Qualitative Analysis

Solubility of Ionic Compounds

Compound	Soluble / Insoluble	Description
Copper(II) Sulfate	Soluble	A: white powdery solid, B: blue crystalline solid
Sodium Hydroxide	Soluble	White powdery solid
Ammonium carbonate	Soluble	White crystalline solid
Silver chloride	Insoluble	White powdery solid
Barium Sulfate	Insoluble	White powdery solid
Iron(II) Sulfate	Soluble	Green crystalline solid

Cation Test

First Method: Addition of Sodium Hydroxide

Experimental procedure:

1. Add 2-3 drops of sodium hydroxide to the given solution and shake gently. Note observations.
2. Continue adding sodium hydroxide to the mixture and shake gently. Note down your observations upon addition of excess sodium hydroxide to the mixture.

Observation

- Precipitate formed?
- Colour of precipitate?

If precipitate is formed, proceed to the next step.

- Shake and observe carefully to see if the precipitate

Test for Cations - Table

Experimental Procedure: Add 2-3 drops of aqueous sodium hydroxide to the solution
Type of Reaction: Precipitation

Sample Solution	Cations Present	Chemical Formulae of Products
Aluminium nitrate	Al^{3+} ion	$Al(OH)_3$ (s) + $NaNO_3$ (aq)
Calcium nitrate	Ca^{2+} ion	$Ca(OH)_2$ (s) + $NaNO_3$ (aq)
Zinc nitrate	Zn^{2+} ion	$Ca(OH)_2$ (s) + $NaNO_3$ (aq)
Copper(II) nitrate	Cu^{2+} ion	$Cu(OH)_2$ (s) + $NaNO_3$ (aq)
Iron(II) nitrate	Fe^{2+} ion	$Fe(OH)_2$ (s) + $NaNO_3$ (aq)
Iron(III) nitrate	Fe^{3+} ion	$Fe(OH)_3$ (s) + $NaNO_3$ (aq)

Experimental Procedure: Add equal volumes of sodium hydroxide and test sample in the test tube and warm. **Type of Reaction:** Base + Ammonium salt

Sample Solution	Cations Present	Chemical Formulae of Products
Ammonium nitrate	NH_4^+ ion	NH_3 (g) + H_2O(l) + $NaNO_3$ (aq)

Dissociation Equation for Aqueous Ammonia

$$NH_3\,(aq) + H_2O\,(l) \rightarrow NH_4^+\,(aq) + OH^-\,(aq)$$

As aqueous ammonia dissociates to form ammonium cations and hydroxide anions, the hydroxide anions are able to react with the metal cations to form the insoluble hydroxides which will appear in the form of precipitates.

Second Method: Addition of Aqueous Ammonia

Experimental Procedure

1. Add 2-3 drops of aqueous ammonia to the given solution and shake gently. Note down the observations.
2. Continue adding aqueous ammonia to the mixture and shake gently. Note down your observations upon addition of excess sodium hydroxide to the mixture.

Why do we need 2 reagents?

What are the observations for addition of aqueous sodium hydroxide and aqueous ammonia to calcium nitrate?

- **Observations for addition of sodium hydroxide:** White precipitate forms upon addition of aqueous sodium hydroxide. When excess aqueous sodium hydroxide is added, the white precipitate does not dissolve.
- **Observations for addition of aqueous ammonia:** No precipitate forms upon addition of aqueous ammonia.

Why is there such a difference in observation for addition of sodium hydroxide and aqueous ammonia?

- The white precipitate formed in the addition of sodium hydroxide is calcium hydroxide, $Ca(OH)_2$. According to the solubility table, calcium hydroxide is partially soluble in water.
- As sodium hydroxide is a strong alkali while aqueous ammonia is a weak alkali, the concentration of OH^- ions present in the solution differs.
- Hence, the concentration of calcium hydroxide when aqueous ammonia is added is lower than that of when aqueous sodium hydroxide is added.
- At lower concentrations, the solid structure of calcium hydroxide does not become a visible size.
- Therefore, we are not able to see the formation of the precipitate.Header name

