Inorganic Qualitative Analysis Notes

Aim: To deduce the ions present in the unknown compound through reaction with various common reagents which cause colour change, precipitation or other visible changes.

Before proceeding:
- Check the reagents and their labels.
- Make sure there is no contamination, i.e. NaOH should not look cloudy
- Test-tubes and other apparatus should be dry.
- Read through the instructions and think about what is the nature of the reagent you are using. What constituents a positive test, i.e. white ppt form.
- Don't do redundant test i.e. don't test for acidic gas after adding conc. Acid.

Heating:
- Remember to close the air hole completely before lighting the Bunsen burner.
- Once it's lighted, you can adjust it to a get a blue flame.
- If you are testing the gas with a litmus paper, do not let it touch the test tube.
- To heat solids, heat it evenly along the length of the test tube and on both sides to prevent condensation.

Observation/recording:
- If ppt formed cannot be clearly observed, allow suspension to settle to bottom of test tube.
- If gas is evolved from solution – "effervescence"; if gas evolved from heating of solid – 'fume"
- If identity of unknown is not required, state the nature, e.g. acidic/basic or oxidizing/reducing

Chemical equations are not required for the deduction column.

Test for Cations using NaOH(aq) and NH_3(aq)

Cation	Reaction with	
	NaOH(aq)	**NH_3(aq)**
Aluminium, Al^{3+}(aq)	White precipitate, soluble in excess. $Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$ $Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$	White precipitate, insoluble in excess. $Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$
Ammonium, NH_4^+(aq)	No ppt. Ammonia gas, NH_3 produced on heating. $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$	
Barium, Ba^{2+}(aq)	No precipitate.	No precipitate.
Calcium, Ca^{2+}(aq)	White precipitate (with high $[Ca^{2+}]$). $Ca^{2+}(aq) + 2OH^-(aq) \rightarrow Ca(OH)_2(s)$	No precipitate.
Chromium(III), Cr^{3+}(aq) (Green)	Grey-green precipitate, soluble in excess to give a dark green solution. $Cr^{3+}(aq) + 3OH^-(aq) \rightarrow Cr(OH)_3(s)$ $Cr(OH)_3(s) + 3OH^-(aq) \rightarrow [Cr(OH)_6]^{3-}(aq)$	Grey-green precipitate, insoluble in excess. $Cr^{3+}(aq) + 3OH^-(aq) \rightarrow Cr(OH)_3(s)$

Cation	Reaction with	
	NaOH(aq)	NH_3(aq)
Copper(II), Cu^{2+}(aq) (Blue)	Pale blue precipitate, insoluble in excess. $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$	Pale blue precipitate, soluble in excess to give a dark blue solution. $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ $Cu(OH)_2(s) + 4NH_3(aq)$ $\rightarrow [Cu(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$
Iron(II), Fe^{2+}(aq) (Pale green)	Green precipitate, insoluble in excess. $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ The green precipitate, $Fe(OH)_2$ is rapidly oxidised to red-brown precipitate, $Fe(OH)_3$(s), on exposure to air.	Green precipitate, insoluble in excess. $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ The green precipitate, $Fe(OH)_2$ is rapidly oxidised to red-brown precipitate, $Fe(OH)_3$(s), on exposure to air.
Iron(III), Fe^{3+}(aq) (Yellow)	Red-brown precipitate, insoluble in excess. $Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$	Red-brown precipitate, insoluble in excess. $Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$
Magnesium, Mg^{2+}(aq)	White precipitate, insoluble in excess. $Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$	White precipitate, insoluble in excess. $Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$
Manganese(II), Mn^{2+}(aq) (Pale pink)	Off-white precipitate, insoluble in excess. $Mn^{2+}(aq) + 2OH^-(aq) \rightarrow Mn(OH)_2(s)$ On exposure to air, the off-white precipitate is rapidly oxidised to the brown precipitate, $Mn(OH)_3$.	Off-white precipitate, insoluble in excess. $Mn^{2+}(aq) + 2OH^-(aq) \rightarrow Mn(OH)_2(s)$ On exposure to air, the off-white precipitate is rapidly oxidised to the brown precipitate, $Mn(OH)_3$.
Zinc, Zn^{2+}(aq)	White precipitate, soluble in excess. $Zn^{2+}(aq) + 2OH^-(aq) \rightarrow Zn(OH)_2(s)$ $Zn(OH)_2(s) + 2OH^-(aq) \rightarrow [Zn(OH)_4]^{2-}(aq)$	White precipitate, **soluble** in excess. $Zn^{2+}(aq) + 2OH^-(aq) \rightarrow Zn(OH)_2(s)$ $Zn(OH)_2(s) + NH_3(aq)$ $\rightarrow [Zn(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$

