Qualitative Analysis

1. Anions

Reagenet addded	Ions tested	Observations	Equations
Dilute Acid (i.e. HCl), heat	$\mathrm{CO_3}^{2-}$	$CO_2(g)$	
	NO_2^-	$NO_2(g)$	
	$\mathrm{SO_3}^{2-}$	$\mathrm{SO_2}(g)$	
$AgNO_3(aq)$, $NH_3(aq)$ dropwise (Precipiation, complex formation)	Cl^-	White ppt, soluble	$\mathrm{AgX\,(s) + 2\,NH_3\,(aq) \longrightarrow [Ag(NH_3)_2]^+\,(aq) + X^-\,(aq)}$
	Br^-	Pale-cream ppt, partially soluble	
	I^-	Yellow ppt, insoluble	
$Ba(NO_3)_2(aq)$, $HNO_3(aq)$ dropwise (Precpitation)	CO_3^{2-}	White ppt of $BaCO3$ ppt Dissolved to form colourless solution, $CO_2(g)$	$\mathrm{BaCO_3\,(s) + 2\,HNO_3\,(aq) \longrightarrow Ba(NO_3)_2\,(aq) + CO_2\,(g) + H_2O\,(l)}$
	SO_4^{2-}	White ppt, insoluble	
	SO_3^{2-}	White ppt Dissolved to form colourless solution, $SO_2(g)$	
$KMnO_4(aq)$ acidified with dilute $H_2SO_4(aq)$ (Redox)	Cl^-	$Cl_2(g)$ Decolourisation	$\mathrm{2\,MnO_4^-\,(aq) + 16\,H^+\,(aq) + 10\,X^-\,(aq) \longrightarrow 5\,X_2\,(aq) + 2\,Mn^{2+}\,(aq) + 8\,H_2O\,(l)}$
	Br^-	Orange colour, decolourisation	
	I^-	Brown colour, decolourisation	
$NaOH(aq)$ with Al foil, heat (Redox)	NO_3^-	$H_2(g)$ $NH_3(g)$ on heating	$\mathrm{3\,NO_3^- + 8\,Al\,(s) + 5\,OH^-\,(aq) + 18\,H_2O\,(l) \longrightarrow 3\,NH_3\,(g) + 8\,[Al(OH)_4]^-\,(aq)}$
	NO_2^-	$H_2(g)$ $NH_3(g)$ on heating	$\mathrm{NO_2^- + 2\,Al\,(s) + OH^-\,(aq) + 5\,H_2O\,(l) \longrightarrow NH_3\,(g) + 2\,[Al(OH)_4]^-\,(aq)}$

2. Cations

Reagent	Ion	General Observations	Equations
$NaCO_3(aq)$	$H+$	$CO_2(g)$	Acid-base
	M^{n+}	ppt formed	$\mathrm{M^{2+}\,(aq) + CO_3^{2-}\,(aq) \longrightarrow MCO_3\,(s)}$
	M^{3+}	ppt formed with $CO_2(g)$	$\mathrm{2\,M^{3+}\,(aq) + 3\,CO_3^{2-}\,(aq) + 3\,H_2O\,(l) \longrightarrow 2\,M(OH)_3\,(s) + 3\,CO_2\,(g)}$
	$NH_4^+(aq)$	$NH_3(g)$	$\mathrm{CO_3^{2-}\,(aq) + H_2O\,(l) \rightleftharpoons HCO_3^-\,(aq) + OH^-\,(aq)}$
$KI(aq)$	Oxidising agents like Cu^{2+}, Fe^{3+}	Blue Cu^{2+} turned brown, cream ppt of CuI in brown I_2 solution	$\mathrm{2\,Cu^{2+}\,(aq) + 4\,I^-\,(aq) \longrightarrow 2\,CuI\,(s) + I_2\,(aq)}$

3. Colours of Cations

Cation	Colour
$Mg^{2+}, Ba^{2+}, Zn^{2+}, Al^{3+}, NH_4^+, Ca^{2+}$	$H+$
Cr^{3+}	Green/Violet
Cu^{2+}	Blue
Fe^{2+}	Pale Green
Fe^{3+}	Yellow/Brown
Mn^{2+}	Pale Pink

