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Raffles Institution
Year 6 H2 Chemistry 2014

Experiment 13 Qualitative Analysis
Worksheet Title: Qualitative Analysis of Inorganic Compounds

**1 Test for gases**

The identities of gases evolved when carrying out experiments give good indication of the anion present in the unknown. Note that the ammonium cation may also be identified by the ammonia gas given off.

When a gas is suspected to be evolved during a reaction, you should:

1. note the colour of gas evolved;
2. carefully sniff the gas with test tube held vertically at a little distance from the nose.

If the gas is colourless and odourless, proceed to test for

- CO₂ with aqueous Ca(OH)₂; or
- H₂ with a lighted splint; or
- O₂ with a glowing splint.

Useful tip:

It is important to know the purpose of each reagent added. This allows you to eliminate the possibility of some gases. For example, when a dilute acid is added to the unknown, you only have to test for acidic gases; ammonia will not be given off, so you need not reach for red litmus paper.

2 Action of heat**Ammonium salts**

Most ammonium salts decompose to give ammonia vapour except:

- Ammonium nitrate. It explodes when heated strongly.
 $\text{NH}_4\text{NO}_3 \rightarrow \text{N}_2\text{O} + 2\text{H}_2\text{O}$
- Ammonium nitrite. It is an explosive deliquescent solid.
 $\text{NH}_4\text{NO}_2 \rightarrow \text{N}_2 + 2\text{H}_2\text{O}$
- Ammonium dichromate(VI). It decomposes with the evolution of gas and sparks.
 $(\text{NH}_4)_2\text{Cr}_2\text{O}_7 \rightarrow \text{Cr}_2\text{O}_3 + \text{N}_2 + 4\text{H}_2\text{O}$

Nitrates

All nitrates decompose on heating.

- Nitrates of sodium and potassium yield O₂ and a solid nitrite.
- Nitrates of heavy metals generally decompose to give a metal oxide and a gaseous mixture of NO₂ and O₂.

Carbonates and hydrogencarbonates

- The carbonates of sodium and potassium are stable to heat.
- The carbonates of aluminium and iron(III) are non-existent.
- The carbonates of other common heavy metals decompose to give the metallic oxides and CO₂.
- All hydrogencarbonates decompose on heating to give CO₂ and H₂O.

Procedure

Place a small amount of the solid in a **clean and dry** boiling tube. Heat the solid gently at first, then strongly until no further change takes place. Test any gas, if any, that is evolved during heating. The identity of the gas is important as it usually helps to identify the anion present. Note the colour of the gas and residue. The colour of the residue may change upon cooling. The colour of the residue may help to identify the cation in the unknown sample.

Pb(NO₃)₂ Pb(NO ₃) ₂ (s) → PbO(s) + NO ₂ (g) + ½O ₂ (g)	<u>Brown</u> gas evolved which turned freshly prepared FeSO ₄ (aq) from <u>pale green</u> to <u>brown</u> . Another gas evolved <u>relighted</u> a glowing splint. <u>Yellow</u> residue remained after heating, which turns <u>white</u> upon cooling	NO ₂ (g) evolved. } NO ₃ ⁻ present. O ₂ (g) evolved. PbO(s).
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3 Analysis of some cations

The analysis of cations is usually done by adding aqueous sodium hydroxide, aqueous ammonia or aqueous sodium carbonate to a small quantity of the unknown sample.

Sodium hydroxide

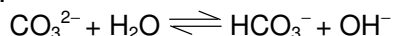
- Sodium hydroxide is a strong base which liberates weak bases such as NH_3 or amines from nitrogenous compounds.
E.g. $(\text{NH}_4)_2\text{SO}_4 + 2\text{OH}^- \rightarrow 2\text{NH}_3 + \text{SO}_4^{2-} + 2\text{H}_2\text{O}$
- All metal ions (except Na^+ and K^+) react with NaOH to form insoluble hydroxides or oxides.
- The hydroxides of the less electropositive metals (e.g. Cr , Zn , Al and Pb) are **amphoteric** and they **dissolve in excess aqueous NaOH** .
E.g. $\text{Pb}^{2+} + 2\text{OH}^- \rightleftharpoons \text{Pb}(\text{OH})_2(\text{s}) \rightleftharpoons [\text{Pb}(\text{OH})_4]^{2-}(\text{aq})$

