Qualitative Analysis

Tests for Anions

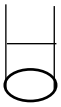
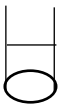
Anion	Test	Observations
CO_3^{2-}	Add a dilute acid. Then pass the gas that is given off into limewater.	Effervescence. Gas given off forms a white precipitate with lime water. $CO_3^{2-}{}_{(aq)} + 2H^+{}_{(aq)} \longrightarrow CO_{2(g)}\uparrow + H_2O_{(l)}$ $CO_{2(g)} + Ca(OH)_{2(aq)} \leftrightarrow \boxed{CaCO_{3(s)}}\downarrow + H2O_{(l)}$ (white precipitate)
NO_2^-	1) Add **dil**. H_2SO_4 acid. 2) Brown ring test: Add freshly prepared cool $FeSO_4$ solution into an aqueous solution of nitrite. Then slowly add concentrated sulphuric acid (H_2SO_4).	Brisk effervescence with evolution of reddish-brown coloured fumes. $NO_2^-{}_{(aq)} + H^+{}_{(aq)} \longrightarrow HNO_{2(aq)}$ $3HNO_{2(aq)} \longrightarrow HNO_{3(aq)} + 2NO_{(g)} + H_2O_{(l)}$ $2NO_{(g)} + O_{2(g)} \longrightarrow \textcircled{2NO2_{(g)}}\uparrow$ (reddish brown gas) A brown ring will be formed at the junction of the 2 layers.
NO_3^-	1) Add **Conc.** H_2SO_4 2) Brown ring test: Add freshly prepared cool $FeSO_4$ solution into an aqueous solution of nitrate. Then slowly add concentrated sulphuric acid (H_2SO_4). 3) Add NaOH solution. Then add powdered Al or (Devarda's alloy / Zn dust) and warm the mixture. Test the gas given off with; i)moist red litmus paper, ii) HCl stopper iii)Nestler's reagent	Brisk effervescence with evolution of brown coloured fumes. A brown ring will be formed at the junction of the 2 layers. $NO_3^- + 3Fe^{2+} + 4H^+ \longrightarrow NO + 3Fe^{3+} + 2H_2O$ $[Fe(H_2O)_6]^{2+} + NO \longrightarrow [Fe(H_2O)_5NO]^{2+} + H_2O$ (brown) Effervescence with a pungent smell. $8Al_{(s)} + 3NaNO_{3(aq)} + 5NaOH \longrightarrow 8AlNaO_2 + 3NH_3\uparrow$ (pungent smell) i)The moist red litmus paper turns to blue. ii) White fumes can be seen with the HCl stopper. iii)It turns yellow coloured Nestler'reagent into brown colour.

Vajira Seneviratne

S^{2-}	1) i)Add $AgNO_3$ or $CuSO_4$ solution	Black colour precipitates. $2Ag^+_{(aq)} + S^{2-}_{(aq)} \longrightarrow \boxed{Ag_2S_{(s)}}\downarrow$ $Cu^{2+}_{(aq)} + S^{2-}_{(aq)} \longrightarrow \boxed{CuS_{(s)}}\downarrow$ } black precipitates
	ii) Addition of Group II cations in the acidic medium. (dil.HCl)	Black Precipitates - $\boxed{CuS, HgS, Bi_2S_3, PbS}\downarrow$ Yellow precipitates - $\boxed{As_2S_3, SnS_2, CdS}\downarrow$ Brown precipitate - $\boxed{SnS}\downarrow$ Orange precipitate – $\boxed{Sb_2S_3}\downarrow$
	iii) Addition of Group IV cations in the basic medium. (NH_4OH)	Black precipitates - $\boxed{CoS, NiS}\downarrow$ White precipitate - $\boxed{ZnS}\downarrow$ Pink precipitate - $\boxed{MnS}\downarrow$
	2) Add dil. HCl solution to the solid compound.	Effervescence with an unpleasant odour. (commonly called "rotten egg" smell) $S^{2-}_{(aq)} + 2H^+_{(aq)} \longrightarrow H_2S\uparrow$ (rotten egg smell)
	Evolved gas was tested with a filter paper soaked with $Pb(CH_3COO)_2$ solution.	Filter paper turned to black colour. $Pb(CH_3COO)_{2(aq)} + H_2S_{(g)} \longrightarrow \boxed{PbS_{(s)}}\downarrow + 2H^+_{(aq)} + SO_4^{2-}_{(aq)}$ (black)
SO_3^{2-}	1) Add dil. HCl to the solid compound and warm.	Effervescence with a pungent smell. $SO_3^{2-}_{(aq)} + 2H^+_{(aq)} \longrightarrow H_2O_{(l)} + SO_{2(g)}\uparrow$ (pungent smell)
	Check the gas evolved with a filter paper moistened with acidified $K_2Cr_2O_7$	Orange colour filter paper turns to green. $Cr_2O_7^{2-}_{(aq)} + 3SO_{2(g)} + 2H^+_{(aq)} \longrightarrow 2Cr^{3+}_{(aq)} + 3SO_4^{2-}_{(aq)} + H_2O_{(l)}$ (orange) (green)
	2) Add $BaCl_2$.	White precipitate. $BaCl_{2(aq)} + SO_3^{2-}_{(aq)} \longrightarrow \boxed{BaSO_{3(s)}}\downarrow + 2Cl^-_{(aq)}$ (white)
	Then check the precipitate with dilute HNO_3.	White precipitate is **soluble** in dil. HNO_3. $BaSO_{3(s)} + 2H^+_{(aq)} \longrightarrow Ba^{2+}_{(aq)} + SO_{2(g)} + H_2O_{(l)}$