Note: Zn^{2+} can be distinguished from Al^{3+} by excess NH_3 (aq)
Transition metal cations give coloured ppts or coloured aqueous solutions.

Cations list: **NH_4^+, Mg^{2+}, Al^{3+}, Ca^{2+}, Cr^{3+}, Mn^{2+}, Fe^{2+}, Fe^{3+}, Cu^{2+}, Zn^{2+}, Ba^{2+}**

Anions list: **CO_3^{2-}, NO_3^-, NO_2^-, SO_4^{2-}, SO_3^{2-}, Cl^-, Br^-, I^-**

Tests for anions

Anion	**Reaction**
Carbonate, $CO_3^{2-}(aq)$	CO_2 liberated by dilute acids. $CO_3^{2-} + H^+(aq) \rightarrow CO_2(g) + H_2O(l)$
Chloride, $Cl^-(aq)$	Gives **white** precipitate with $Ag^+(aq)$, **soluble** in excess $NH_3(aq)$. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ $AgCl(s) + 2NH_3(aq) \rightarrow [Ag(NH_3)_2]^+(aq)$
Bromide, $Br^-(aq)$	Gives **cream** precipitate with $Ag^+(aq)$, partially soluble in excess $NH_3(aq)$. $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$
Iodide, $I^-(aq)$	Gives **yellow** precipitate with $Ag^+(aq)$, insoluble in excess $NH_3(aq)$. $Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$
Sulfate(VI), $SO_4^{2-}(aq)$	Gives white precipitate with $Ba^{2+}(aq)$, insoluble in dilute strong acids. $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
Anion	**Reaction**
Sulfate(IV), $SO_3^{2-}(aq)$	Gives white precipitate with $Ba^{2+}(aq)$ soluble in dilute strong acids, liberating SO_2. $Ba^{2+}(aq) + SO_3^{2-}(aq) \rightarrow BaSO_3(s)$ $SO_3^{2-}(s) + 2H^+(aq) \rightarrow SO_2(g) + H_2O(l)$
Nitrate(V), $NO_3^-(aq)$	NH_3 gas liberated on heating with NaOH(aq) and *Al* foil (**Devarda's alloy**). $3NO_3^-(aq) + 8Al(s) + 5OH^-(aq) + 18H_2O(l) \rightarrow 3NH_3(g) + 8[Al(OH)_4]^-(aq)$ (*Al* in a basic medium is a reducing agent, reduces NO_3^- to NH_3 gas).
Nitrate(III), $NO_2^-(aq)$	NH_3 gas liberated on heating with NaOH(aq) and *Al* foil (or Devarda's alloy). $NO_2^-(aq) + 2Al(s) + OH^-(aq) + 5H_2O(l) \rightarrow NH_3(g) + 2[Al(OH)_4]^-(aq)$ (*Al* in a basic medium is a reducing agent, reduces NO_2^- to NH_3 gas). **N.B:** Nitrogen(II) oxide, NO gas liberated with dilute strong acids. $NO_2^-(aq) + H^+(aq) \rightarrow NO(g) + H_2O(l)$ (colourless NO gives pale brown NO_2 gas in air).
Anion	**Reaction**
Chromate (VI), $CrO_4^{2-}(aq)$ (Yellow) **Note:** Not in the syllabus	Yellow solution turns orange with $H^+(aq)$. $2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$ yellow orange Gives yellow precipitate with $Ba^{2+}(aq)$. $Ba^{2+}(aq) + CrO_4^{2-}(aq) \rightarrow BaCrO_4(s)$