Aqueous ammonia

- Aqueous ammonia is a weak base which ionises partially: $\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$
- The concentration of hydroxide ions in aqueous ammonia is less than that in aqueous sodium hydroxide. Thus, the slightly soluble hydroxides like $\text{Ca}(\text{OH})_2$ and $\text{Ba}(\text{OH})_2$ are not precipitated by aqueous NH_3 .
- When excess aqueous NH_3 is added, the metal hydroxides of Zn and Cu will dissolve as the cations are able to form **complexes** with aqueous NH_3 .
E.g. $\text{Zn}^{2+} + 2\text{OH}^- \rightarrow \text{Zn}(\text{OH})_2$ (white ppt)
 $\text{Zn}^{2+} + 4\text{NH}_3 \rightarrow [\text{Zn}(\text{NH}_3)_4]^{2+}$ (white ppt dissolve in excess aq. NH_3)

Sodium carbonate

- Sodium carbonate solution is used to precipitate insoluble carbonates from solutions of metallic salts. (All metal carbonates are insoluble except for Na_2CO_3 and K_2CO_3 .)
- Due to hydrolysis, sodium carbonate can also behave like sodium hydroxide solution (but it is a much weaker base than NaOH):



Other reagents

Besides aqueous NaOH , aqueous NH_3 and aqueous Na_2CO_3 , other reagents can also be used to identify specific cations.

Procedure

- To approximately 1 cm depth of solution in a test tube, add reagent dropwise with shaking until no further change is observed unless you are instructed otherwise.
- Note the changes during the reaction and record your observations.

1. Aluminium ion, $\text{Al}^{3+}(\text{aq})$ – colourless solution, acidic

Test	Observations	Deduction	Equations
1. Add aqueous NaOH .	White ppt formed, <u>soluble</u> in excess $\text{NaOH}(\text{aq})$ to give a <u>colourless</u> solution.	$\text{Al}(\text{OH})_3(\text{s})$ $[\text{Al}(\text{OH})_4]^- (\text{aq})$	$\text{Al}^{3+}(\text{aq}) + 3\text{OH}^-(\text{aq}) \longrightarrow \text{Al}(\text{OH})_3(\text{s})$ $\text{Al}(\text{OH})_3(\text{s}) + \text{OH}^-(\text{aq}) \longrightarrow [\text{Al}(\text{OH})_4]^- (\text{aq})$
Then add dilute H_2SO_4 .	White ppt re-formed, <u>dissolved</u> in excess H_2SO_4 .	$\text{Al}(\text{OH})_3(\text{s})$	$[\text{Al}(\text{OH})_4]^- (\text{aq}) + \text{H}^+(\text{aq}) \longrightarrow \text{Al}(\text{OH})_3(\text{s}) + \text{H}_2\text{O}(\text{l})$ $\text{Al}(\text{OH})_3(\text{s}) + 3\text{H}^+(\text{aq}) \longrightarrow \text{Al}^{3+}(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$

2. Add aqueous NH_3 .	<u>White ppt</u> formed, <u>insoluble</u> in excess $\text{NH}_3(\text{aq})$.	$\text{Al}(\text{OH})_3(\text{s})$	$\text{Al}^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \longrightarrow \text{Al}(\text{OH})_3(\text{s})$
3. Add aqueous Na_2CO_3 .	<u>White ppt</u> formed. Effervescence was observed. Colourless gas evolved gave a <u>white ppt</u> when bubbled into $\text{Ca}(\text{OH})_2(\text{aq})$.	$\text{Al}(\text{OH})_3(\text{s})$. $\text{Al}^{3+}(\text{aq})$ present. $\text{CO}_2(\text{g})$ evolved. Test solution is acidic.	$\text{Al}(\text{H}_2\text{O})_6^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons [\text{Al}(\text{OH})(\text{H}_2\text{O})_5]^{2+}(\text{aq}) + \text{H}_3\text{O}^{+}(\text{aq})$ $[\text{Al}(\text{OH})(\text{H}_2\text{O})_5]^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons [\text{Al}(\text{OH})_2(\text{H}_2\text{O})_4]^{+}(\text{aq}) + \text{H}_3\text{O}^{+}(\text{aq})$ $[\text{Al}(\text{OH})_2(\text{H}_2\text{O})_4]^{+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons [\text{Al}(\text{OH})_3(\text{H}_2\text{O})_3](\text{s}) + \text{H}_3\text{O}^{+}(\text{aq})$ $\text{CO}_3^{2-}(\text{aq}) + 2\text{H}_3\text{O}^{+}(\text{aq}) \longrightarrow \text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l})$