Vajira Seneviratne

SO_4^{2-}	Add $BaCl_2$ solution.	White precipitate. $BaCl_{2(aq)} + SO_4^{2-}{}_{(aq)} \longrightarrow \underset{\text{(white)}}{\boxed{BaSO_{4(s)}}}\downarrow + 2Cl^-_{(aq)}$
	Then check the precipitate with dil. HNO_3.	White precipitate is **insoluble** in dil. HNO_3
$S_2O_3^{2-}$	1) Add dil. HCl.	Effervescence with a pungent smell. Turbid solution. $S_2O_3^{2-}{}_{(aq)} + H^+_{(aq)} \longrightarrow SO_{2\,(g)}\uparrow + H_2O + \underset{\text{(pale yellow precipitate)}}{\boxed{S_{(s)}}}\downarrow$
	Check the gas evolved with a filter paper moistened with acidified $K_2Cr_2O_7$.	Orange colour filter paper turns to green. $Cr_2O_7^{2-}{}_{(aq)} + 3SO_{2(g)} + 2H^+_{(aq)} \longrightarrow 2Cr^{3+}_{(aq)} + 3SO_4^{2-}{}_{(aq)} + H_2O_{(l)}$ (orange) (green)
	2) Add $AgNO_3$ and warm the solution.	Initially a white precipitate can be observed and eventually it will be turned to black. $S_2O_3^{2-}{}_{(aq)} + 2Ag^+_{(aq)} \longrightarrow \boxed{Ag_2S_2O_{3\,(s)}}\downarrow$ (white precipitate) $Ag_2S_2O_{3(s)} + H_2O_{(l)} \xrightarrow{\text{heat }\Delta} \underset{\text{(black)}}{\boxed{Ag_2S_{(s)}}}\downarrow + SO_4^{2-}{}_{(aq)} + 2H^+_{(aq)}$ (white)
	3) Add $Pb(CH_3COO)_2$ solution.	White precipitate. $S_2O_3^{2-}{}_{(aq)} + Pb^{2+}_{(aq)} \longrightarrow \boxed{PbS_2O_{3\,(s)}}\downarrow$ (white precipitate)
	Heat the resulting solution.	Black precipitate $PbS_2O_{3(s)} + H_2O_{(l)} \xrightarrow{\text{heat }\Delta} \underset{\text{(black)}}{\boxed{PbS_{(s)}}}\downarrow + SO_4^{2-}{}_{(aq)} + 2H^+_{(aq)}$ (white)
PO_4^{3-}	Add Ammonium molibdate.	Yellow precipitate. $PO_4^{3-}{}_{(aq)} + 3NH_4^+{}_{(aq)} + 12MoO_4^{2-}{}_{(aq)} + 24H^+_{(aq)}$ $\longrightarrow \underset{\text{(yellow)}}{\boxed{(NH_4)_3[PO_4(Mo_3O_9)_4]_{(s)}}}\downarrow + 24H_2O_{(l)}$
Cl^-	1) Add $AgNO_3$.	White precipitate $Cl^-_{(aq)} + AgNO_{3(aq)} \longrightarrow \underset{\text{(White)}}{\boxed{AgCl_{(s)}}}\downarrow + NO_3^-{}_{(aq)}$
	Test the solubility of the precipitate with **dil.NH_3** solution.	**Soluble** in dil.NH_3. $AgCl_{(s)} + 2NH_{3(aq)} \longrightarrow [Ag(NH_3)_2]Cl$

