QUALITATIVE ANALYSIS

Charcoal Cavity Test :

Observation		Inference
Incrustation or Residue	**Metallic bead**	
Yellow when hot, white when cold	None	Zn^{2+}
Brown when hot, yellow when cold	Grey bead which marks the paper	Pb^{2+}
No characteristic residue	Red beads or scales	Cu^{2+}
White residue which glows on heating	None	Ba^{2+},Ca^{2+}, Mg^{2+}
Black	None	Nothing definite–generally coloured salt

Cobalt Nitrate Test :

S.No.	Metal	Colour of the mass
1	Zinc	Green
2	Aluminium	Blue
3	Magnesium	Pink
4	Tin	Bluish-green

Flame test :

Colour of Flame	Inference
Crimson Red / Carmine Red	Lithium
Golden yellow	Sodium
Violet/Lilac	Potassium
Brick red	Calcium
Crimson	Strontium
Apple Green/Yellowish Green	Barium
Green with a Blue centre/Greenish Blue	Copper

Borax Bead test :

Metal	Colour in oxidising flame		Colour in reducing flame	
	When Hot	When Cold	When Hot	When Cold
Copper	Green	Blue	Colourless	Brown red
Iron	Brown yellow	Pale yellow/Yellow	Bottle green	Bottle green
Chromium	Yellow	Green	Green	Green
Cobalt	Blue	Blue	Blue	Blue
Manganese	Violet/Amethyst	Red/Amethyst	Grey/Colourless	Grey/Colourless
Nickel	Violet	Brown/Reddish brown	Grey	Grey

Analysis of ANIONS (Acidic Radicals) :

(a) DILUTE SULPHURIC ACID/DILUTE HYDROCHLORIC ACID GROUP:

1. CARBONATE ION (CO_3^{2-}) :

- Dilute H_2SO_4 test : A colourless odourless gas is evolved with brisk effervescence.
  $CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + CO_2\uparrow$
- Lime water/Baryta water ($Ba(OH)_2$) test :
  $CO_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow$(milky) + H_2O

$CaCO_3 + CO_2 + H_2O \longrightarrow Ca(HCO_3)_2$ (soluble) $\xrightarrow{\Delta} CaCO_3\downarrow + H_2O + CO_2$

2. SULPHITE ION (SO_3^{2-}) :

- **Dilute H_2SO_4 test :**
  $CaSO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + SO_2\uparrow$;
  SO_2 has suffocating odour of burning sulphur.
- **Acidified potassium dichromate test :** The filter paper dipped in acidified $K_2Cr_2O_7$ turns green.
  $Cr_2O_7^{2-} + 2H^+ + 3SO_2 \longrightarrow 2Cr^{3+}$ (green) + $3SO_4^{2-}$ + H_2O.
- **Barium chloride/Strontium chloride solution :**
  $SO_3^{2-} + Ba^{2+}/Sr^{2+} \longrightarrow BaSO_3/SrSO_3\downarrow$ (white).

☞ White precipitate dissolves in dilute HCl.
$BaSO_3\downarrow + 2H^+ \longrightarrow Ba^{2+} + SO_2\uparrow + H_2O$.

3. SULPHIDE ION (S^{2-}) :

- **Dilute H_2SO_4 test :** Pungent smelling gas like that of rotten egg is obtained.
  $S^{2-} + 2H^+ \longrightarrow H_2S\uparrow$
- **Lead acetate test :**
  $(CH_3COO)_2Pb + H_2S \longrightarrow PbS\downarrow$ (black) + $2CH_3COOH$.
- **Sodium nitroprusside test :** Purple coloration is obtained.
  $S^{2-} + [Fe(CN)_5(NO)]^{2-} \longrightarrow [Fe(CN)_5NOS]^{4-}$ (violet).
- **Cadmium carbonate suspension/ Cadmium acetate solution:**
  $Na_2S + CdCO_3 \longrightarrow CdS\downarrow$ (Yellow) + Na_2CO_3

4. NITRITE ION (NO_2^-) :

- **Dilute H_2SO_4 test :**
  $NO_2^- + H^+ \longrightarrow HNO_2$; $(2HNO_2 \longrightarrow H_2O + N_2O_3)$;
  $3HNO_2 \longrightarrow HNO_3 + 2NO + H_2O$; $2NO + O_2 \longrightarrow 2NO_2 \uparrow$
- **Starch iodide test :**
  $2NO_2^- + 3I^- + 4CH_3COOH \longrightarrow I_3^- + 2NO \uparrow + 4CH_3COO^- + 2H_2O$
  Starch + I_3^- $\longrightarrow$ Blue (starch iodine adsorption complex)

