Salt Analysis

- Analysis of Anion By Wet Test
- Analysis of Cation By Dry Test, By Flame Test, By Wet Test

MIND MAP

Salt Analysis

Analysis of Anions (Acidic Radicals)

Group 'A' Radicals

Gases Liberated With Dilute HCl/Dilute H_2SO_4

Carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), Sulphide (S^{2-}), Sulphite (SO_3^{2-}), bisulphite (HSO_3^-), Acetate (CH_3COO^-), thiosulphate ($S_2O_3^{2-}$) and Nitrite(NO_2^-).

Gases or Acid Vapours Evolved With Concentrated H_2SO_4

Fluoride (F^-), Chloride (Cl^-), Bromide (Br^-), Iodide (I^-), Nitrate (NO_3^-) Borate(BO_3^{3-}) and Oxalate ($C_2O_4^{2-}$)

Group 'B' Radicals

Precipitation Reactions

SO_4^{2-}, PO_4^{3-}, CrO_4^{2-}, $Cr_2O_7^{2-}$ etc.

Oxidation and Reduction in Solution

CrO_4^{2-}, $Cr_2O_7^{2-}$, MnO_4^-, MnO_4^{2-} etc.

Types of Reaction

Ion Exchange Reaction

(a) ppt. formation reaction

(b) double ppt. formation reaction

(c) ppt. exchange reaction

(d) ppt. dissolution reaction

Complexation Reaction

$$6KCN + FeSO_4 \longrightarrow K_4[Fe(CN)_6] + K_2SO_4$$

$$K_4[Fe(CN)_6] + 2CuSO_4 \longrightarrow Cu_2[Fe(CN)_6]\downarrow + 2K_2SO_4$$

Chocolate brown ppt.

Comproportionation Reactions

$$SO_2(aq) + 2H_2S \longrightarrow 3S + 2H_2O$$

Oxidation of Metalloids

Heating Effect of Carbonate & Bicarbonate Salts

Heating effect of Carbonate salts

$$\text{Metal Carbonate} \xrightarrow{\Delta} \text{Metal Oxide} + CO_2$$

[M = Be, Mg, Ca, Sr, Ba]

Group 'A' Radicals

Radicals Detected With Dilute HCl/Dilute H_2SO_4

Carbonate (CO_3^{2-})

All normal carbonates, with the exception of those of the alkali metals and of Ammonium, are insoluble in water.

With Dilute Hydrochloric Acid

$$CO_3^{2-} + 2H^+ \longrightarrow CO_2 + H_2O$$

The gas can be identified by its property of rendering lime water (or baryta water) turbid

$$CO_2 + Ca^{2+} + 2OH^- \longrightarrow CaCO_3\downarrow + H_2O$$

$$CO_2 + Ba^{2+} + 2OH^- \longrightarrow BaCO_3\downarrow + H_2O$$

With prolonged passage of Carbon Dioxide, the turbidity slowly disappears as a result of the formation of a soluble hydrogen carbonate

$CaCO_3\downarrow + CO_2 + H_2O \longrightarrow Ca^{2+} + 2HCO_3^-$

With Silver Nitrate Solution

White precipitate of Silver carbonate

$CO_3^{2-} + 2Ag^+ \longrightarrow Ag_2CO_3\downarrow$

Hydrogen Bicarbonate, HCO_3^-

Most of the reactions of Hydrogen carbonates are similar to those of carbonates.

$2HCO_3^- \longrightarrow CO_3^{2-} + H_2O + CO_2\uparrow$

Carbon dioxide, formed in this way, can be identified with lime water or baryta water.

With Mercury(II)Chloride (POISON)

No precipitate is formed with hydrogen carbonate ions, while in a solution of normal carbonates a reddish-brown precipitate of basic mercury(II)carbonate ($3HgO.HgCO_3 = Hg_4O_3CO_3$) is formed

$CO_3^{2-} + 4Hg^{2+} + 3H_2O \longrightarrow Hg_4O_3CO_3\downarrow + 6H^+$

On adding Ammonia to the filtrate, a white precipitate or cloudiness is obtained if Hydrogen carbonates are present

$2HCO_3^- + 2Ca^{2+} + 2NH_3 \longrightarrow 2CaCO_3\downarrow + 2NH_4^+$

Sulphite (SO_3^{2-})

Solubility

Only the Sulphites of the alkali metals and of Ammonium are soluble in water

With Dilute Hydrochloric Acid (Or Dilute Sulphuric Acid)

Decomposition, more rapidly on warming, with the evolution of Sulphur Dioxide

$SO_3^{2-} + 2H^+ \longrightarrow SO_2\uparrow + H_2O$

The gas may be identified

(i) By its suffocating odour of burning Sulphur.

(ii) By the green Colouration, due to the formation of Chromium

(III) ions, produced when a filter paper, moistened with acidified Potassium dichromate solution, is held over the mouth of the test-tube.