Test for gases

Gas	Test and test result
Carbon dioxide, CO_2	Gives a white precipitate with limewater, $Ca(OH)_2(aq)$. (Precipitate dissolves with excess CO_2 gas). $CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(g)$ $CaCO_3(s) + CO_2(g) + H_2O(l) \rightarrow Ca(HCO_3)_2(aq)$
Ammonia, NH_3	Turns **damp** red litmus paper blue. (basic)
Oxygen, O_2	Relights a glowing splint.
Hydrogen, H_2	'Pops' with a lighted splint.
Chlorine, Cl_2	Bleaches **damp** litmus paper.
Sulfur dioxide, SO_2	Turns acidified $K_2Cr_2O_7(aq)$ from orange to green or turns **acidified $KMnO_4(aq)$** from purple to colourless. $Cr_2O_7^{2-}(aq) + 3SO_2(g) + 2H^+(aq) \rightarrow 2Cr^{3+}(aq) + 3SO_4^{2-}(aq) + H_2O(l)$ orange green $2MnO_4^-(aq) + 5SO_2(g) + 2H_2O(l) \rightarrow 2Mn^{2+}(aq) + 5SO_4^{2-}(aq) + 4H^+(aq)$ purple colourless/pale pink **Note:** $K_2Cr_2O_7$ is carcinogenic, $KMnO_4$ is the preferred choice.

Colour of halogens

Halogen	Colour of element	Colour in aqueous solution	Colour in hexane
Chlorine, Cl_2	Greenish yellow gas	Pale yellow	Pale yellow
Bromine, Br_2	Reddish brown gas/liquid	Orange	Orange-red
Iodine, I_2	Black solid/purple gas	Brown	Purple

Planning

Planning for Inorganic QA usually requires a **sequence** of tests presented in table form to identify the cations and anions or the nature (acidic/basic) of the unknown compound.

Example

	Test	Observations for FA1	Observations for FA2
(a)	Add 1 cm depth of each sample to a test-tube. Add reagent **E** and warm gently.	Gas evolved which relights a glowing splinter	No gas evolved

Other tests

<table>
<tr><th></th><th>TEST</th><th>OBSERVATION</th><th>DEDUCTION</th></tr>
<tr><td rowspan="2">(a)(i)</td><td rowspan="2">Add potassium iodide, KI(aq) to test sample,

followed by addition of sodium thiosulfate, $Na_2S_2O_3$(aq).</td><td>Brown solution (sometimes, black solid at bottom of test tube),

brown solution is decolourised.</td><td>Iodine liberated.

Test sample is an oxidising agent (OA). I^- is oxidised to I_2.

I_2 is reduced to I^- by $S_2O_3^{2-}$.</td></tr>
<tr><td colspan="2">Oxidizing agent present, I_2 is reduced.
$2I^-$ (aq) → I_2 + $2e^-$ (aq)

$2S_2O_3^{2-}$ (aq) + I_2(aq) → $S_4O_6^{2-}$ (aq) + $2I^-$ (aq)
brown colourless</td></tr>
<tr><td rowspan="4">(ii)</td><td rowspan="4">Add KI(aq) to test sample,

followed by addition of $Na_2S_2O_3$(aq).</td><td>Cream/off white ppt in brown solution,</td><td>Iodine liberated.

Test sample is an OA. I^- is oxidised to I_2.

Cu^{2+} present.</td></tr>
<tr><td colspan="2">$2Cu^{2+}$(aq) + $4I^-$ (aq) → 2CuI(s) + I_2(aq)
cream ppt brown</td></tr>
<tr><td>brown solution is decolourised leaving behind cream/off white ppt.</td><td>I_2 is reduced to I^- by $S_2O_3^{2-}$.</td></tr>
<tr><td colspan="2">$2S_2O_3^{2-}$ (aq) + I_2(aq) → $S_4O_6^{2-}$ (aq) + $2I^-$ (aq)
brown colourless</td></tr>
<tr><td rowspan="2">(b)(i)</td><td rowspan="2">Add silver nitrate, $AgNO_3$(aq) to test sample followed by addition of dilute nitric acid, HNO_3.