	Experimental Procedure	Chemical Formula	Ionic Equation
1)	Add 2-3 drops of aqueous sodium hydroxide to copper(II) nitrate solution	$Cu(NO_3)_2$ (aq) + NaOH (aq)	$\ce{Cu^{2+} (aq) + 2OH^- (aq) -> Cu(OH)_2 (s) }
2)	Add 2-3 drops of aqueous sodium hydroxide to iron(III) nitrate solution.	$Fe(NO_3)_3$ (aq) + NaOH (aq)	Fe^{3+} (aq) + 3 OH^- (aq) → $Fe(OH)_3$ (s)
3)	Add 2-3 drops of aqueous sodium hydroxide to zinc nitrate solution	$Zn(NO_3)_2$ (aq) + NaOH (aq)	Zn^{2+} (aq) + 2 OH^- (aq) → $Zn(OH)_2$ (s)
4)	Add 2-3 drops of **aqueous ammonia** to aluminium nitrate solution	$Al(NO_3)_2$ (aq) + NH_3 (g) + H_2O (l)	Al^{3+} + 3 OH^- (aq) → $Al(OH)_3$ (s)
5)	Add 2-3 drops of **aqueous ammonia** to iron(II) nitrate solution	$Fe(NO_3)_2$ (aq) + NH_3 (g) + H_2O (l)	Fe^{2+} (aq) + 2 OH^- (aq) → $Fe(OH)_2$ (s)

Anion Tests

	Aqueous Anions Present	Sample Solutions Containing Ions	Experimental Procedure	Chemical formula of reagents	Chemical formula of products	Ty Re
1)	Chlorides	Aqueous coppper (II) chloride (any soluble chloride)	Add dilute nitric acid, then add silver nitrate solution	$CuCl_2$ (aq) + $AgNO_3$ (aq)	$Cu(NO_3)_2$ (aq) + AgCl (s)	Prec
2)	Iodides	Aqueous sodium iodide	Add dilute nitric acid, then add silver nitrate solution	NaI (aq) + $AgNO_3$ (aq)	$NaNO_3$ (aq) + Ag(s)	Prec

	Aqueous Anions Present	Sample Solutions Containing Ions	Experimental Procedure	Chemical formula of reagents	Chemical formula of products	Ty Re
3)	Sulfates	Aqueous aluminium sulfate	Add dilute nitric acid, then add barium nitrate solution	$Al_2(SO_4)_3$ (aq) + $Ba(NO_3)_2$ (aq)	$Al(NO_3)_3$ (aq) + $BaSO_4$ (s)	Prec
4)	Carbonates	Aqueous ammonium carbonate	Add dilute hydrochloric acid	$(NH_4)_2CO_3$ (aq) + HCl(aq)	NH_4 Cl (aq) + H_2O (l) + CO_2 (g)	react betw and carb
5)	Nitrates	Aqueous potassium nitrate	Add dilute sodium hydroxide, then add a piece of aluminium foil. Warm carefully.			

Purpose of Adding Nitric Acid

- There may be impurities present: i.e. hydroxide and carbonate ions that can precipitate with the same test reagents and give misleading positive results.
    - Most carbonates and hydroxides are **insoluble.**
- Thus, nitric acid is added to acidify the test sample, so as to **react away any possible carbonates and hydroxides** in the test sample.
- These carbonates and hydroxides (if present) can also precipitate with the same test reagent and give false positive results.

Testing for Water

- Copper (II) sulfate has two different forms. One is anhydrous and one is hydrated.
- The anhydrous copper(II) sulfate is a white powdery solid while hydrated copper(II) sulfate is a blue crystalline solid.

Summary

Test for anions

Anion	Test	Test Result
Carbonate	add dilute acid	effervescence, carbon dioxide produced.

Anion	Test	Test Result
Chloride	Acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
Iodide	Acidify with dilute nitric acid, then add aqueous silver nitrate	yellow ppt.
Nitrate	Add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced
Sulfate	Acidify with dilute nitric acid, then add aqueous barium sulfate	white ppt.

Test for aqueous cations

Cation	Effect of Aqueous Sodium Hydroxide	Effect of Aqueous Ammonia
Aluminium	White ppt., soluble in excess giving a colourless solution	white ppt., insoluble in excess
Ammonium	Ammonia produced on warming	-
Calcium	White ppt., insoluble in excess	No ppt.
Copper (II)	light blue ppt., insoluble in excess	light blue ppt., soluble in excess giving a dark blue solution
Iron (II)	green ppt., insoluble in excess	green ppt., insoluble in excess
Iron (III)	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess
Zinc	White ppt., soluble in excess giving a colourless solution	White ppt., soluble in excess giving a colourless solution

Test for gases

Gas	Test and Test Result
Ammonia	Turns damp red litmus paper blue
Carbon dioxide	Gives white ppt. with limewater (ppt. dissolves with excess CO_2)
Chlorine	Bleaches damp litmus paper
Hydrogen	'pops' with a lighted splint
Oxygen	Relights a glowing splint
Sulfur Dioxide	Turns aqueous acidified potassium manganate (VII) from purple to colourless.