$3SO_2\uparrow + Cr_2O_7^{2-} + 2H^+ \longrightarrow 3SO_4^{2-} + 2Cr^{3+} + H_2O$

On the addition of more reagent, a white, crystalline precipitate of Silver sulphite is formed

$[AgSO_3]^- + Ag^+ \longrightarrow Ag_2SO_3\downarrow$

The precipitate dissolves if sulphite ions are added in excess

$Ag_2SO_3\downarrow + SO_3^{2-} \rightarrow [Ag(SO_3)]_2^{-3}$

$2[AgSO_3]^- \longrightarrow 2Ag\downarrow + SO_4^{2-} + SO_2\downarrow$

$Ag_2SO_3 + H_2O \longrightarrow 2Ag\downarrow + SO_4^{2-} + 2H^+$

The precipitate is soluble in dilute Nitric acid, and Sulphur dioxide gas is evolved

$Ag_2SO_3\downarrow + 2H^+ \longrightarrow SO_2 + 2Ag^+ + H_2O$

$$3SO_3^{2-} + Cr_2O_7^{2-} + 8H^+ \longrightarrow 2Cr^{3+} + 3SO_4^{2-} + 4H_2O$$

With Lead Acetate or Lead Nitrate Solution

$$SO_3^{2-} + Pb^{2+} \longrightarrow PbSO_3$$

With Zinc and Sulphuric Acid

Hydrogen sulphide gas is evolved, which may be detected by holding lead acetate paper to the mouth of the test-tube

$$SO_3^{2-} + 3Zn + 8H^+ \longrightarrow H_2S\uparrow + 3Zn^{2+} + 3H_2O$$

With Lime water

This test is carried out by adding dilute hydrochloric acid to the solid sulphite, and bubbling the evolved sulphur dioxide through lime water; a white precipitate of Calcium sulphite CaSO3 is formed.

$$SO_3^{2-} + Ca^{2+} \longrightarrow CaSO_3\downarrow$$

The dichromate oxidizes and destroys the Sulphur dioxide without affecting the Carbon dioxide.

Distinction Between Sulphites And Hydrogen Sulphites

Solutions of normal alkali sulphites show an alkaline reaction against litmus paper, because of hydrolysis

$$SO_3^{2-} + H_2O \rightleftharpoons HSO_3^- + OH^-$$

Solubility

The acid, normal, and polysulphides of alkali metals are soluble in water, their aqueous solutions exhibit an alkaline reaction because of Hydrolysis.

$$S^{2-} + H_2O \rightleftharpoons SH^- + OH^-$$

$$SH^- + H_2O \rightleftharpoons H_2S + OH^-$$

The normal sulphides of most other metals are insoluble; those of the alkaline earths are sparingly soluble, but are gradually changed by contact with water into soluble Hydrogen sulphides

$$CaS + H_2O \longrightarrow Ca^{2+} + SH^- + OH^-$$

A more sensitive test is attained by the use of Sodium tetrahydroxoplumbate (II) solution, prepared by adding Sodium hydroxide to lead acetate until the initial precipitate of lead Hydroxide has just dissolved

$$Pb^{2+} + 2OH^- \longrightarrow Pb(OH)_2\downarrow$$

Hydrogen sulphide is a good reducing agent.

It reduces (1) acidified Potassium Permanganate, (2) acidified Potassium dichromale, and (3) Potassium Triiodide (Iodine) solution

With Silver Nitrate Solution

Black precipitate of Silver sulphide Ag_2S, insoluble in cold but soluble in hot dilute Nitric acid.

$$S^{2-} + 2Ag^+ \longrightarrow Ag_2S$$

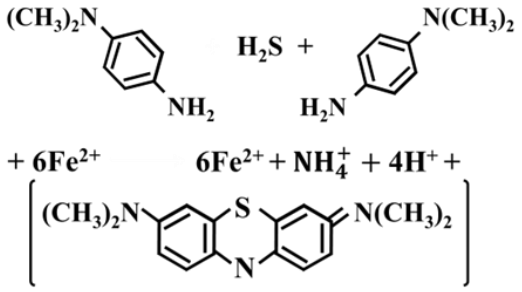
With Barium Chloride Solution

No precipitate

With Sodium Nitroprusside Solution ($Na_2[Fe(CN)_5NO]$)

Transient purple colour in the presence of solutions of alkalis.

$$S^{2-} + [Fe(CN)_5NO]^{2-} \longrightarrow [Fe(CN)_5NOS]^{4-}$$



MIND MAP

Salt Analysis

Nitrite (NO_2^-)

With Dilute Hydrochloric Acid

Cautious addition of the acid to a solid Nitrite in the cold yields a transient, pale-blue liquid (due to the presence of free Nitrous acid, HNO_2 or its anhydride, N_2O_3)

$$NO_2^- + H^+ \longrightarrow HNO_2$$

$$2HNO_2 \longrightarrow H_2O + N_2O_3$$

$$3HNO_2 \longrightarrow HNO_3 + 2NO\uparrow + H_2O$$

$$2NO\uparrow + O_2 \longrightarrow 2NO_2\uparrow$$

With Iron(II)Sulphate Solution

When the Nitrite solution is added carefully to a saturated solution of Iron(II)sulphate acidified with dilute acetic acid or with dilute sulphuric acid, a brown ring, due to the compound $[Fe(H_2O)_5NO]SO_4$, is formed at the junction of the two liquids.