Add $AgNO_3$(aq) to test sample followed by addition of NH_3(aq).</td><td>White ppt insoluble in acid.

White ppt soluble in excess NH_3(aq) to give a colourless solution.</td><td>Cl^-</td></tr>
<tr><td colspan="2">Ag^+(aq) + Cl^-(aq) → AgCl(s)
white ppt
AgCl(s) + $2NH_3$(aq) → $[Ag(NH_3)_2]^+Cl^-$ (aq)
Colourless</td></tr>
<tr><td rowspan="2">(ii)</td><td rowspan="2">Add $AgNO_3$(aq) to test sample followed by addition of dilute HNO_3 and then NH_3(aq).</td><td>Pale yellow/cream ppt insoluble in acid and sparingly soluble in NH_3(aq).</td><td>Br^-</td></tr>
<tr><td colspan="2">Ag^+(aq) + Br^- (aq) → AgBr(s)
cream ppt</td></tr>
<tr><td rowspan="2">(iii)</td><td rowspan="2">Add $AgNO_3$(aq) to test sample followed by addition of dilute HNO_3 and then NH_3(aq).</td><td>Yellow ppt insoluble in acid and insoluble in NH_3(aq).</td><td>I^-</td></tr>
<tr><td colspan="2">Ag^+(aq) + I^- (aq) → AgI(s)
yellow ppt</td></tr>
</table>

(iv)	Add **$AgNO_3$**(aq) to test sample followed by addition of dilute HNO_3.	No ppt.	Absence of halides/Cl^-, Br^-, I^-.
	TEST	**OBSERVATION**	**DEDUCTION**
(v)	Add **$AgNO_3$(aq)** to test sample. Filter the mixture, discarding the filtrate. Wash the residue by pouring distilled water though it. Discard the washings and then pour NH_3(aq) through the residue. Collect the filtrate produced and add dilute HNO_3 **dropwise** to this.	White ppt. White residue is insoluble in water. White residue dissolves in excess NH_3(aq) to give a colourless solution. White ppt reappears on addition of acid.	Cl^- present.
		$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ white ppt $AgCl(s) + 2NH_3(aq) \rightleftharpoons [Ag(NH_3)_2]^+Cl^-(aq)$ residue (H$^+$) filtrate Addition of acid (H^+) shifts position of equilibrium to left (due to reaction with NH_3 to give NH_4^+, decreasing $[NH_3]$) and the white ppt, AgCl reforms.	
(c)	Add dilute sulfuric acid, H_2SO_4 to test sample followed by addition of chlorine, **Cl_2**(aq) or **NaClO**(aq) or **bleaching solution**. Then add the **organic solvent, hexane** provided and shake the mixture gently.	(i) Purple organic layer. (ii) Orange-red layer. (iii)Colourless organic layer.	I^- present in test sample. Br^- present in test sample. Absence of I^-, Br^- in test sample.
		I_2, Br_2  org layer / aq layer $2I^-(aq) \xrightarrow{Cl_2(aq)} I_2(aq)$ $2Br^-(aq) \xrightarrow{Cl_2(aq)} Br_2(aq)$ (oxidised) Br_2 and I_2 are more soluble in **organic layer** (hexane) and distribute between the organic and aqueous layers according to their partition coefficients (equilibrium constants, K_c).	
(d)	Add sodium hydroxide, **NaOH**(aq) to test sample and heat gently. Cool and then cautiously add **Al powder** or **Devarda's alloy**. Reheat if necessary. (Devarda's alloy = Al, Cu and Zn mixture)	No effect on damp red litmus paper. Gas liberated turns damp red litmus turns blue.	No NH_3 gas liberated. Absence of NH_4^+. NH_3 gas liberated. NO_3^-, NO_2^- present.
		$Al(s) + OH^-(aq) + 3H_2O(l) \rightarrow Al(OH)_4^-(aq) + \frac{3}{2}H_2(g)$ NO_3^- or $NO_2^- \rightarrow NH_3(g)$ Reduction	