5. ACETATE ION (CH_3COO^-)

- **Dilute H_2SO_4 test :**
  $(CH_3COO)_2Ca + H_2SO_4 \longrightarrow 2CH_3COOH$ (vinegar like smell) + $CaSO_4$
- **Neutral ferric chloride test :**
  $6CH_3COO^- + 3Fe^{3+} + 2H_2O \longrightarrow [Fe_3(OH)_2(CH_3COO)_6]^+$ (deep red/ blood red colouration) + $2H^+$
  $[Fe_3(OH)_2(CH_3COO)_6]^+ + 4H_2O \xrightarrow{\text{Boil}} 3Fe(OH)_2CH_3COO\downarrow$ (brownish red) + $3CH_3COOH + H^+$

(b) CONC . H_2SO_4 GROUP :

1. CHLORIDE ION (Cl^-) :

- **Concentrated H_2SO_4 test :** $Cl^- + H_2SO_4 \longrightarrow HCl$ (colourless pungent smelling gas) + HSO_4^-
- $NH_4OH + HCl \longrightarrow NH_4Cl \uparrow$ (white fumes) + H_2O.
- **Silver nitrate test :** $Cl^- + Ag^+ \longrightarrow AgCl \downarrow$ (white)

☞ White precipitate is soluble in aqueous ammonia and precipitate reappears with HNO_3.
$AgCl + 2NH_4OH \longrightarrow [Ag(NH_3)_2]Cl$ (Soluble) + $2H_2O$;
$[Ag(NH_3)_2]Cl + 2H^+ \longrightarrow AgCl \downarrow + 2NH_4^+$.

- **Chromyl chloride test :**
  $4Cl^- + Cr_2O_7^{2-} + 6H^+$ (conc.) $\longrightarrow 2CrO_2Cl_2$ (deep red vapours) + $3H_2O$
  $CrO_2Cl_2 + 4OH^- \longrightarrow CrO_4^{2-} + 2Cl^- + 2H_2O$;
  $CrO_4^{2-} + Pb^{+2} \longrightarrow PbCrO_4 \downarrow$ (yellow)

2. BROMIDE ION (Br^-) :

- **Concentrated H_2SO_4 test :**
  $2NaBr + H_2SO_4 \longrightarrow Na_2SO_4 + 2HBr$;
  $2HBr + H_2SO_4 \longrightarrow Br_2 \uparrow$ (reddish-brown) + $2H_2O + SO_2$
- **Silver nitrate test :**
  $NaBr + AgNO_3 \longrightarrow AgBr \downarrow$ (pale yellow) + $NaNO_3$

☞ Yellow precipitate is partially soluble in dilute aqueous ammonia but readily dissolves in concentrated ammonia solution.
$AgBr + 2NH_4OH \longrightarrow [Ag(NH_3)_2]\,Br + H_2O$

- **Chlorine water test (organic layer test) :**
  $2Br^- + Cl_2 \longrightarrow 2Cl^- + Br_2 \uparrow$.
  $Br_2 + CHCl_3 / CCl_4 \longrightarrow Br_2$ dissolve to give reddish brown colour in organic layer.

3. IODIDE ION (I^-) :

- **Concentrated H_2SO_4 test :** $2NaI + H_2SO_4 \longrightarrow Na_2SO_4 + 2HI$
  $2HI + H_2SO_4 \longrightarrow I_2 \uparrow$ (pungent smelling dark violet) $+ 2H_2O + SO_2$
- **Starch paper test :** Iodides are readily oxidised in acid solution to free iodine; the free iodine may than be identified by deep blue colouration produced with starch solution.
  $3I^- + 2NO_2^- + 4H^+ \longrightarrow I_3^- + 2NO \uparrow + 2H_2O$.
- **Silver nitrate test :** Bright yellow precipitate is formed.
  $I^- + Ag^+ \longrightarrow AgI \downarrow$

☞ Bright yellow precipitate is insoluble in dilute aqueous ammonia but is partially soluble in concentrated ammonia solution.

- **Chlorine water test (organic layer test) :**
  $2NaI + Cl_2 \longrightarrow 2NaCl + I_2$
  $I_2 + CHCl_3 \longrightarrow I_2$ dissolves to give violet colour in organic layer.