$$NO_2^- + CH_3COOH \longrightarrow HNO_2 + CH_3COO^-$$

$$3HNO_2 \longrightarrow HNO_3 + H_2O + 2NO$$

$$Fe^{2+} + SO_4^{2-} + NO \longrightarrow [Fe(H_2O)5NO]SO_4$$

With Urea $CO(NH_2)_2$

When a solution of a Nitrite is treated with solid urea and the mixture acidified with dilute hydrochloric acid, the Nitrite is decomposed, and Nitrogen and Carbon dioxide are evolved.

$$CO(NH_2)_2 + 2HNO_2 \longrightarrow 2N_2\uparrow + CO_2\uparrow + 3H_2O$$

The later may be identified by the red colour produced with dilute HCl and $FeCl_3$ Solution.

$$CS(NH_2)_2 + HNO_2 \longrightarrow N_2\uparrow + H^+ + SCN^- + 2H_2O$$

Acetate (CH_3COO^-)

Solubility: all normal acetates, with the exception of silver and mercury(I) acetates which are sparingly soluble, are readily soluble in water.

With Dilute Sulphuric Acid

Acetic acid, easily recognized by its vinegar-like odour, is evolved on warming.

$$CH_3COO^- + H^+ \longrightarrow CH_3COOH\uparrow$$

With Concentrated Sulphuric Acid

Acetic acid is evolved on heating, together with Sulphur dioxide, the latter tending to mask the penetrating odour of the concentrated acetic acid vapour.

Ethyl acetate $CH_3COOC_2H_5$ is formed, which is recognized by its pleasant, fruity odour.

The precipitate is more soluble in boiling water and readily soluble in dilute Ammonia solution.

$$CH_3COO^- + Ag^+ \longrightarrow CH_3COOAg$$

With Barium Chloride, Calcium Chloride or Mercury (ii) Chloride Solution

With Iron(III)Chloride Solution

Deep-red colouration, owing to the formation of a complex ion, $[Fe_3(OH)_2(CH_3COO)_6]^+$.

$6CH_3COO^- + 3Fe^{3+} + 2H_2O \longrightarrow$

$\{Fe_3(OH)_2(CH_3COO)_6]^+ + 2H^+$

$[Fe_3(OH)_2(CH_3COO)_2]^+ + 4H_2O \longrightarrow$

$3Fe(OH)_2CH_3COO + 3CH_3COOH + H^+$

Chloride (Cl^-)

With Concentrated Sulphuric Acid

Considerable decomposition of the Chloride occurs in the cold, becoming complete on warming, with the evolution of Hydrogen Chloride.

$Cl^- + H_2SO_4 \longrightarrow HCl + H_2SO_4^-$

its pungent odour

With Manganese Dioxide And Concentrated Sulphuric Acid

$MnO_2 + 2H_2SO_4 + 2Cl^- \longrightarrow$

$Mn^{2+} + Cl_2 + 2SO_4^{2-} + 3H_2O$

suffocating odour, Yellowish green

With Potassium Dichromate And Sulphuric Acid (Chromyl Chloride Test)

$4Cl^- + Cr_2O_7^{2-} + 6H^+ \longrightarrow$

$2CrO_2Cl_2 \uparrow + 3H_2O$

$2CrO_2Cl_2 + 4OH^- \longrightarrow$

$CrO_4^{2-} + 2Cl^- + 2H_2O$

MIND MAP

Salt Analysis

Bromide (Br^-)

With Concentrated Sulphuric Acid

If concentrated sulphuric acid is poured on some solid Potassium Bromide, first a reddish-brown solution is formed.

$KBr + H_2SO_4 \longrightarrow HBr \uparrow + HSO_4^- + K^+$

$2KBr + 2H_2SO_4 \longrightarrow Br_2 \uparrow + SO_2 \uparrow$

reddish-brown

$+ SO_4^{2-} + 2K^+ + 2H_2O$

With Manganese Dioxide And Concentrated Sulphuric Acid

When a mixture of a solid bromide, precipitated manganese dioxide, and concentrated sulphuric acid is warmed, reddish-brown vapour of Bromine is evolved.

$2KBr + MnO_2 + 2H_2SO_4 \longrightarrow$

$Br_2 \uparrow + 2K^+ + Mn^{2+} + 2SO_4^{2-} + 2H_2O$

reddish-brown

The precipitate is also soluble in Potassium Cyanide and Sodium Thiosulphate solutions, but insoluble in dilute Nitric acid.

$Br^- + Ag^+ \longrightarrow AgBr \downarrow$

reddish-brown

With Lead Acetate Solution

White crystalline precipitate of Lead Bromide

$2Br^- + Pb^{2+} \longrightarrow PbBr_2 \downarrow$

The precipitate is soluble in boiling water.

With Potassium Dichromate And Concentrated Sulphuric Acid

$6KBr + K_2Cr_2O_7 + 7H_2SO_4 \longrightarrow$

$3Br_2 \uparrow + 2Cr^{3+} + 8K^+ + 7SO_4^{2-} \uparrow + 7H_2O$

yellowish-brown

With Nitric Acid

$6Br^- + 8HNO_3 \longrightarrow 3Br_2 \uparrow$

$+ 2NO \uparrow + 6NO_4^- + 4H_2O$

Iodide (I^-)

With Concentrated Sulphuric Acid

With a solid Iodide, Iodine is liberated; on warming, violet vapour is evolved, which turns starch paper blue.