	TEST	OBSERVATION	DEDUCTION
(e)	Add barium chloride, **$BaCl_2(aq)$**/$Ba(NO_3)_2$ to test sample followed by dilute hydrochloric acid, **HCl**/HNO_3.	White ppt insoluble in acid. White ppt soluble in acid. No ppt.	SO_4^{2-} present SO_3^{2-} present Absence of SO_4^{2-}, SO_3^{2-}.
		$Ba^{2+}(aq) + SO_4^{2-} \rightarrow BaSO_4(s)$ white ppt $BaSO_4$ is insoluble in acid. $Ba^{2+}(aq) + SO_3^{2-} \rightarrow BaSO_3(s)$ white ppt $BaSO_3$ is soluble in acid. $BaSO_3(s) + 2HCl(aq) \rightarrow BaCl_2(aq) + SO_2(g) + H_2O(l)$ soluble	
(f)	Add **$NaOH(aq)$** to test sample.	White ppt soluble in excess $NaOH(aq)$.	Al^{3+}, Zn^{2+} present
		$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$ white ppt $Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$ soluble $Zn^{2+}(aq) + 2OH^-(aq) \rightarrow Zn(OH)_2(s)$ white ppt $Zn(OH)_2(s) + 2OH^-(aq) \rightarrow [Zn(OH)_4]^{2-}(aq)$ soluble	
(g)	Add **$NaOH(aq)$** to test sample and heat gently.	No ppt. Upon heating, gas liberated turns damp red litmus paper blue.	NH^{4+} ? NH_3 gas liberated. NH_4^+ present.
		$NH^{4+}(s) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$ All ammonium salts liberate NH_3 gas when heated with a base.	
		No ppt. Upon heating, no effect on damp red litmus paper.	NH^{4+} ? No NH_3 gas liberated. Absence of NH^{4+}.

	TEST	OBSERVATION	DEDUCTION
(h)	Add ammonia, **$NH_3(aq)$** to test sample.	White ppt **soluble** in excess $NH_3(aq)$.	Zn^{2+} present
		$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ $Zn^{2+}(aq) + 2OH^-(aq) \rightleftharpoons Zn(OH)_2(s)$ white ppt $Zn(OH)_2(s) + 4NH_3(aq) \rightarrow [Zn(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$ soluble	
(i)	Add **$NH_3(aq)$** to test sample. Filter and add dilute $H_2SO_4/HCl/HNO_3$ **dropwise** to the filtrate till in excess.	White ppt insoluble in excess $NH_3(aq)$. Colourless filtrate. White ppt with acid, soluble in excess acid.	Al^{3+} present in residue. Filtrate contains Zn^{2+}.
		$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ **Residue**: $Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$ white ppt **Filtrate**: $[Zn(NH_3)_4]^{2+}(aq)$ $Zn^{2+}(aq) + 2OH^-(aq) \underset{H^+}{\rightleftharpoons} Zn(OH)_2(s) \underset{H^+}{\overset{NH_3}{\rightleftharpoons}} [Zn(NH_3)_4]^{2+}(aq)$ white ppt With $H_2SO_4/HCl/HNO_3$, $Zn(OH)_2$ is formed, then with excess acid, soluble $ZnSO_4/ZnCl_2/Zn(NO_3)_2$ is formed as the positions of equilibrium above shift to the left.	
(j)	Add **$NH_3(aq)$** to test sample. Then add aqueous or solid ammonium chloride, **NH_4Cl**.	White ppt. White ppt dissolves in the presence of NH_4Cl.	Hydroxides of **high K_{sp}** suspected, e.g., Mg^{2+}.
		$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ $NH_4Cl(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$ NH_4Cl provides a large excess of NH_4^+, therefore position of equilibrium above shifts to left due to the common ion effect. So, **$[OH^-]$ decreases**. So, hydroxides of **high K_{sp}** will not be precipitated as $[OH^-]$ is too low to exceed the K_{sp} of the hydroxides.	
(k)	Add dilute H_2SO_4 to test sample followed by **iron(II) ammonium sulfate** or freshly prepared iron(II) sulfate.	Green solution turns yellow or brownish-yellow.	Test sample is an oxidising agent (OA). Fe^{2+} is oxidised to Fe^{3+}.
		$Fe^{2+}(aq) \xrightarrow{OA} Fe^{3+}(aq)$ green yellow	
		No change in colour.	Test sample is not an OA.