2. Zinc(II) ion, $\text{Zn}^{2+}(\text{aq})$ – colourless solution

Test	Observations	Deduction	Equations
1. Add aqueous NaOH .	<u>White ppt</u> formed, <u>soluble</u> in excess $\text{NaOH}(\text{aq})$ to give a <u>colourless</u> solution.	$\text{Zn}(\text{OH})_2(\text{s})$ $[\text{Zn}(\text{OH})_4]^{2-}(\text{aq})$	$\text{Zn}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \longrightarrow \text{Zn}(\text{OH})_2(\text{s})$ $\text{Zn}(\text{OH})_2(\text{s}) + 2\text{OH}^{-}(\text{aq}) \longrightarrow [\text{Zn}(\text{OH})_4]^{2-}(\text{aq})$
Then add dilute HNO_3 .	<u>White ppt</u> re-formed, <u>dissolved</u> in excess HNO_3 to give a <u>colourless</u> solution.	$\text{Zn}(\text{OH})_2(\text{s})$ $\text{Zn}^{2+}(\text{aq})$	$[\text{Zn}(\text{OH})_4]^{2-}(\text{aq}) + 2\text{H}^{+}(\text{aq}) \longrightarrow \text{Zn}(\text{OH})_2(\text{s}) + 2\text{H}_2\text{O}(\text{l})$ $\text{Zn}(\text{OH})_2(\text{s}) + 2\text{H}^{+}(\text{aq}) \longrightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$
2. Add aqueous NH_3 .	<u>White ppt</u> formed, <u>soluble</u> in excess $\text{NH}_3(\text{aq})$ to give a <u>colourless</u> solution.	$\text{Zn}(\text{OH})_2(\text{s})$ $[\text{Zn}(\text{NH}_3)_4]^{2+}(\text{aq})$	$\text{Zn}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \longrightarrow \text{Zn}(\text{OH})_2(\text{s})$ $\text{Zn}(\text{OH})_2(\text{s}) + 4\text{NH}_3(\text{aq}) \longrightarrow [\text{Zn}(\text{NH}_3)_4]^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq})$
Then add dilute H_2SO_4 .	<u>White ppt</u> re-formed, <u>dissolved</u> in excess H_2SO_4 to give a <u>colourless</u> solution.	$\text{Zn}(\text{OH})_2(\text{s})$ $\text{Zn}^{2+}(\text{aq})$	$[\text{Zn}(\text{NH}_3)_4]^{2+}(\text{aq}) + 2\text{H}^{+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \longrightarrow \text{Zn}(\text{OH})_2(\text{s}) + 4\text{NH}_4^{+}(\text{aq})$ $\text{Zn}(\text{OH})_2(\text{s}) + 2\text{H}^{+}(\text{aq}) \longrightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$
3. Add aqueous Na_2CO_3 .	<u>White ppt</u> formed.	$\text{ZnCO}_3(\text{s})$	$\text{Zn}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \longrightarrow \text{ZnCO}_3(\text{s})$