4. NITRATE ION (NO_3^-) :

- **Concentrated H_2SO_4 test :** Pungent smelling reddish brown vapours are evolved.
  $4NO_3^- + 2H_2SO_4 \longrightarrow 4NO_2 \uparrow + O_2 + 2SO_4^{2-} + 2H_2O$

☞ Addition of bright copper turnings or paper pellets intensifies the evolution of reddish brown gas.
$2NO_3^- + 4H_2SO_4 + 3Cu \longrightarrow 3Cu^{2+} + 2NO \uparrow + 4SO_4^{2-} + 4H_2O$;
$2NO \uparrow + O_2 \longrightarrow 2NO_2 \uparrow$
$4\,C$ (paper pellet) $+ 4HNO_3 \longrightarrow 2H_2O + 4NO_2 + 4CO_2$.

- ***Brown ring test :***
  $2NO_3^- + 4H_2SO_4 + 6Fe^{2+} \longrightarrow 6Fe^{3+} + 2NO \downarrow + 4SO_4^{2-} + 4H_2O$.
  $Fe^{2+} + NO \uparrow + 5H_2O \longrightarrow [Fe^{I}(H_2O)_5\,NO^+]^{2+}$ (brown ring).

3. Miscellaneous Group :

1. SULPHATE ION (SO_4^{2-}) :

- **Barium chloride test :**
  $Na_2SO_4 + BaCl_2 \longrightarrow BaSO_4 \downarrow$ (white) $+ 2NaCl$.

☞ White precipitate is insoluble in warm dil. HNO_3 as well as HCl but moderately soluble in boiling concentrated hydrochloric acid.

● **Lead acetate test :**

$Na_2SO_4 + (CH_3COO)_2Pb \longrightarrow PbSO_4\downarrow (White) + 2CH_3COONa$

☞ White precipitate soluble in excess of hot ammonium acetate.

$PbSO_4 + 2CH_3COONH_4 \longrightarrow (CH_3COO)_2Pb\ (soluble) + (NH_4)_2SO_4$

2. PHOSPHATE ION (PO_4^{3-}) :

● **Ammonium molybdate test :**

$Na_2HPO_4(aq) + 12(NH_4)_2MoO_4 + 23HNO_3 \rightarrow (NH_4)_3PMo_{12}O_{40}\downarrow$ (canary yellow) $+ 2NaNO_3 + 21NH_4NO_3 + 12H_2O$

ANALYSIS OF CATIONS

1. AMMONIUM ION (NH_4^+) :

$2NH_3 + Mn^{2+} + H_2O_2 + H_2O \longrightarrow MnO(OH)_2\downarrow (brown) + 2NH_4^+$

Nessler's reagent (Alkaline solution of potassium tetraidomercurate(II) :

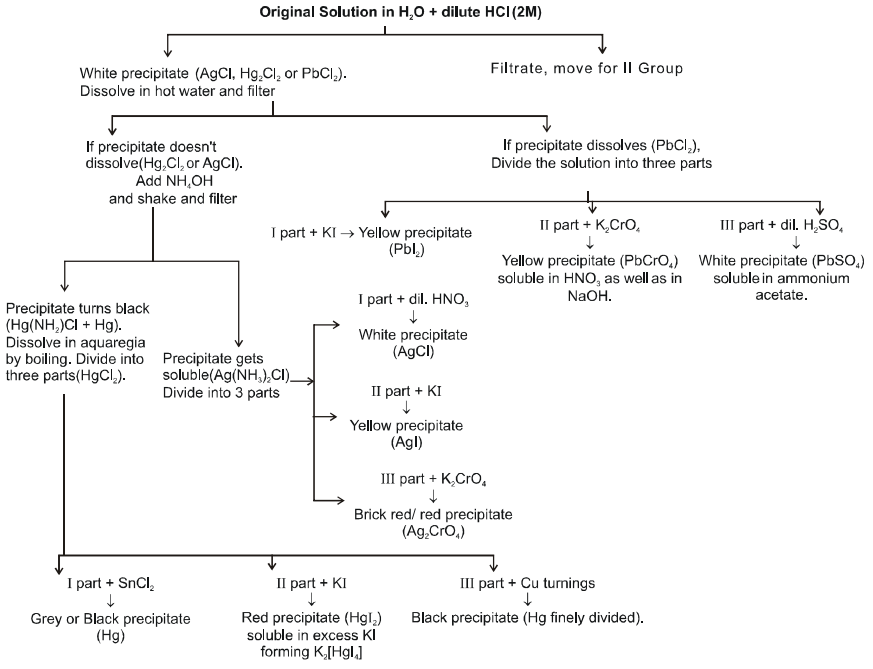
$NH_4^+ + 2[HgI_4]^{2-} + 4OH^- \longrightarrow HgO\ Hg(NH_2)I\downarrow (brown) + 7I^- + 3H_2O$