Equations

- Oxidation in air to form brown prepcipitate
  - $4\,\mathrm{M(OH)_2\,(s)} + 2\,\mathrm{H_2O\,(l)} + \mathrm{O_2\,(g)} \longrightarrow 4\,\mathrm{M(OH)_3\,(s)}$
- Soluble complex
  - $\mathrm{Al(OH)_3\,(s)} + \mathrm{OH^-\,(aq)} \longrightarrow \mathrm{[Al(OH)_4]^-\,(aq)}$
  - $\mathrm{Cu(OH)_2\,(s)} + 4\,\mathrm{NH_3\,(aq)} \longrightarrow \mathrm{[Cu(NH_3)_4]^{2+}\,(aq)} + 2\,\mathrm{OH^-\,(aq)}$
  - All soluble complexes have number of ions twice of charge, except for $[Al(OH)_4]^-(aq)$
- Reaction with $NH_3(aq)$ and $NH_4Cl(s)$
  - Addition of NH_4Cl: hydroxide precipitate eventually dissolves completely to form colourless solution
  - Applicable for cations which forms hydroxides with moderately high K_{sp} values ($\mathrm{Mg^{2+}}$, $\mathrm{Mn^{2+}}$, $\mathrm{Zn^{2+}}$)
- $\mathrm{NaOH - H_2SO_4}$ Reaction (for any cation soluble in excess NH_3)
  - $\mathrm{Al^{3+} + 3\,OH^-} \longrightarrow \mathrm{Al(OH)_3}$ precipitate
  - $\mathrm{Al(OH)_3 + OH^-} \longrightarrow \mathrm{[Al(OH)_4]^-}$ aqueous complex
  - $\mathrm{Al(OH)_4^- + H^+} \longrightarrow \mathrm{Al(OH)_3}$ precipitate
  - $\mathrm{Al(OH)_3 + H^+} \longrightarrow \mathrm{Al^{3+}}$ solution
- Reaction of $Na_2CO_3(aq)$ with M^{3+} ions
  - $\mathrm{[Al(H_2O)_6]^{3+}\,(aq) + H_2O\,(l)} \rightleftharpoons \mathrm{[Al(OH)(H_2O)_5]^{2+}\,(aq) + H_3O^+\,(aq)}$ (and 2 more equilibrium until formation of $\mathrm{[Al(OH)_3(H_2O)_3]\,(s)}$) due to acidic nature of Al^{3+} cation (as result of high charge density and polarising power)
  - Addition of $CO_3^{2-}(aq)$, effervescence observed as $\mathrm{CO_3^{2-}\,(aq) + 2\,H_3O^+\,(aq)} \longrightarrow \mathrm{CO_2\,(g) + 3\,H_2O\,(l)}$ (Acid carbonate reactions)
  - Equilibrium shift to right, more H_3O+ ions removed, shifts all 3 equilibrium, white precipitate of $Al(OH)_3$ obtained together with evolution of $CO_2(g)$

Special Case

- Cu^{2+} forms a blue solution of $\mathrm{[Cu(H_2O)_6]^{2+}}$ in aqueous medium.
- When concentrated HCl is added, yellow solution of $\mathrm{[CuCl_4]^{2-}}$ is formed: $\mathrm{[Cu(H_2O)_6]^{2+} + 4\,Cl^-} \longrightarrow \mathrm{[CuCl_4]^{2-} + 6\,H_2O}$
- Appears as green originally due to mixture of blue and yellow but becomes yellow when heated

Observations

- When writing for metals, (ion) reacted with () to give a (colour) ppt of (formula), which was insoluble/soluble in excess to give (solution)
- Role of compound - probably either oxidising or reducing agent, especially when cation is iron
    - If H_2O_2 is added, test for O_2 evolved, likely a redox reaction
- If gas evolved - "Effervescence observed. (formula) gas evolved (passed test)"