$3I^- + 2H_2SO_4 \longrightarrow I_2\uparrow + SO_4^{2-}\uparrow + 2H_2O + SO_2\uparrow$

Yellowish-brown

$I^- + H_2SO_4 \longrightarrow HI\uparrow + HSO_4^{2-}$

If Manganese dioxide is added to the mixture, only Iodine is formed and the Sulphuric acid does not get reduced

$2I^- + MnO_2 + 2H_2SO_4 \longrightarrow$

$I_2\uparrow + Mn^{2+} + 2SO_4^{2-} + 2H_2O$

Violet gas

With Potassium Dichromate And Concentrated Sulphuric Acid

Only Iodine is liberated, and no chromate is present in the distillate (difference from Chloride).

$6I^- + Cr_2O_7^{2-} + 7H_2SO_4 \longrightarrow 3I_2\uparrow$

$+ 2Cr^{3+} + 7SO_4^{2-} + 7H_2O$

Starch test

The Iodine may be identified by colouring starch paste blue, or Chloroform violet.

$3I^- + 2NO_2^- + 4H^+ \longrightarrow I_2 + 2NO\uparrow + 2H_2O$

Nitrate (NO_3^-)

With Concentrated Sulphuric Acid

Reddish-brown vapour of Nitrogen dioxide, and pungent acid vapour of Nitric acid which fumes in the air are formed on heating the solid Nitrate with the reagent.

Dilute sulphuric acid has no effect (difference from Nitrite)

$4NO_3^- + 2H_2SO_4 \longrightarrow$

$4NO_2 + O_2 + 2SO_4^{2-} + 2H_2O$

Reddish-brown vapour

With Concentrated Sulphuric Acid And Bright Copper Turnings

On heating these with the solid nitrate, reddish-brown fumes of Nitrogen dioxide are evolved, and the solution acquires a blue colour owing to the formation of Copper(ll) ions.

A solution of the nitrate may also be used; the sulphuric acid is then added very cautiously.

$2NO_3^- + 4H_2SO_4 + 3Cu \longrightarrow$

$3Cu^{2+} + 4NO_2\uparrow + 4SO_4^{2-} + 4H_2O$

$2NO\uparrow + 2O_2 \longrightarrow 2NO_2\uparrow$

With Iron(II)Sulphate Solution And Concentrated Sulphuric Acid (Brown Ring Test)

This test is carried out in this way: (a) Add 3 ml freshly prepared saturated solution of Iron(II)Sulphate to 2 ml Nitrate solution

The brown ring is due to the formation of the $[Fe(NO)]^{2+}$.

$2NO_3^- + 4H_2SO_4 + 6Fe^{2+} \longrightarrow 6Fe^{3+} + 2NO_2$

$\uparrow + 4SO^2{}_4^- + 4H_2O$

$Fe^{2+} + NO\uparrow \longrightarrow [Fe(NO)]^{2+}$

Anions Of Group 'B'

Sulphate (SO_4^{2-})

Solubility

The sulphates of Barium, Strontium, and Lead are practically insoluble in water.

With Barium Chloride Solution

White precipitate of Barium Sulphate $BaSO_4$, insoluble in warm dilute Hydrochloric acid and in dilute Nitric acid, but moderately soluble in boiling, concentrated Hydrochloric acid

$SO_4^{2-} + Ba^{2+} \longrightarrow BaSO_4$

With Lead Acetate Solution

White precipitate of Lead Sulphate $PbSO_4$, soluble in hot concentrated sulphuric acid, in solutions of Ammonium Acetate and of Ammonium Tartrate and in Sodium Hydroxide solution.

$SO_4^{2-} + Pb^{+2} \longrightarrow PbSO_4\downarrow$

MIND MAP

Salt Analysis

Phosphate (PO_4^{-3})

With Silver Nitrate Solution

Yellow precipitate of normal Silver orthophosphate, Ag_3PO_4 (distinction from meta and pyrophosphate), soluble in dilute Ammonia solution and in dilute Nitric acid.

$$H_2PO_4^- + 3Ag \longrightarrow Ag_3PO_4\downarrow + H^+$$

$$Ag_3PO_4\downarrow + 2H^+ \longrightarrow H_2PO_4^- + 3Ag^+$$

$$Ag_3PO_4\downarrow + 6NH_3 \longrightarrow 3[Ag(NH_3)_2]^+ + PO_4^{3-}$$

With Ammonium Molybdate Reagent

The addition of a large excess (2-3 ml) of this reagent to a small volume (0.5 ml) of a phosphate solution produces a yellow, crystalline precipitate of Ammonium Phosphomolybdate $(NH_4)_3[P(Mo_3O_{10})_4]$

Analysis of Cations

Colour of flame	Cation
Golden yellow	Na^+
Violet (Lilac)	K^+
Carmine–red	Li^+
Brick–red	Ca^{2+}

Colour of flame	Cation
Apple–green	Ba^{2+}
Green	Cu^{2+}
Crimson–red	Sr^{2+}

Borax Bead Test

$$\underset{\text{Borax}}{Na_2B_4O_7.10H_2O} \longrightarrow Na_2B_4O_7 + 10H_2O$$

$$Na_2B_4O_7 \longrightarrow \underset{\text{Sodium metaborate}}{2NaBO_2} + \underset{\text{Boric anhydride}}{B_2O_3}$$

Qualitative Analysis of Cation Mixtures

The identification of individual species of Cations present in an unknown mixture of electrolytes involves a preliminary segregation of the cations into selected classifiable groups.