3. Chromium(III) ion, $\text{Cr}^{3+}(\text{aq})$ – green solution, acidic

Test	Observations	Deduction	Equations
1. Add aqueous NaOH.	Greyish-green ppt formed, <u>soluble</u> in excess NaOH(aq) to give a <u>dark green</u> solution.	$\text{Cr}(\text{OH})_3(\text{s})$ $[\text{Cr}(\text{OH})_6]^{3-}(\text{aq})$ Cr^{3+} present.	$\text{Cr}^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s})$ $\text{Cr}(\text{OH})_3(\text{s}) + 3\text{OH}^{-}(\text{aq}) \rightarrow [\text{Cr}(\text{OH})_6]^{3-}(\text{aq})$
Then add dilute H_2SO_4 .	Greyish-green ppt re-formed, <u>soluble</u> in excess $\text{H}_2\text{SO}_4(\text{aq})$ to give a <u>dark green</u> solution.	$\text{Cr}(\text{OH})_3(\text{s})$ Cr^{3+} present.	$[\text{Cr}(\text{OH})_6]^{3-}(\text{aq}) + 3\text{H}^{+}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s}) + 3\text{H}_2\text{O}(\text{l})$ $\text{Cr}(\text{OH})_3(\text{s}) + 3\text{H}^{+}(\text{aq}) \rightarrow \text{Cr}^{3+}(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$
2. Add aqueous NH_3 .	Greyish-green ppt formed, <u>insoluble</u> in excess $\text{NH}_3(\text{aq})$.	$\text{Cr}(\text{OH})_3(\text{s})$ Cr^{3+} present.	$\text{Cr}^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s})$
3. Add aqueous Na_2CO_3 .	Greyish-green ppt formed. Effervescence was also observed. Colourless gas evolved gave a <u>white ppt</u> when bubbled into $\text{Ca}(\text{OH})_2(\text{aq})$.	$\text{Cr}(\text{OH})_3(\text{s})$ Cr^{3+} present. $\text{CO}_2(\text{g})$ evolved. Test solution is acidic.	$\text{Cr}(\text{H}_2\text{O})_6^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons [\text{Cr}(\text{OH})(\text{H}_2\text{O})_5]^{2+}(\text{aq}) + \text{H}_3\text{O}^{+}(\text{aq})$ $[\text{Cr}(\text{OH})(\text{H}_2\text{O})_5]^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons [\text{Cr}(\text{OH})_2(\text{H}_2\text{O})_4]^{+}(\text{aq}) + \text{H}_3\text{O}^{+}(\text{aq})$ $[\text{Cr}(\text{OH})_2(\text{H}_2\text{O})_4]^{+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons [\text{Cr}(\text{OH})_3(\text{H}_2\text{O})_3] + \text{H}_3\text{O}^{+}(\text{aq})$ $\text{CO}_3^{2-}(\text{aq}) + 2\text{H}_3\text{O}^{+}(\text{aq}) \rightarrow \text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l})$
4. Add aqueous NaOH till excess. Then add aqueous H_2O_2 and boil. (Teacher's demo)	Greyish-green ppt formed, <u>dissolved</u> in excess NaOH(aq) to give a <u>dark green solution</u> . <u>Yellow solution</u> formed.	$\text{Cr}(\text{OH})_3(\text{s})$ $[\text{Cr}(\text{OH})_6]^{3-}(\text{aq})$ $\text{CrO}_4^{2-}(\text{aq})$ formed.	$\text{Cr}^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s})$ $\text{Cr}(\text{OH})_3(\text{s}) + 3\text{OH}^{-}(\text{aq}) \rightarrow [\text{Cr}(\text{OH})_6]^{3-}$ $2[\text{Cr}(\text{OH})_6]^{3-}(\text{aq}) + 3\text{H}_2\text{O}_2(\text{aq}) \rightarrow 2\text{CrO}_4^{2-}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) + 8\text{H}_2\text{O}(\text{l})$

4. Iron(II) ion, $\text{Fe}^{2+}(\text{aq})$ – pale green solution

Test	Observations	Deduction	Equations
1. Add aqueous NaOH.	<u>Dirty green ppt</u> formed, <u>insoluble</u> in excess NaOH(aq)	$\text{Fe}(\text{OH})_2(\text{s})$ Fe^{2+} present.	$\text{Fe}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \rightarrow \text{Fe}(\text{OH})_2(\text{s})$
Then leave the mixture to stand.	Ppt turned <u>reddish-brown</u> .	$\text{Fe}(\text{OH})_3(\text{s})$	$2\text{Fe}(\text{OH})_2(\text{s}) + \frac{1}{2}\text{O}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow 2\text{Fe}(\text{OH})_3(\text{s})$

2. Add aqueous NH_3	<u>Dirty green ppt</u> formed, <u>insoluble</u> in excess.	$\text{Fe}(\text{OH})_2(\text{s})$ Fe^{2+} present.	$\text{Fe}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \longrightarrow \text{Fe}(\text{OH})_2(\text{s})$
Then leave the mixture to stand.	Ppt turned <u>reddish-brown</u> .	$\text{Fe}(\text{OH})_3(\text{s})$	$2\text{Fe}(\text{OH})_2(\text{s}) + \frac{1}{2}\text{O}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \longrightarrow 2\text{Fe}(\text{OH})_3(\text{s})$
3. Add aqueous Na_2CO_3 .	<u>Green ppt</u> formed.	$\text{FeCO}_3(\text{s})$	$\text{Fe}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \longrightarrow \text{FeCO}_3(\text{s})$
4. Add aqueous H_2O_2 followed by dilute H_2SO_4 .	<u>Yellow solution</u> obtained.	$\text{Fe}^{3+}(\text{aq})$ formed Fe^{2+} present.	$2\text{Fe}^{2+}(\text{aq}) + \text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^{+}(\text{aq}) \longrightarrow 2\text{Fe}^{3+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$
Then add aqueous NaOH .	<u>Reddish brown ppt</u> formed, <u>insoluble</u> in excess $\text{NaOH}(\text{aq})$.	$\text{Fe}(\text{OH})_3(\text{s})$	$\text{Fe}^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \longrightarrow \text{Fe}(\text{OH})_3(\text{s})$
5. Add aqueous $\text{K}_3[\text{Fe}(\text{CN})_6]$.	Turnbull's blue ppt. (or dark blue ppt.).	$\text{Fe}_4[\text{Fe}(\text{CN})_6]_3(\text{s})$ Fe^{2+} present.	$\text{Fe}^{2+}(\text{aq}) + [\text{Fe}(\text{CN})_6]^{3-}(\text{aq}) \longrightarrow \text{Fe}^{3+}(\text{aq}) + [\text{Fe}(\text{CN})_6]^{4-}(\text{aq})$ $4\text{Fe}^{3+}(\text{aq}) + 3[\text{Fe}(\text{CN})_6]^{4-}(\text{aq}) \longrightarrow \text{Fe}_4[\text{Fe}(\text{CN})_6]_3(\text{s})$