	2) Add $Pb(NO_3)_2$. Check the precipitate with hot water.	White precipitate and soluble in hot water (Needle like crystals will be precipitated again after cooling) $2Cl^-_{(aq)} + Pb(NO_3)_{2(aq)} \longrightarrow \boxed{PbCl_{2(s)}}\downarrow + 2NO_3^-{}_{(aq)}$ (White)
	3) Add Cl_2 /CCl_4	No colour in the organic layer.
Br^-	1) Add $AgNO_3$.	White precipitate $Br^-_{(aq)} + AgNO_{3(aq)} \longrightarrow \boxed{AgBr_{(s)}}\downarrow + NO_3^-{}_{(aq)}$ (pale yellow)
	Test the solubility of the precipitates with **dilute and Conc.NH_3** solutions.	**Insoluble in dil.NH_3 and soluble in Conc. NH_3** $AgBr_{(s)} + 2NH_{3(aq)} \longrightarrow [Ag(NH_3)_2]Br$
	2) Add $Pb(NO_3)_2$. Check the precipitate with hot water.	White precipitate and soluble in hot water (Needle like crystals will be precipitated again after cooling) $2Br^-_{(aq)} + Pb(NO_3)_{2(aq)} \longrightarrow \boxed{PbBr_{2(s)}}\downarrow + 2NO_3^-{}_{(aq)}$ (White)
	3) Add Cl_2 /CCl_4	CCl_4 layer turns to brown red colour. $Br^-_{(aq)} + Cl_{2(aq)} \longrightarrow Br_{2(aq)} + 2Cl^-_{(aq)}$  (brown)
I^-	1) Add $AgNO_3$.	White precipitate $I^-_{(aq)} + AgNO_{3(aq)} \longrightarrow \boxed{AgI_{(s)}}\downarrow + NO_3^-{}_{(aq)}$ (yellow)
	Test the precipitate with dilute and Conc.NH_3.	**Insoluble in both dil.NH_3 and Conc. NH_3**
	2) Add $Pb(NO_3)_2$. Check the precipitate with hot water.	yellow precipitate and soluble in hot water (This will precipitate again after cooling) – gold dust test $2I^-_{(aq)} + Pb(NO_3)_{2(aq)} \longrightarrow \boxed{PbI_{2(s)}}\downarrow + 2NO_3^-{}_{(aq)}$ (yellow)
	3) Add Cl_2 /CCl_4	CCl_4 layer turns to purple colour. $I^-_{(aq)} + Cl_{2(aq)} \longrightarrow I_{2(aq)} + 2Cl^-_{(aq)}$  (purple)

Identification of gases

NH_3 - Pungent smell.
Turns red litmus paper to blue colour.
Forms a white fume with HCl vapour. $NH_{3(g)} + HCl_{(g)} \longrightarrow (NH_4Cl_{(g)})$
Gives a brown colour for Nessler reagent.

CO_2 - Forms a white precipitate with lime water.

NO_2 - Reddish brown gas

	$H^+ / KMnO_4$	$H^+ / Cr_2O_7^{2-}$	$Pb(CH_3COO)_2$	Moistened and coloured petals
SO_2	Purple colour solution turns to colourless.	Orange colour Solution turns to a **green colour clear solution.**	No precipitate formation.	Bleach the colour
H_2S	Purple colour solution turns to colourless.	Orange colour Solution turns to a **green colour turbid solution.** (due to the precipitation of S)	Black precipitate (PbS)	Cannot bleach the colour

❖ Anions which evolve gases with dilute acids:

$S^{2-} + 2H^+ \longrightarrow H_2S_{(g)}\uparrow$

$SO_3^{2-} + 2H^+ \longrightarrow SO_{2(g)}\uparrow + H_2O$

$S_2O_3^{2-} + 2H^+ \longrightarrow SO_{2(g)}\uparrow + \boxed{S_{(s)}}$ (pale yellow precipitate)$\downarrow + H_2O$

$CO_3^{2-} + 2H^+ \longrightarrow CO_{2(g)}\uparrow + H_2O$

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

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

$2NO + O_2 \longrightarrow (2NO_{2(g)})\uparrow$ (reddish brown gas)

- NO_2 is the only coloured gas. (Reddish brown)
- H_2S and SO_2 can act as reducing agents.
- HSO_3^- and HCO_3^- can also produce gases with dilute acids.
- $S_2O_3^{2-}$ gives a turbid solution due to S formation.