Group	Group Reagent	Cations	ppt/colour					
II	IIB dil. HCl/H_2S	As^{3+}, As^{5+}, Sb^{3+}, Sb^{5+}, Sn^{2+}, Sn^{4+}	As_2S_3 ↓ Yellow	As_2S_5 ↓ Yellow	Sb_2S_3 ↓ orange	Sb_2S_3 ↓ orange	SnS ↓ Brown	SnS_2 ↓ Yellow

MIND MAP

Salt Analysis

Group	Group Reagent	Cations	ppt/colour
I	Dil. HCl	Ag^{+}, Hg_2^{2+}, Pb^{2+}	AgCl Hg_2Cl_2 $PbCl_2$ White

Group	Group Reagent	Cations	ppt/colour
III	NH_4Cl/NH_4OH	Al^{3+}, Cr^{3+}, Fe^{3+}	$Al(OH)_3$ ↓ White; $Cr(OH)_3$ ↓ Green; $Fe(OH)_3$ ↓ Brown

Group	Group Reagent	Cations	ppt/colour
	IIA dil. HCl/H_2S	Pb^{+2}, Cu^{2+}, Bi^{3+}, Hg^{2+}, Cd^{2+}	PbS ↓ Black; CuS ↓ Black; Bi_2S_3 ↓ Brown; HgS ↓ Black; CdS ↓ Yellow

Group	Group Reagent	Cations	ppt/colour
IV	$NH_4Cl/NH_4OH/H_2S$	Ni^{2+}, Co^{2+}, Mn^{2+}, Zn^{2+}	NiS ↓ Black; CoS ↓ Black; MnS ↓ Pink/Buff/Skin; ZnS ↓ Dirty white

Group	Group Reagent	Cations	ppt/colour
V	$NH_4Cl/NH_4OH/(NH_4)_2CO_3$	Ba^{2+}, Sr^{2+}, Ca^{2+}	$BaCO_3$ ↓ White; $SrCO_3$ ↓ White; $CaCO_3$ ↓ White

Group	Group Reagent	Cations	ppt/colour
VI	No Common group reagent	Na^{+}, Mg^{2+}, K^{+}	No Common ppt
Zero	No Common group reagent	$\oplus$ NH_4	No Common ppt (Generally identify by Nessler's reagent)

MIND MAP

Salt Analysis

Group I

The sparingly soluble chlorides derived from Pb^{2+}, Hg_2^{2+} and Ag^+ ions are precipitated by the addition of dilute HCl.

Group I(Pb^{2+}, Ag^+, Hg_2^{2+}) Radicals

On adding dilute HCl to the salt solution if white precipitate is obtained, it indicates the presence of Pb^{2+}, Ag^+ or Hg_2^{2+} ion in the solution.

Lead (II)

Sodium Hydroxide Solution

With NaOH, Pb^{2+} forms a white precipitate of Lead Hydroxide.

The precipitate dissolves in excess of the reagent when tetrahydroxyplumbate(II) ions are formed.

$$Pb^{2+} + 2OH^- \longrightarrow Pb(OH)_2\downarrow$$

White ppt

$$Pb(OH)_2\downarrow + 2OH^- \longrightarrow [Pb(OH)_4]^{2-}$$

Soluble

Ammonia Solution

With ammonia solution, Pb^{2+} gives a white precipitate of Lead Hydroxide.

$$Pb^{+2} + 2NH_4OH \longrightarrow Pb(OH)_2 + 2NH_4^+$$

White ppt

The precipitate is insoluble in excess reagent.

Potassium Chromate Solution

$PbCl_2$ is soluble in hot water and gives a yellow precipitate with K_2CrO_4.

The precipitate obtained is insoluble in acetic acid but soluble in NaOH and Nitric acid.

$$PbCl_2 + K_2CrO_4 \longrightarrow PbCrO_4\downarrow + 2KCl$$

Yellow ppt

$$PbCrO_4\downarrow + 4NaOH \longrightarrow Na_2[Pb(OH)_4] + Na_2CrO_4$$

$$2PbCrO_4\downarrow + 2H^+ \longrightarrow 2Pb^{2+} + Cr_2O_7^{2-} + H_2O$$

Potassium Iodide Solution

$PbCl_2$ on addition of KI solution gives bright yellow precipitate of PbI_2.

$$PbCl_2 + 2KI \longrightarrow PbI_2\downarrow + 2KCl$$

Yellow ppt

$$PbI_2 + 2KI\ (excess) \rightleftharpoons K_2[PbI_4]$$

Soluble

The reaction is reversible and on diluting with H_2O, the precipitate reappears.