$3NH_4^+ + [Co(NO_2)_6]^{3-} \longrightarrow (NH_4)[Co(NO_2)_6]\downarrow$ (yellow)

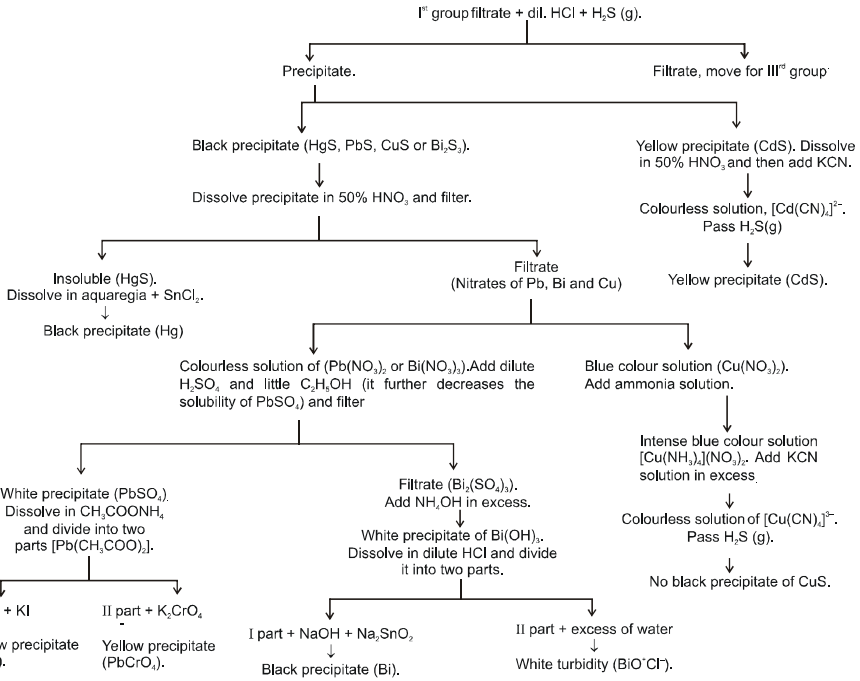
$2NH_4^+ + [PtCl_6]^- \longrightarrow (NH_4)_2[PtCl_6]\downarrow$ yellow

$NH_4^+ + HC_4H_4O_6^- \longrightarrow NH_4HC_4H_4O_6\downarrow$

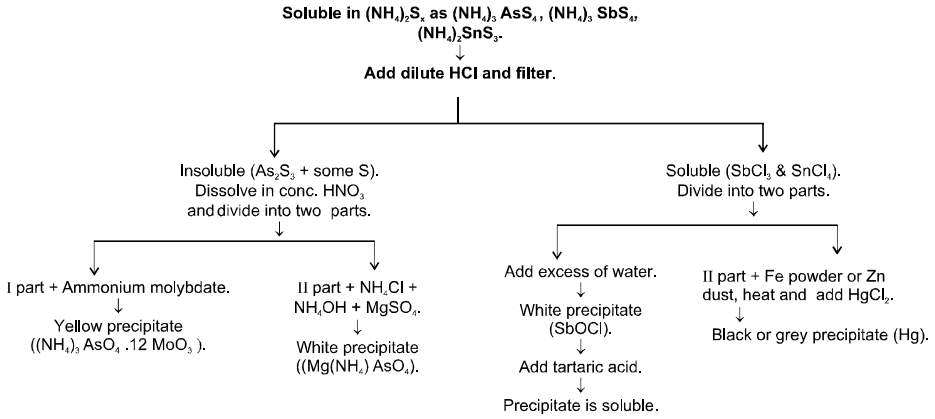
Ist GROUP (Pb^{2+}, Hg_2^{2+}, Ag^+) :