5. Iron(III) ion, $\text{Fe}^{3+}(\text{aq})$ – yellow/brown solution, acidic

Test	Observations		Equations
1. Add aqueous NaOH .	<u>Reddish-brown ppt</u> formed, <u>insoluble</u> in excess $\text{NaOH}(\text{aq})$.	$\text{Fe}(\text{OH})_3(\text{s})$ Fe^{3+} present.	$\text{Fe}^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \longrightarrow \text{Fe}(\text{OH})_3(\text{s})$
2. Add aqueous NH_3 .	<u>Reddish-brown ppt</u> formed, <u>insoluble</u> in excess.	$\text{Fe}(\text{OH})_3(\text{s})$ Fe^{3+} present.	$\text{Fe}^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \longrightarrow \text{Fe}(\text{OH})_3(\text{s})$
3. Add aqueous Na_2CO_3 .	<u>Reddish-brown ppt</u> formed. <u>Effervescence</u> observed. Colourless gas evolved gave a <u>white ppt</u> when bubbled into $\text{Ca}(\text{OH})_2(\text{aq})$.	$\text{Fe}(\text{OH})_3(\text{s})$ Fe^{3+} present. CO_2 evolved. Test solution is acidic.	$\text{Fe}(\text{H}_2\text{O})_6^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons [\text{Fe}(\text{OH})(\text{H}_2\text{O})_5]^{2+}(\text{aq}) + \text{H}_3\text{O}^{+}(\text{aq})$ $[\text{Fe}(\text{OH})(\text{H}_2\text{O})_5]^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons [\text{Fe}(\text{OH})_2(\text{H}_2\text{O})_4]^{+}(\text{aq}) + \text{H}_3\text{O}^{+}(\text{aq})$ $[\text{Fe}(\text{OH})_2(\text{H}_2\text{O})_4]^{+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons [\text{Fe}(\text{OH})_3(\text{H}_2\text{O})_3](\text{s}) + \text{H}_3\text{O}^{+}(\text{aq})$ $\text{CO}_3^{2-}(\text{aq}) + 2\text{H}_3\text{O}^{+}(\text{aq}) \longrightarrow \text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l})$
4. Add aqueous KI .	Solution turned <u>brown</u> .	$\text{I}_2(\text{aq})$ formed. Oxidising agent (e.g. Fe^{3+}) present.	$2\text{Fe}^{3+}(\text{aq}) + 2\text{I}^{-}(\text{aq}) \longrightarrow 2\text{Fe}^{2+}(\text{aq}) + \text{I}_2(\text{aq})$
5. Add $\text{NH}_4\text{SCN}(\text{aq})$.	<u>Blood red</u> colouration formed.	$[\text{Fe}(\text{SCN})(\text{H}_2\text{O})_5]^{2+}(\text{aq})$ Fe^{3+} present.	$\text{Fe}^{3+}(\text{aq}) + \text{SCN}^{-}(\text{aq}) \longrightarrow [\text{Fe}(\text{SCN})(\text{H}_2\text{O})_5]^{2+}(\text{aq})$
6. Add aqueous $\text{K}_4[\text{Fe}(\text{CN})_6]$.	<u>Prussian blue ppt</u> . (or dark blue ppt.).	$\text{Fe}_4[\text{Fe}(\text{CN})_6]_3(\text{s})$ Fe^{3+} present.	$4\text{Fe}^{3+}(\text{aq}) + 3[\text{Fe}(\text{CN})_6]^{4-}(\text{aq}) \longrightarrow \text{Fe}_4[\text{Fe}(\text{CN})_6]_3(\text{s})$