Silver (I)

Dilute Hydrochloric Acid

With dilute Hydrochloric acid (or soluble chlorides), a white precipitate of silver Chloride is formed.

$$Ag^+ + Cl^- \longrightarrow AgCl\downarrow$$

White ppt

It can be dissolved in concentrated Hydrochloric acid, when a dichloroargentate complex is formed.

$$AgCl^- + Cl^- \rightleftharpoons [AgCl_2]^-$$

Soluble

Dilute ammonia solution dissolves the precipitate to form the Diammineargentate(I) complex ion.

$AgCl\downarrow + 2NH_3 \rightleftharpoons [Ag(NH_3)_2]^+ + Cl^-$

Soluble

$3Ag^+ + HPO_4^{2-} \longrightarrow Ag_3PO_4\downarrow + H^+$

Yellow ppt

Nitric acid and Ammonia solution dissolves the precipitate.

$4[Ag(NH_3)_2]^+ + H_2N{-}NH_2.H_2SO_4 \longrightarrow$

$4Ag\downarrow + N_2\uparrow + 6NH_4^+ + 2NH_3 + SO_4^{2-}$

Silver mirror

Mercury (I)

When the solution is boiled, the colour of precipitate changes to Grey owing to the disproportionation, when Mercury (II) Oxide and Mercury metal are formed.

$Hg_2O\downarrow \longrightarrow HgO\downarrow + Hg\downarrow$

$2Hg_2Cl_2 + 4NH_4OH \longrightarrow$

$HgO.Hg\begin{matrix}NH_2\\Cl\end{matrix}\downarrow + 2Hg\downarrow + 3NH_4Cl + 3H_2O$

Amido mercuric chloride (black)

Potassium Iodide Solution

Hg2+2 give a green precipitate of Mercury(I)Iodide on reaction with KI solution.

$Hg_2^{+2} + 2I^- \longrightarrow Hg_2I_2$

Green ppt

MIND MAP

Salt Analysis

Group II

The sparingly soluble sulphides derived from Hg^{2+}, Pb^{2+}, Cu^{2+}, Cd^{2+} and Bi^{3+} ions (and in addition the sparingly soluble covalent sulphides As_2S_3, Sb_2S_3 and SnS) are precipitated by the passage of Hydrogen sulphide (H_2S) through an acidic solution whose concentration of Hydrogen ions is small.

The K_{sp} value of group II sulphide is quite low in comparison to K_{sp} values of group IV sulphides, hence they do not get precipitated in acidic medium, where S^{2-} ion concentration is quite low.

Group II A (Pb^{2+}, Hg^{2+}, Cu^{2+}, Bi^{3+}, Cd^{2+}) Radicals

The precipitates of group IIA are insoluble in yellow Ammonium Sulphide.

Mercury (II)

HgS precipitated dissolves in aqua regia forming undissociated $HgCl_2$.

$3HgS\downarrow + 6HCl + 2HNO_3 \longrightarrow$

$3HgCl_2 + 3S\downarrow + 2NO\uparrow + 4H_2O$

Tin(II)Chloride Solution

When $SnCl_2$ solution is added to a solution of Hg^{2+}, a white silky precipitate of Mercury(I) Chloride(calomel) is obtained.

$2Hg^{2+} + SnCl_2 \longrightarrow Hg_2Cl_2\downarrow + Sn^{4+}$

White Silky ppt

Copper(II)

Hot, concentrated Nitric acid dissolves Copper(II) Sulphide, leaving behind Sulphur as a white precipitate.

$3CuS\downarrow + 8HNO_3 \longrightarrow$

$3Cu^{2+} + 6NO_3^- + 3S\downarrow + 2NO\uparrow + 4H_2O$

White ppt

$I_3^- + 2S_2O_3^{2-} \longrightarrow 3I^- + S_4O_6^{2-}$

These reactions are used in quantitative analysis for the Iodometric determination of Copper.

Potassium Hexacyanoferrate(II) Solution

Cu^{2+} ions give chocolate–brown precipitate with $K_4[Fe(CN)_6]$ solution.

$2Cu^{2+} + K_4[Fe(CN)_6] \longrightarrow Cu_2[Fe(CN)_6]\downarrow + 4K^+$

Chocolate – brown ppt

$2Cu(SCN)_2 \downarrow + SO_2 + 2H_2O \longrightarrow$

$2CuSCN \downarrow + 2SCN^- + SO_4^{2-} + 4H^+$

White ppt

$2Cu^{2+} + 4CN^- \longrightarrow 2CuCN + (CN)_2$

Cyanogen

$CuCN + 3CN^- \longrightarrow [Cu(CN)_4]^{3-}$

Tetrahedral

Group III (Al^{3+}, Cr^{3+}, Fe^{3+})

Iron(III)

With Ammonium Sulphide solution, Fe^{3+} gives a black precipitate of Iron(II) Sulphide and Sulphur.

$2Fe^{3+} + 3S^{2-} \longrightarrow 2FeS \downarrow + S \downarrow$

Black ppt

The damp Iron(II) Sulphide precipitate, when exposed to air, is slowly Oxidized to brown Iron(III) Hydroxide.