❖ Anions which evolve gases with Conc. Acids:

Br^-, I^-, NO_3^-, $C_2O_4^{2-}$ → Conc. Acids →

$(Br_{2(g)})\uparrow$ (brown coloured gas)

$(I_{2(g)})\uparrow$ (purple coloured gas)

$(NO_{2(g)})\uparrow$ (brown red gas)

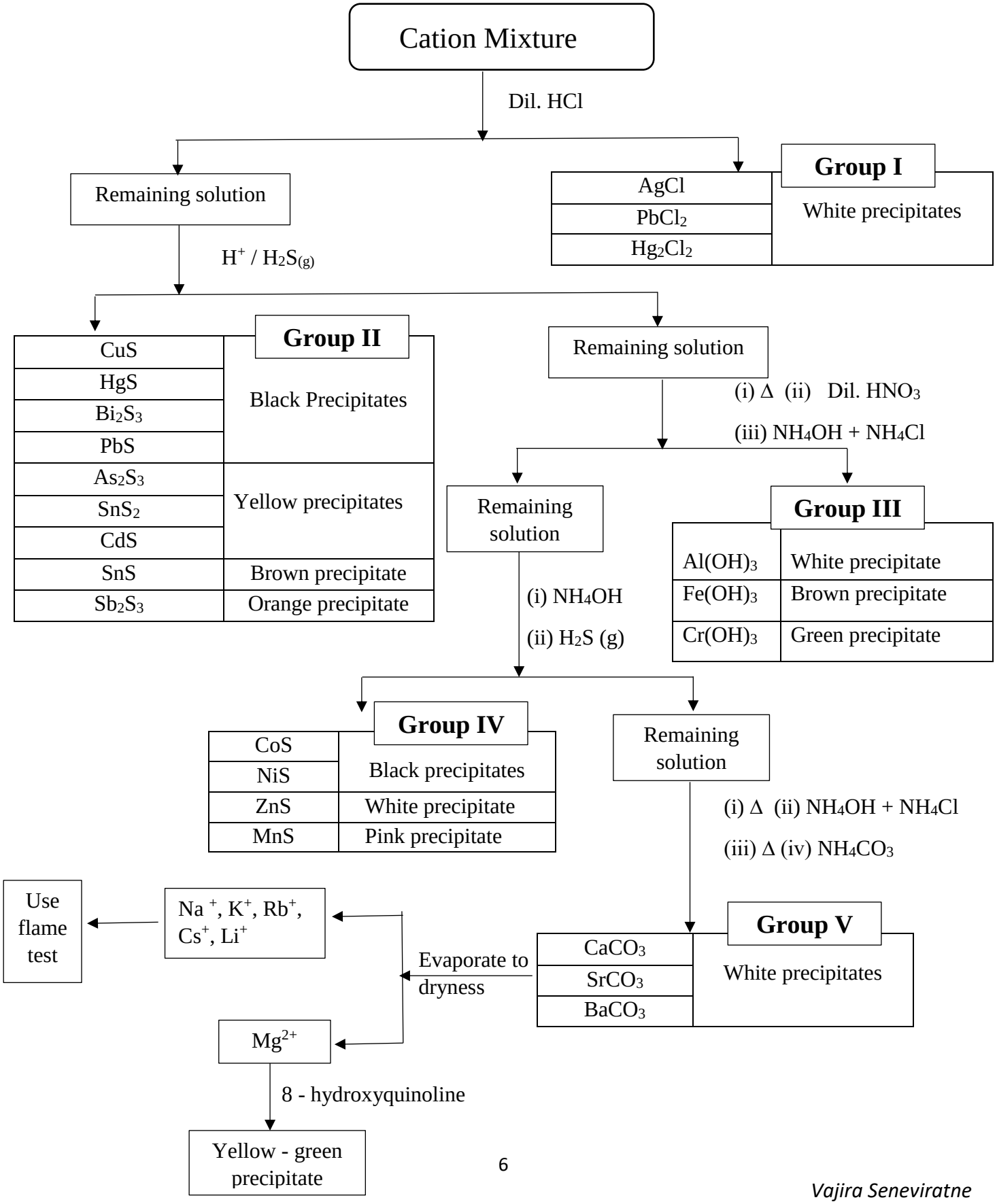
$(CO_{2(g)})\uparrow + (CO_{(g)})\uparrow$ (colourless gases)

- Br^- and I^- undergo oxidation in the presence of Conc. H_2SO_4.
- SO_4^{2-} and PO_4^{3-} do not produce gases with Conc. H_2SO_4.
- Both Br^- and NO_3^- produce brown colour gases.
- I^- gives a purple colour gas.