(l)	Add dilute H_2SO_4 to test sample followed by potassium manganate(VII), **$KMnO_4(aq)$**.	Purple MnO_4^-/H^+ is decolourised.	Test sample is a reducing agent (RA).
		$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$ purple colourless	
		Purple MnO_4^-/H^+ is not decolourised.	Test sample is not a RA.

	TEST	OBSERVATION	DEDUCTION
(m)	Add sodium sulfite, $Na_2SO_3(aq)$ to test sample followed by $BaCl_2(aq)$. Add dilute HCl to the resulting mixture.	White ppt insoluble in acid.	SO_4^{2-}. SO_3^{2-} is oxidised to SO_4^{2-}. Test sample is an OA.
		$SO_3^{2-}(aq) \xrightarrow{OA} SO_4^{2-}(aq)$ $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ white ppt, insoluble in acid	
(n)	Add **conc HCl** to test sample and heat.	Gas liberated bleaches damp litmus paper.	Cl_2 liberated; test sample is an OA. HCl is oxidised to Cl_2.
		<u>N.B.</u> Do not report and test for HCl! $HCl \xrightarrow{OA} Cl_2$	
(o)	Add **concentrated H_2SO_4** to test sample and heat.	Brown fumes liberated.	Br_2 or NO_2 liberated. Br^- or NO_3^- present.
		$H_2SO_4(l) + Br^-(s) \rightarrow HSO_4^-(aq) + HBr(g)$ $2HBr(g) + H_2SO_4(l) \rightarrow SO_2(g) + 2H_2O(l) + Br_2(g)$ $H_2SO_4(l) + NO_3^-(aq) \rightarrow HSO_4^-(aq) + HNO_3(l)$ $2HNO_3(l) \rightarrow 2NO_2(g) + \frac{1}{2} O_2(g) + H_2O(l)$	
		Gas which has a vinegar smell liberated.	CH_3CO_2H vapour liberated. $CH_3CO_2^-$ present.
		$H_2SO_4(l) + CH_3CO_2^-(s) \rightarrow HSO_4^-(aq) + CH_3CO_2H(g)$	
(p)	Add solid sodium carbonate, **Na_2CO_3**/sodium hydrogen carbonate, **$NaHCO_3$** to test sample.	Effervescence. Gas liberated gives a white ppt with limewater.	CO_2 liberated. Test sample is an acid/acidic.
		$2H^+(aq) + CO_3^{2-}(s) \rightarrow CO_2(g) + H_2O(l)$ $H^+(aq) + HCO_3^-(s) \rightarrow CO_2(g) + H_2O(l)$	
(q)	Add magnesium, **Mg** ribbon to test sample.	Effervescence. Gas liberated gives a 'pop' sound with a lighted splinter.	H_2 liberated. Test sample is an acid/acidic.
		$2H^+(aq) + Mg(s) \rightarrow Mg^{2+}(aq) + H_2(g)$	

(r)	Add **solid Na_2SO_3** to test sample and heat cautiously.	Gas liberated decolourises purple acidified $KMnO_4$(aq).	SO_2 liberated. Test sample is an acid/acidic.
		$2H^+(aq) + SO_3^{2-}(s) \rightarrow SO_2(g) + H_2O(l)$	