$4FeS \downarrow + 6H_2O + 3O_2 \longrightarrow 4Fe(OH)_3 \downarrow 4S \downarrow$

Bismuth(III)

Black precipitate of Bi_2S_3 is obtained by dissolving in hot dilute Nitric acid, leaving behind Sulphur in the form of a white precipitate.

$Bi_2S_3 \downarrow + 8H^+ + 2NO_3^- \longrightarrow$

MIND MAP

Salt Analysis

$2Bi^{3+} + 3S + 2NO + 4H_2O$

White ppt

With NaOH solution, Bi^{3+} give a white precipitate of Bismuth(III) Hydroxide.

$Bi^{3+} + 3OH^- \longrightarrow Be(OH)_3$

White ppt

Cadmium(II)

Yellow precipitate of CdS dissolves in hot dilute Nitric acid giving Cd^{+2} ions.

Potassium Iodide

With KI solution, no precipitate is formed (distinction from Copper).

Group IIB (As^{3+}, Sb^{3+}, Sn^{2+}, Sn^{4+}) Radicals

Potassium Hexacyanoferrate(II)

With Potassium Hexacyanoferrate(II) solution, Fe^{3+} gives intense blue precipitate of Iron(III) Hexacyanoferrate (Prussian blue)

$4Fe^{3+} + 3[Fe(CN)_6]^{4-} \longrightarrow Fe_4[Fe(CN)_6]_3 \downarrow$

Prussian blue

$Fe_4[Fe(CN)_6]_3 \downarrow + 12OH^- \longrightarrow$

$4Fe(OH)_3 \downarrow + 3[Fe(CN)_6]^{4-}$

Reddish-brown ppt

Oxalic acid also dissolves Prussian blue forming a blue solution.

Potassium Hexacyanoferrate(III)

With Potassium Hexacyanoferrate(III), a brown colouration is produced, due to the formation of an undissociated complex, Iron(III) hexacyanoferrate(III).

$Fe^{3+} + [Fe(CN)_6]^{3-} \longrightarrow$

$Fe[Fe(CN)_6]$ Brown colouration

Disodium Hydrogen Phosphate Solution

With Disodium Hydrogen Phosphate solution a yellowish-white precipitate of Iron(III) Phosphate is formed.

$Fe^{3+} + HPO_4^{2-} \longrightarrow FePO_4 + H^+$

Yellowish-White ppt

MIND MAP

Salt Analysis

$[Fe_3(OH)_2(CH_3COO)_6]^+ + 4H_2O \longrightarrow$

$3Fe(OH)_2CH_3COO + 3CH_3COOH + H^+$

Reddish-brown ppt

$Fe^{3+} + 3SCN \longrightarrow Fe(SCN)_3$

Deep-red colouration

This neutral molecule can be extracted by ether or amyl Alcohol.

Aluminum(III)

With Sodium Hydroxide solution, Al^{3+} gives a white precipitate of Aluminum Hydroxide.

$Al^{3+} + 3OH^- \longrightarrow Al(OH)_3 \downarrow$

White ppt

The precipitate dissolves in excess reagent, forming Tetrahydroxoaluminate ions.

$Al(OH)_3 + OH^- \rightleftharpoons [Al(OH)_4]^-$ Soluble

Disodium Hydrogen Phosphate Solution

With Disodium Hydrogen Phosphate solution, a white gelatinous precipitate of Aluminium Phosphate is obtained.

$Al^{3+} + HPO_4^{2-} \rightleftharpoons AlPO_4 \downarrow + H^+$

White ppt

$2Al_2O_3 + 2Co^{2+} + 4NO^-_3 \longrightarrow$

$2CoAl_2O_4 + 4NO_2 \uparrow + O_2 \uparrow$

Use of excess Cobalt Nitrate solution should be avoided since this will produce black Cobalt oxide (Co_3O_4) upon Ignition, which will mask the blue colour.

Chromium(III)

With Sodium Hydroxide solution, a green precipitate of Chromium(III) Hydroxide is formed

$Cr^{3+} + 3OH^- \longrightarrow Cr(OH)_3 \downarrow$

Green ppt

In excess reagent, the precipitate dissolves readily, Tetrahydroxochromate(III) ions (or Chromite ions) are formed.

$Cr(OH)_3 + OH^- \rightleftharpoons [Cr(OH)_4]^-$

Soluble

Ammonia Solution

Bluish-green gelatinous precipitate of $Cr(OH)_3$ is obtained when treated with Ammonia solution but dissolves in excess of Ammonia due to the formation of a soluble complex.

In aqueous solution, the blue colour fades rapidly, because Chromium Pentoxide decomposes to Chromium(III) and Oxygen.

$4CrO_5 + 12H^+ \longrightarrow 4Cr^{3+} + 7O_2 \uparrow + 6H_2O$

$CrCl_3 + 3NH_4OH \longrightarrow Cr(OH)_3 + 3NH_4Cl$

Bluish-green ppt

$Cr(OH)_3 + 6NH_3 \longrightarrow [Cr(NH_3)_6]^{3+} + 3OH^-$

Excess — Pink colouration

Group IV (Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+})

Zinc(II)

With Sodium Hydroxide solution, a white gelatinous precipitate of Zinc hydroxide is formed

$Zn^{2+} + 2OH^- \longrightarrow Zn(OH)_2 \downarrow$

White gelatinous ppt

The precipitate is soluble in acids.