6. Copper(II) ion, $\text{Cu}^{2+}(\text{aq})$ – blue solution

Test	Observations	Deduction	Equations
1. Add aqueous NaOH.	Blue ppt formed, insoluble in excess NaOH(aq).	$\text{Cu}(\text{OH})_2(\text{s})$ formed. Cu^{2+} present.	$\text{Cu}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \longrightarrow \text{Cu}(\text{OH})_2(\text{s})$
2. Add aqueous NH_3 .	<u>Blue ppt</u> formed, <u>soluble</u> in excess $\text{NH}_3(\text{aq})$ to give a <u>deep blue</u> solution.	$\text{Cu}(\text{OH})_2(\text{s})$ formed. Cu^{2+} present. $[\text{Cu}(\text{NH}_3)_4]^{2+}(\text{aq})$	$\text{Cu}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \longrightarrow \text{Cu}(\text{OH})_2(\text{s})$ $\text{Cu}(\text{OH})_2(\text{s}) + 4\text{NH}_3(\text{aq}) \rightarrow [\text{Cu}(\text{NH}_3)_4]^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq})$
Then add dilute H_2SO_4 .	<u>Pale blue ppt</u> re-formed, <u>dissolved</u> in excess $\text{H}_2\text{SO}_4(\text{aq})$ to give a <u>pale blue solution</u> .	$\text{Cu}(\text{OH})_2(\text{s})$ formed. $\text{Cu}^{2+}(\text{aq})$	$[\text{Cu}(\text{NH}_3)_4]^{2+}(\text{aq}) + 2\text{H}^{+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{Cu}(\text{OH})_2(\text{s}) + 4\text{NH}_4^{+}(\text{aq})$ $\text{Cu}(\text{OH})_2(\text{s}) + 2\text{H}^{+}(\text{aq}) \longrightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$
3. Add aqueous Na_2CO_3 .	Green ppt formed.	$2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2(\text{s})$ a basic carbonate	$3\text{Cu}^{2+}(\text{aq}) + 2\text{CO}_3^{2-}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \rightarrow 2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2(\text{s})$
Then heat.	Black ppt formed.	$\text{CuO}(\text{s})$	$2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2(\text{s}) \longrightarrow 3\text{CuO}(\text{s}) + 2\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$
4. Add aqueous KI, and allow it to settle	<u>Cream ppt</u> in <u>brown</u> solution.	$\text{CuI}(\text{s})$ $\text{I}_2(\text{aq})$ Cu^{2+} present.	$2\text{Cu}^{2+}(\text{aq}) + 4\text{I}^{-}(\text{aq}) \longrightarrow 2\text{CuI}(\text{s}) + \text{I}_2(\text{aq})$ $\text{I}_2(\text{aq}) + 2\text{S}_2\text{O}_3^{2-}(\text{aq}) \longrightarrow 2\text{I}^{-}(\text{aq}) + \text{S}_4\text{O}_6^{2-}(\text{aq})$
Then add aqueous $\text{Na}_2\text{S}_2\text{O}_3$.	<u>Brown</u> solution was decolourised. <u>Cream</u> ppt <u>dissolved</u> in excess $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ to give a <u>colourless</u> solution.	$[\text{Cu}(\text{S}_2\text{O}_3)_2]^{3-}(\text{aq})$	$\text{CuI}(\text{s}) + 2\text{S}_2\text{O}_3^{2-}(\text{aq}) \longrightarrow [\text{Cu}(\text{S}_2\text{O}_3)_2]^{3-}(\text{aq}) + \text{I}^{-}(\text{aq})$
5. Add conc. HCl.	<u>Green</u> solution. With more conc. HCl, a <u>yellow</u> solution formed.	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ and $[\text{CuCl}_4]^{2-}(\text{aq})$ $[\text{CuCl}_4]^{2-}(\text{aq})$	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}(\text{aq}) + 4\text{Cl}^{-}(\text{aq}) \rightleftharpoons [\text{CuCl}_4]^{2-}(\text{aq}) + 6\text{H}_2\text{O}(\text{l})$

4 Reactions of some anions

With the exception of sulfate anions, most of the common anions of the salts prescribed in the syllabus can be detected by either dilute acid (e.g. dilute HCl or H₂SO₄) or concentrated sulfuric acid.