	TEST	OBSERVATION	DEDUCTION
(s)	Add copper(II) sulfate, **$CuSO_4$(aq)** to test sample.	Blue colour turns green.	Concentrated HC*l* or C*l*⁻.
		$[Cu(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons CuCl_4^{2-}(aq) + 6H_2O(l)$ blue ... yellow blue + yellow = green!	
(t)	Add **$CuSO_4$(aq)** to test sample followed by **$Na_2S_2O_3$(aq)**.	Cream ppt/off white ppt in a brown solution. With $S_2O_3^{2-}$, brown solution is decolourised leaving behind the cream/off white ppt.	I_2 liberated. I^- present in test sample. I^- is oxidised by Cu^{2+} to I_2. $S_2O_3^{2-}$ reduces I_2 to I^-.
		$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$ cream ppt ... brown $2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$ brown ... colourless	

Cations with coloured solutions – Transition Metals

Cations	Colour
Cu^{2+}	Blue
Fe^{2+}	Pale green
Fe^{3+}	Pale yellow
Cr^{3+}	Green
Mn^{2+}	Colourless/pale pink

Always take note of the appearance of the unknown solution, these provides a clue to the ions present.

Coloured cation solids

White ⇒ **Non-transition metal** cpds
Yellow when hot, white when cold ⇒ **Zn cpds**
Brown ⇒ **Fe cpds**
Black ⇒ **Mn or Cu cpds**

Acidic Cations

Cations	Explanation	Comment
Al^{3+}, Fe^{3+}, Cr^{3+}	Acidic solution due to the high charge density of cations which undergoes hydrolysis with water to release H^+ $M(H_2O)_6^{3+} \rightleftharpoons M(H_2O)_5(OH)^{2+} + H^+$	Cations with +3 charge and small ionic size
NH_4^+	NH_4^+ hydrolyse in water to release H^+ $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$	NH_4^+ is a conjugate acid

Test for acidity: Na_2CO_3 -> CO_2 gas evolved

Cations which forms amphoteric hydroxides

Zn^{2+} | $Zn(OH)_2$, Pb^{2+} | $Pb(OH)_2$, Al^{3+} | $Al(OH)_3$, Cr^{3+} | $Cr(OH)_3$

When to test for gases?

Reagents added	Gases to test	Deductions
Solid/residue and heat	Litmus paper turns blue (NH_3) Litmus paper turns red (CO_2, SO_2) Litmus paper bleached (Cl_2) Relights glowing splinter (O_2)	NH_4^+ CO_3^{2-}, SO_3^{2-} Cl^- or ClO_3^- Oxyanions
Dilute acids	Pop sound with lighted splinter (H_2)	Reactive metal
Dilute acids with heat	CO_2, SO_2, NO_2 (brown)	CO_3^{2-}, SO_3^{2-}, NO_2^{-}
NaOH and heat	Litmus paper turns blue (NH_3)	NH_4^+

Qualitative Analysis Arranged by Reagents

Reagent	Observation	Deduction
NaOH *Test for metal cations* *Look for ppt colour, soluble in excess?* *NH_3 gas*	White ppt; insoluble in excess White ppt; insoluble in excess Off-white ppt, rapidly turns brown on contact with air, insoluble in excess NaOH Green ppt; turns brown on contact with air; insoluble in excess NaOH Red-brown ppt; insoluble in excess NaOH	Ca^{2+} Mg^{2+} Mn^{2+} Fe^{2+} Fe^{3+}