$Zn(OH)_2 + 2H^+ \longrightarrow Zn^{2+} + 2H_2O$

Manganese(II)

It rapidly oxidizes on exposure to air, becoming brown, when Hydrated Manganese dioxide, $MnO(OH)_2$, is formed.

$2Mn(OH)_2 + O_2 \longrightarrow 2MnO(OH)_2 \downarrow$

Brown ppt

MIND MAP

Salt Analysis

With Disodium Hydrogen Phosphate solution, a pink precipitate of Manganese Ammonium Phosphate $Mn(NH_4)PO_4.7H_2O$, in the presence of Ammonia (or Ammonium ions) is obtained.

The liquid acquires a violet-red (or purple) colour due to Permagnate acid.

$$5PbO_2 + 2Mn^{2+} + 4H^+ \longrightarrow$$

$$2MnO_4^- + 5Pb^{2+} + 2H_2O$$

Purple colour

Nickel(II)

The precipitate dissolves in excess reagent and the solution turns deep blue.

$$NiS\downarrow + HNO_3 + 3HCl \longrightarrow$$

$$Ni^{2+} + S\downarrow + NOCl + 2Cl^- + 2H_2O$$

$$Ni^{2+} + 2OH^- \longrightarrow Ni(OH)_2\downarrow$$

Green ppt

$$Ni(OH)_2\downarrow + 6NH_3 \longrightarrow [Ni(NH_3)_6]^{2+} + 2OH^-$$

Deep–blue colouration

$$Ni(OH)_2\downarrow + 6NH_4^+ + 4OH^- \longrightarrow$$

$$[Ni(NH_3)_6]^{2+} + 6H_2O$$

Deep–blue colouration

Potassium Nitrite Solution

No precipitate is produced in the presence of Acetic acid (difference from Cobalt)

Cobalt(II)

Potassium Nitrite Solution

Yellow precipitate is produced in the presence of Acetic acid (difference from Nickel)

With Ni^{2+}, NaOH gives a green precipitate of $Ni(OH)_2$.

$$Ni(OH)_2\downarrow + 6NH_3 \longrightarrow [Ni(NH_3)_6]^{2+} + 2OH^-$$

Deep-blue colouration

Group V (Ba^{2+}, Ca^{2+}, Sr^{2+})

Barium(II)

Potassium Chromate Solution

Ba^{2+} ion in solution produces a yellow precipitate with K_2CrO_4 solution.

$$Ba^{2+} + K_2CrO_4 \longrightarrow BaCrO_4\downarrow + 2K^+$$

Yellow ppt

Addition of acid to K_2CrO_4 solution causes the yellow colour of the solution to change to reddish–orange due to formation of $Cr_2O_7^{2-}$.

$$2CrO_4^{2-} + 2H^+ \rightleftharpoons Cr_2O_7^{2-} + H_2O$$

Strontium(II)

Ammonium Sulphate Solution

Sr^{2+} ions give a white precipitate with $(NH_4)_2SO_4$ solution.

$$Sr^{2+} + (NH_4)_2SO_4 \longrightarrow SrSO_4 + 2NH_4^+$$

White ppt

Ammonium Oxalate Solution

Sr^{2+} ions give a white precipitate with $(NH_4)_2C_2O_4$ solution.

$$Sr^{2+} + (NH_4)_2C_2O_4 \longrightarrow SrC_2O_4 + 2NH_4^+$$

White ppt

Group VI (Na^+, K^+, Mg^{2+})

Magnesium(II)

Ammonia Solution

Mg^{2+} gives white gelationous precipitate of Magnesium Hydroxide on reaction with Ammonium Hydroxide.

$$Mg^{2+} + 2NH_4OH \longrightarrow Mg(OH)_2 + 2NH_4^+$$

White ppt

$$5Mg^{2+} + 6CO_3^{2-} + 7H_2O \longrightarrow$$

$$4MgCO_3.Mg(OH)_2.5H_2O + 2HCO_3^-$$

White ppt

MIND MAP

Salt Analysis

Sodium Hydroxide Solution

All Ammonium salts on heating with Alkali (NaOH) gives smell of NH_3.

$$NH_4^+ + OH^- \longrightarrow NH_3 + H_2O$$

The gas evolved can be detected by its smell.

Gas evolved gives white fumes of NH_4Cl with HCl.

$$NH_3 + HCl \longrightarrow NH_4Cl\uparrow$$

White fumes

Disodium Hydrogen Phosphate Solution

With Disodium Hydrogen Phosphate solution, Mg^{2+} gives a white crystalline precipitate Magnesium Ammonium Phosphate in the absence of NH_4Cl.

A white flocculent precipitate of Magnesium Hydrogen Phosphate ($MgHPO_4$) is obtained in neutral solutions.

$$Mg^{2+} + HPO_4^{2-} \longrightarrow MgHPO_4$$

White ppt

Gas can be identified by its ability to turn filter paper moistened with Mercury(I) Nitrate solution black.