Other reagents can also be used to identify specific cations (e.g. aqueous AgNO₃ to test for halides, Devarda's Alloy to test for NO₂⁻).

Procedure

1. To approximately 1 cm depth of solution in a test tube, add reagent dropwise with shaking until no further change is observed unless you are instructed otherwise.
2. Note the changes during the reaction and record your observations.

1. Carbonate ion, CO₃²⁻(aq) — colourless solution

Test	Observations	Deduction	Equations
1. Add aqueous BaCl ₂ . Then add dilute HCl.	<u>White ppt</u> formed. The ppt <u>dissolved</u> to form a <u>colourless</u> solution. <u>Effervescence</u> was observed and the gas evolved gave a <u>white</u> ppt. with Ca(OH) ₂ (aq).	BaCO ₃ (s) formed. CO ₂ (g) evolved. CO ₃ ²⁻ present.	Ba ²⁺ (aq) + CO ₃ ²⁻ (aq) → BaCO ₃ (s) CO ₃ ²⁻ (aq) + 2H ⁺ (aq) → CO ₂ (g) + H ₂ O(l) CO ₂ (g) + Ca(OH) ₂ (aq) → CaCO ₃ (s) + H ₂ O(l)

2. Chloride ion, Cl⁻(aq) — colourless solution

Test	Observations	Deduction	Equations
1. Add aqueous AgNO ₃ .	<u>White ppt</u> formed.	AgCl(s) Cl ⁻ present.	Ag ⁺ (aq) + Cl ⁻ (aq) → AgCl (s)
Then add aqueous NH ₃ .	The ppt <u>dissolved</u> to form a <u>colourless</u> solution.	[Ag(NH ₃) ₂] ⁺ (aq) formed.	AgCl (s) + 2NH ₃ (aq) → [Ag(NH ₃) ₂] ⁺ (aq) + Cl ⁻ (aq)

3. Bromide ion, Br⁻(aq) — colourless solution

Test	Observations	Deduction	Equations
1. Add aqueous AgNO ₃ .	<u>Cream (or pale yellow) ppt</u> formed.	AgBr(s) Br ⁻ present.	Ag ⁺ (aq) + Br ⁻ (aq) → AgBr(s)
Then add aqueous NH ₃ .	The ppt was <u>insoluble</u> .		

4. Iodide ion, I⁻(aq) — colourless solution

Test	Observations	Deduction	Equations
1. Add aqueous AgNO ₃ .	<u>Yellow ppt</u> formed.	AgI(s) formed. I ⁻ present.	Ag ⁺ (aq) + I ⁻ (aq) → AgI(s)
Then add aqueous NH ₃ .	The ppt was <u>insoluble</u> .		

5. Nitrate(V) ion, $\text{NO}_3^-(\text{aq})$ — colourless solution

Test	Observations	Deduction	Equations
1. Add an excess of NaOH and warm gently. Add a piece of Al foil or add a little Devarda's alloy.	Pungent gas evolved turned damp red litmus paper blue.	$\text{NH}_3(\text{g})$ evolved. NO_2^- or NO_3^- present.	$3\text{NO}_3^-(\text{aq}) + 8\text{Al}(\text{s}) + 5\text{OH}^-(\text{aq}) + 18\text{H}_2\text{O}(\text{l}) \longrightarrow 3\text{NH}_3(\text{g}) + 8[\text{Al}(\text{OH})_4]^- (\text{aq})$ $\text{NO}_3^-(\text{aq}) + 4\text{Zn}(\text{s}) + 7\text{OH}^-(\text{aq}) + 6\text{H}_2\text{O}(\text{l}) \longrightarrow \text{NH}_3(\text{g}) + 4[\text{Zn}(\text{OH})_4]^{2-}(\text{aq})$

