Zn(NO_3)_2 (s) \longrightarrow 2ZnO (s) + 4NO_2 (g) + O_2 (g)$

$Pb(NO_3)_2 (s) \longrightarrow PbO (s) + NO_2 (g) + O_2 (g)$

(ii) Zinc oxide and lead oxide can be reduced by hydrogen gas on heating

$ZnO (s) + H_2 (g) \longrightarrow Zn (s) + H_2O (l)$

$PbO (s) + H_2 (g) \longrightarrow Pb (s) + H_2O (l)$

(iii) Lead hydroxide like zinc hydroxide are amphoteric

(iv) Both zinc oxide and lead oxide can be reduced by carbon monoxide gas

$ZnO (s) + CO (g) \longrightarrow Zn (s) + CO_2 (g)$

$PbO (s) + CO (g) \longrightarrow Pb (s) + CO_2 (g)$

Differences between Zn and Pb

- Zinc metal is an amphoteric metal dissolves in hot concentrated alkali with the evolution of hydrogen gas whereas lead metal does not.

  $Zn (s) + 2\overline{O}H (aq) + 2H_2O (l) \longrightarrow Zn(OH)_4^{2-} (aq) + H_2 (g)$

- Most salts of lead (II) ion such as lead (II) sulphate, lead (II) chloride etc are insoluble in water where as salts of zinc (II) ion are highly soluble in water

- Lead (II) oxide is orange when hot and yellow on cooling while zinc oxide is yellow when hot and white on cooling.

- Zinc hydroxide dissolves in ammonia solution to form tetraaminezinc(II)ions while lead(II)hydroxide is insoluble in excess ammonia solution.

- Lead dissolves in dilute mineral acids to form a white precipitate for example in HCl, H_2SO_4 while zinc dissolves in these acids to form colourless solutions

Compare the chemistry of Zinc and Aluminium

(i) Reaction with air

Zinc when heated in air forms its oxide.

$2Zn(s) + O_2(g) \longrightarrow 2ZnO\ (s)$

Aluminium like zinc when strongly heated in air forms its oxide

$Al(s)\ + 3O_2\ (g) \longrightarrow 2Al_2O_3\ (s)$

Strongly heated aluminium in air also may combine with nitrogen gas to form aluminium nitride.

$2Al\ (s) + N_2\ (s) \longrightarrow 2AlN\ (s)$

(ii) Reaction with water

Heated zinc reacts with steam to form zinc oxide and hydrogen

$Zn\ (s) + H_2O\ (l) \longrightarrow ZnO\ (s) + H_2(g)$

Aluminium however doesn't react with water neither with steam.

(iii) Reaction with dilute acids

Both zinc and aluninium react with dilute acids liberating hydrogen gas and forming respective salts.

$2Al\ (s)\ + 6H^+\ (aq) \longrightarrow 2Al^{3+}\ (aq) + 3H_2\ (g)$

$Zn\ (s) + 2H^+(aq) \longrightarrow Zn^{2+}\ (aq) + H_2(g)$

Reaction with concentrated acids

(a) *Concentrated sulphuric acid*

Both zinc and aluminium dissolve in hot concentrated sulphuric acid with evolution of sulphur dioxide gas

$Zn(s) + H_2SO_4\ (aq) \longrightarrow ZnSO_4\ (aq) + SO_2(g) + 2H_2O\ (l)$

$2Al(s) + 6H_2SO_4\ (aq) \longrightarrow Al_2(SO_4)_3\ (aq) + 3SO_2\ (g) + 6H_2O\ (l)$

(b) *Concentrated nitric acid*

Zinc dissolves in hot concentrated nitric acid

$Zn(s) + 4HNO_3\ (aq) \longrightarrow Zn(NO_3)_2\ (aq) + 2NO_2\ (g) + 2H_2O\ (l)$

Aluminium however does not react with hot conc nitric aci

(c) *Concentrated hydrochloric acid*

Both zinc and aluminium react with hot concentrated hydrochloric acid to form respective chlorides and hydrogen gas.

$Zn\ (s) + 2HCl\ (aq) \longrightarrow ZnCl_2\ (aq) + 2H\ (g)$

$2Al\ (s) + 6HCl\ (aq) \longrightarrow AlCl_3\ (aq) + 3H_2\ (g)$

(iv) Properties of the oxides

The oxides of both zinc and aluminium are amphoteric in nature.

$Al_2O_3\ (s) +\ 6H^+\ (aq) \longrightarrow 2Al^{3+}\ (aq) + H_2O\ (l)$

$ZnO\ (s) + 2H^+\ (aq) \longrightarrow Zn^{2+}\ (aq) + H_2O\ (l)$

$Al_2O_3\ (s) + 2\bar{O}H\ (aq) + 3H_2O\ (l) \longrightarrow [2Al(OH)_4]^-\ (aq)$

$ZnO\ (s) + 2\bar{O}H\ (aq) + H_2O\ (l) \longrightarrow [Zn(OH)_4]^{2-}\ (aq)$

(v) Properties of the hydroxides

The hydroxides of both zinc and aluminium are amphoteric in nature.

$Zn(OH)_2 (s) + 2\overline{O}H (aq) \longrightarrow [Zn(OH)_4]^{2-}$

$Al(OH)_3 (s) + \overline{O}H (aq) \longrightarrow [Al(OH)_4]^{-} (aq)$