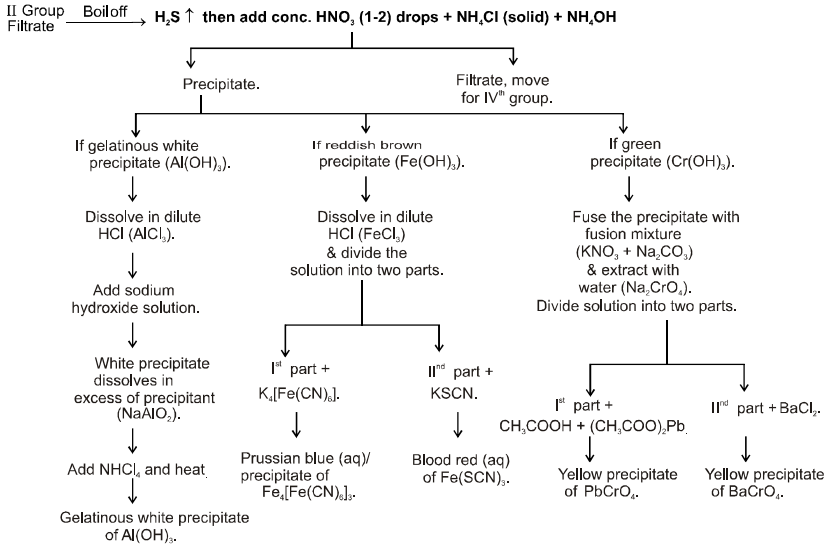
IIA Group (Hg^{2+}, Pb^{2+}, Bi^{3+}, Cu^{2+}, Cd^{2+})



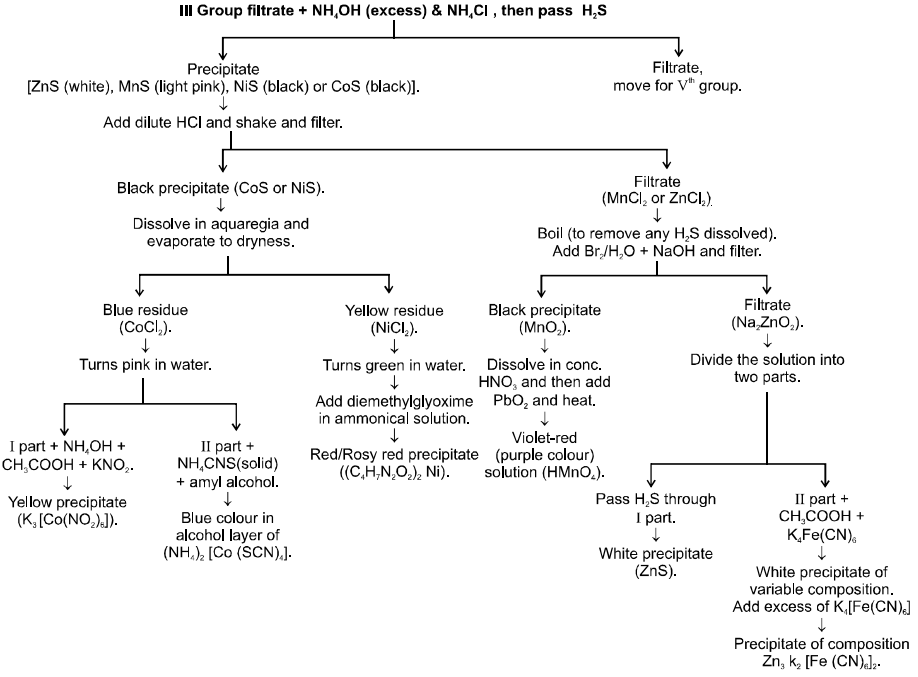
IIB Group (As^{3+}, Sb^{3+}, Sn^{2+}, Sn^{4+})



III[rd] Group (Al , Cr , Fe)



IV[th] GROUP (Zn^{2+}, Mn^{2+}, Ni^{2+}, Co^{2+}) :



Vth Group (Ba , Sr , Ca) :

IV Group filtrate $\longrightarrow$ Boil off H_2S then add $(NH_4)_2CO_3$ (aq), NH_4OH & NH_4Cl (s)

White precipitate ($BaCO_3$, $SrCO_3$ or $CaCO_3$).

Filtrate, move for VI group.

↓

Dissolve in CH_3COOH and divide into three parts and test in the sequence given below.

I part + K_2CrO_4. ↓ Yellow precipitate ($BaCrO_4$ insoluble in CH_3COOH).

II Part + $(NH_4)_2SO_4$. ↓ White precipitate ($SrSO_4$).

III part + $(NH_4)_2C_2O_4$. ↓ White precipitate (CaC_2O_4).

VIth GROUP :

MAGNESIUM ION (Mg^{2+}) :

$$Mg^{2+} + NH_3 + HPO_4^{2-} \longrightarrow Mg(NH_4)PO_4 \downarrow \text{(white)}$$

$$5\ Mg^{2+} + 6\ CO_3^{2-} + 7\ H_2O \longrightarrow 2\ MgCO_3.\ Mg(OH)_2.\ 5\ H_2O \downarrow + 2HCO_3^-$$

Titan Yelllow (a water soluble yellow dyestuff) :

It is adsorbed by $Mg(OH)_2$ producing a deep red colour or precipitate.