6. Nitrite ion, $\text{NO}_2^-(\text{aq})$ — colourless solution

Test	Observations	Deduction	Equations
1. Add dilute H_2SO_4 and warm gently Using a dropper, transfer the gas formed into freshly prepared FeSO_4 solution.	<u>Brown</u> gas evolved turned aqueous FeSO_4 from <u>pale green</u> to <u>brown</u> .	$\text{NO}_2(\text{g})$ evolved. NO_2^- present.	$\text{NO}_2^-(\text{aq}) + \text{H}^+(\text{aq}) \longrightarrow \text{HNO}_2(\text{aq})$ $3\text{HNO}_2(\text{aq}) \longrightarrow \text{HNO}_3(\text{aq}) + 2\text{NO}(\text{g}) + \text{H}_2\text{O}(\text{l})$ $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{NO}_2(\text{g})$
2. Add an excess of NaOH and warm gently. Add a piece of Al foil or add a little Devarda's alloy.	<u>Pungent</u> gas evolved turned damp <u>red</u> litmus paper <u>blue</u> .	$\text{NH}_3(\text{g})$ evolved. NO_2^- or NO_3^- present.	$\text{NO}_2^-(\text{aq}) + 2\text{Al}(\text{s}) + \text{OH}^-(\text{aq}) + 5\text{H}_2\text{O}(\text{l}) \longrightarrow \text{NH}_3(\text{g}) + 2[\text{Al}(\text{OH})_4]^- (\text{aq})$ $\text{NO}_2^-(\text{aq}) + 3\text{Zn}(\text{s}) + 5\text{OH}^-(\text{aq}) + 5\text{H}_2\text{O}(\text{l}) \longrightarrow \text{NH}_3(\text{g}) + 3[\text{Zn}(\text{OH})_4]^{2-}(\text{aq})$

7. Sulfate(VI) ion, $\text{SO}_4^{2-}(\text{aq})$ — colourless solution

Test	Observations	Deduction	Equations
1. Add aqueous BaCl_2 .	White ppt.	$\text{BaSO}_4(\text{s})$ formed. SO_4^{2-} present.	$\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \longrightarrow \text{BaSO}_4(\text{s})$
Then add dilute HCl.	Ppt <u>insoluble</u> in excess dilute HCl.		

Note: To distinguish between SO_3^{2-} and SO_4^{2-} , add dil HCl to the white ppt formed (after adding aq. BaCl_2). White BaSO_3 ppt will dissolve and SO_2 will be produced while white BaSO_4 ppt remains insoluble in excess dil HCl.

8. Sulfite ion, $\text{SO}_3^{2-}(\text{aq})$ — colourless solution

Test	Observations	Deduction	Equations
1. Add aqueous BaCl_2 .	<u>White ppt</u> formed.	$\text{BaSO}_3(\text{s})$ formed.	$\text{Ba}^{2+}(\text{aq}) + \text{SO}_3^{2-}(\text{aq}) \longrightarrow \text{BaSO}_3(\text{s})$
Then add dilute HCl.	The ppt <u>dissolved</u> . Gas also decolourises <u>acidified</u> purple KMnO_4 on filter paper.	$\text{SO}_2(\text{g})$ evolved. SO_3^{2-} present.	$\text{SO}_3^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) \longrightarrow \text{SO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$

9. Chromate(VI) ion, $\text{CrO}_4^{2-}(\text{aq})$ — yellow solution

Test	Observations	Deduction	Equations
1. Add dilute H_2SO_4 .	<u>Orange</u> solution formed.	$\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ formed. CrO_4^{2-} present.	$2\text{CrO}_4^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) \longrightarrow \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
Then add aqueous NaOH .	<u>Yellow</u> solution.	$\text{CrO}_4^{2-}(\text{aq})$ re-formed.	$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 2\text{OH}^-(\text{aq}) \longrightarrow 2\text{CrO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
2. Add aqueous BaCl_2 .	<u>Pale yellow</u> ppt.	$\text{BaCrO}_4(\text{s})$ formed. CrO_4^{2-} present.	$\text{Ba}^{2+}(\text{aq}) + \text{CrO}_4^{2-}(\text{aq}) \longrightarrow \text{BaCrO}_4(\text{s})$
Then add dilute HCl .	The ppt <u>dissolved</u> to form an <u>orange</u> solution.	$\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ formed.	$2\text{BaCrO}_4(\text{s}) + 2\text{H}^+(\text{aq}) \longrightarrow 2\text{Ba}^{2+}(\text{aq}) + \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$

Note: Tests which can be used to distinguish between NaNO_2 & NaNO_3 :

1. Add dilute sulfuric acid to either solid samples or aqueous solutions of the two salts. NaNO_2 would react with the acid to yield brown $\text{NO}_2(\text{g})$ while NaNO_3 does not react with the acid.
2. Add acidified $\text{KMnO}_4(\text{aq})$ to aqueous solutions of the two salts. Decolourisation of purple $\text{KMnO}_4(\text{aq})$ would be observed in the case of $\text{NaNO}_2(\text{aq})$ but not $\text{NaNO}_3(\text{aq})$.