Vajira Seneviratne

Tests for Cations

❖ Group Analysis



❖ Flame test colours

- Red

- Brick red

- Lilac

- Apple green

- Green

- Crimson red

- Golden yellow

❖ Metal complexes and their colours

Metal	Nature of the ligand			
	$H_2O_{(l)}$	$OH^-_{(aq)}$	$NH_{3(aq)}$	$Cl^-_{(aq)}$
Cr	$[Cr(H_2O)_6]^{3+}$ Purple	$Cr(OH)_3$ blue-green precipitate	$Cr(OH)_3$ blue-green precipitate	$[CrCl_6]^{3-}$ blue-violet (precipitate)
Mn	$[Mn(H_2O)_6]^{2+}$ pale pink	$Mn(OH)_2$ white/ cream colour precipitate	$Mn(OH)_2$ white/ cream colour precipitate	$[MnCl_4]^{2-}$ greenish yellow
Fe (+2) (+3)	$[Fe(H_2O)_6]^{2+}$ pale green $[Fe(H_2O)_6]^{3+}$ yellow – brown	$Fe(OH)_2$ dirty green precipitate $Fe(OH)_3$ reddish-brown precipitate	$Fe(OH)_2$ dirty green precipitate $Fe(OH)_3$ reddish-brown precipitate	$[FeCl_4]^-$ Yellow
Co	$[Co(H_2O)_6]^{2+}$ Pink	$Co(OH)_2$ Pink precipitate With excess OH^- $[Co(OH)_4]^{2-}$ deep-blue	$[Co(NH_3)_6]^{2+}$ yellowish-brown $[Co(NH_3)_6]^{3+}$ brownish-red	$[CoCl_4]^{2-}$ blue
Ni	$[Ni(H_2O)_6]^{2+}$ Green	$Ni(OH)_2$ green precipitate	$[Ni(NH_3)_6]^{2+}$ blue	$[NiCl_4]^{2-}$ yellow
Cu	$[Cu(H_2O)_6]^{2+}$ pale blue	$Cu(OH)_2$ blue precipitate	$[Cu(NH_3)_4]^{2+}$ deep blue	$[CuCl_4]^{2-}$ yellow
Zn	$[Zn(H_2O)_6]^{2+}$ Colourless	$Zn(OH)_2$ white precipitate With excess OH^- $[Zn(OH)_4]^{2-}$ Colourless	$[Zn(NH_3)_4]^{2+}$ colourless	$[ZnCl_4]^{2-}$ colourless

❖ Colours of 3d cations in aqueous medium – aqua complexes

Colourless	Purple	Green	Pink	Brown	Blue
Sc^{3+}	Ti^{3+}	Fe^{2+}	Co^{2+}	Fe^{3+}	Cu^{2+}
Zn^{2+}	Cr^{3+}	Ni^{2+}	Mn^{2+}	-	Cr^{2+}
Cu^{+}	Mn^{3+}	V^{3+}	-	-	-
Ti^{4+}	V^{2+}	-	-	-	-

❖ Distinguish between Fe^{2+} and Fe^{3+}

Test	Fe^{2+}	Fe^{3+}
NaOH / NH_4OH	$Fe(OH)_2$ green precipitate	$Fe(OH)_3$ brown precipitate
$K_3[Fe(CN)_6]$	$KFe[Fe(CN)_6]$ percian blue	yellow – brown solution
$K_4[Fe(CN)_6]$	white precipitate	$KFe[Fe(CN)_6]$ percian blue
NH_4SCN or KSCN	-	$[Fe(SCN)n]^m$ (n = 1,2,3,4) blood red

❖ Colours of Vanadium species

Oxidation No.	Species	Colour
+5	VO_2^+	Yellow
+4	VO^{2+}	Blue
+3	V^{3+}	Green
+2	V^{2+}	Purple