	Pale-blue ppt, soluble in excess NaOH. Pale blue ppt turns black on boiling White ppt, soluble in excess NaOH to form colourless solution Grey-green ppt, soluble in excess NaOH to form dark green solution	Cu^{2+} Zn^{2+}, (Pb^{2+}), Al^{3+} Cr^{3+}
NaOH with heat	Gas evolved turns red litmus blue	NH_4^+
NaOH, Al foil and heat *Look for NH_3 gas*	Gas evolved turns red litmus blue	NO_3^-, NO_2^-
NH_3 *Test for metal cations* *Look for ppt colour, soluble in excess?*	No ppt White ppt, insoluble in excess Grey-green ppt, insoluble in excess Off-white ppt, rapidly turn brown on contact with air; insoluble in excess Green ppt, turn brown on contact with air, insoluble in excess Red-brown ppt, insoluble in excess White ppt, soluble in excess to form colourless solution Blue ppt soluble in excess to form dark blue solution	Ca^{2+} Mg^{2+}, Al^{3+}, Pb^{2+} Cr^{3+} Mn^{2+} Fe^{2+} Fe^{3+} Zn^{2+} Cu^{2+}
Na_2CO_3 *Look for ppt colour, CO_2, NH_3 gas*	White ppt Red-brown ppt Green ppt Gas evolved forms white ppt with limewater	Al^{3+} Fe^{3+} Cr^{3+}
	Gas evolved forms white ppt with limewater	H^+
	Gas evolved turns moist red litmus paper blue	NH_4^+ (needs warming)
	White ppt formed Off-white ppt, turns brown on standing	Mg^{2+}, Ca^{2+}, Zn^{2+}, Ba^{2+} Mn^{2+}

	Dirty-green ppt turns brown on standing Red-brown ppt Pale-blue ppt turn black on boiling	Fe^{2+} Fe^{3+} Cu^{2+}
$H_2SO_4/HNO_3/HCl$ *Look for CO_2, SO_2, NO_2*	Gas evolved form white ppt with limewater Gas evolved turn purple $KMnO_4$ colourless Pungent brown gas (colourless NO turns brown NO_2 in air)	CO_3^{2-} SO_3^{2-} (warming needed) NO_2^- (warming needed)
$Pb(NO_3)_2$ *Look for ppt*	White ppt Yellow ppt	SO_4^{2-}, Cl^-, Br^- I^-
$Ba(NO_3)_2$ *Look for ppt*	White ppt White ppt insoluble in dilute HCl/HNO_3 White ppt soluble in dilute HCl/HNO_3	SO_3^{2-}, SO_4^{2-} $BaSO_4$ $BaSO_3$
$CuSO_4$ *Look for ppt or colour change*	White/grey-white ppt in brown solution Decolourisation of brown solution when $Na_2S_2O_3$ is added White ppt dissolves to form a colourless solution when $Na_2S_2O_3$ is added in excess	I^-
	Blue solution turns yellow-green	Cl^-
$KMnO_4$ with H_2SO_4 *Look for ppt or colour change*	Decolourisation of purple $KMnO_4$ Gas/ppt/solution colour change	Reducing agent (warming may be needed)
KI	White/grey-white ppt in brown solution Decolourisation of brown solution when $Na_2S_2O_3$ is added White ppt dissolves to form a colourless solution when $Na_2S_2O_3$ is added in excess	Cu^{2+}

$K_4Fe(CN)_6$ *Look for colour of ppt*	Pale blue ppt Prussian blue ppt Reddish brown ppt Light green ppt White ppt White ppt	Fe^{2+} Fe^{3+} Cu^{2+} Ni^{2+} Zn^{2+} Mn^{2+}
$Cl_{(aq)}$ *Look for colour change*	Reddish brown solution Decolourisation of yellow green solution Black ppt in brown solution Decolourisation of yellow green solution	Br^- I^-
$AgNO_3$ *Look for ppt*	White ppt Cream ppt Yellow ppt	Cl^- Br^- I^-
Mg *Look for H_2 gas or metal deposits*	Cu^{2+} -> pink deposit on metal Fe^{2+}/Fe^{3+} -> black deposit on metal Gas evolved give a pop sound with lighted splinter	Solution has less reactive metals H^+
Conc HCl *Look for colour change*	Blue solution turns green then yellow. Cl_2 produced.	Cu^{2+}
H_2O_2 *Look for oxygen gas*	Effervescence of O_2	Oxidising agent
$FeCl_3$ *Look for colour change*	Yellow solution turned green	Reducing agent