

Chapter 3

Analytical Chemistry: Uses of Ammonium Hydroxide and Sodium Hydroxide

- Key Difference – Qualitative vs Quantitative Analysis in Chemistry:-

• Qualitative vs Quantitative Analysis in Chemistry

- Qualitative analysis in chemistry is a branch of chemistry that analyses the chemical

- Quantitative analysis in chemistry is a branch of chemistry that deals with the

composition of a sample.

quantities of different components in a sample.

• Details

- Qualitative analysis in chemistry gives the presence or absence of different chemical components in a sample.

- Quantitative analysis in chemistry gives the amount of different chemical components present in a given sample.

• Techniques

- Qualitative analysis in chemistry uses techniques such as distillation, extraction, and change in colour, chromatography, etc.

- Quantitative analysis in chemistry uses techniques such as titrations, gravimetric analysis, combustion analysis, AES, etc.

- Color of the salts:-
- Salts of the elements of the group IA to VIIA are generally colourless.
- Salts of the transition elements of group IB to VIIB and group VIII are generally coloured.

Colourless ions		Coloured ions		
Cation	Symbol	Cation	Symbol	Colour
Ammonium ion	NH_4^+	Cupric ion	Cu^{2+}	Blue
Sodium ion	Na^+	Ferrous ion	Fe^{2+}	Light green
Potassium ion	K^+	Ferric ion	Fe^{3+}	Yellowish brown
Calcium ion	Ca^{2+}	Nickel ion	Ni^{2+}	Green
Magnesium ion	Mg^{2+}	Chromium ion	Cr^{3+}	Green
Aluminium ion	Al^{3+}	Manganese ion	Mn^{2+}	Pink
Lead ion	Pb^{2+}			
Zinc ion	Zn^{2+}			
Anion	Symbol	Anion	Symbol	Colour
Chloride ion	Cl^-	Permanganate ion	MnO_4^-	Pink / Purple
Sulphate ion	SO_4^{2-}	Dichromate ion	$\text{Cr}_2\text{O}_7^{2-}$	Orange
Carbonate ion	CO_3^{2-}	Chromate ion	CrO_4^{2-}	Yellow
Hydrogen carbonate ion	HCO_3^-			
Sulphide ion	S^{2-}			
Bromide ion	Br^-			
Acetate ion	CH_3COO^-			

● Precipitation:-

- A precipitation reaction is a type of chemical reaction in which two soluble salts in aqueous solution combine and one of the products is an insoluble salt called a precipitate. The precipitate may stay in the solution as a suspension, fall out of solution on its own, or can be separated from the liquid using centrifugation, decantation, or filtration. The liquid that remains when a precipitate forms is called the supernate.
- The reaction between silver nitrate and potassium chloride is a precipitation reaction because solid silver chloride is formed as a product.
$$\text{AgNO}_3(\text{aq}) + \text{KCl}(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{KNO}_3(\text{aq})$$

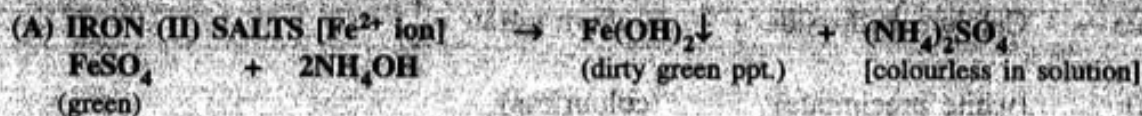
- The reaction may be recognized as a precipitation because two ionic aqueous solutions (aq) react to yield a solid product (s).
- **Action of sodium hydroxide solution on certain metallic salt solutions:-**

1. CALCIUM SALTS [Ca²⁺ ion]					
Ca(NO₃)₂	+ 2NaOH	→	Ca(OH)₂↓	+ 2NaNO₃	SPARINGLY SOLUBLE
Calcium nitrate (colourless)	+ Caustic soda (colourless)	→	Calcium hydroxide (white precipitate)	+ Sodium nitrate (colourless)	
2. IRON :					
(A) FERROUS SALTS [Fe²⁺ ion]					
FeSO₄	+ 2NaOH	→	Fe(OH)₂↓	+ Na₂SO₄	INSOLUBLE
Ferrous sulphate (pale green)	+ Caustic soda (colourless)	→	Ferrous hydroxide (dirty green, gelatinous ppt.)	+ Sodium sulphate (colourless)	
(B) FERRIC SALT [Fe³⁺ ion]					
FeCl₃	+ 3NaOH	→	Fe(OH)₃↓	+ 3NaCl	INSOLUBLE
Ferric chloride (yellow)	+ Caustic soda (colourless)	→	Ferric hydroxide (reddish brown ppt.)	+ Sodium chloride (colourless)	
3. COPPER SALTS [Cu²⁺ ion]					
CuSO₄	+ 2NaOH	→	Cu(OH)₂↓	+ Na₂SO₄	INSOLUBLE
Copper sulphate (blue)	+ Caustic soda (colourless)	→	Copper (II) hydroxide (pale blue ppt.)	+ Sodium sulphate (colourless)	
4. ZINC SALTS [Zn²⁺ ion]					
ZnSO₄	+ 2NaOH	→	Zn(OH)₂↓	+ Na₂SO₄	SOLUBLE
Zinc sulphate (colourless)	+ Caustic soda (colourless)	→	Zinc hydroxide (white, gelatinous ppt.)	+ Sodium sulphate (colourless)	Zn(OH)₂ + 2NaOH (excess) → Na₂ZnO₂ + 2H₂O Sodium zincate (colourless)
5. LEAD SALTS [Pb²⁺ ion]					
Pb(NO₃)₂	+ 2NaOH	→	Pb(OH)₂↓	+ 2NaNO₃	SOLUBLE
Lead nitrate (colourless)	+ Caustic soda (colourless)	→	Lead hydroxide (white ppt.)	+ Sodium nitrate (colourless)	Pb(OH)₂ + 2NaOH (excess) → Na₂PbO₂ + 2H₂O Sodium plumbite (colourless)
(White precipitate of lead hydroxide is readily soluble in acetic acid)					
5. AMMONIUM SALTS [NH₄⁺ ion]					
When Sodium hydroxide (or any water soluble base) is heated with ammonium salts, ammonia gas is evolved					
NH₄Cl	+ NaOH	$\xrightarrow{\Delta}$	NaCl	+ H₂O + NH₃	
(NH₄)₂SO₄	+ 2NaOH	$\xrightarrow{\Delta}$	Na₂SO₄	+ 2H₂O + 2NH₃	

1. CALCIUM SALTS

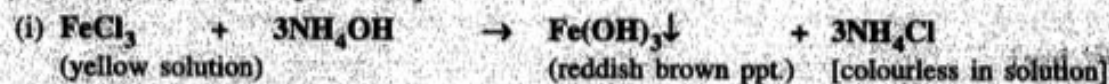
No precipitation of Ca(OH)_2 occurs even with addition of excess of NH_4OH .
This is because the concentration of OH^- ions from the ionisation of NH_4OH is so low that it cannot precipitate the hydroxide of calcium.

2. IRON

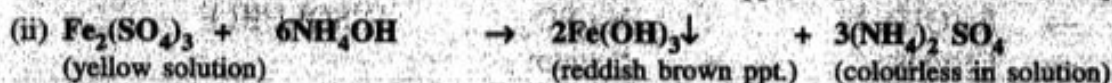


INSOLUBLE

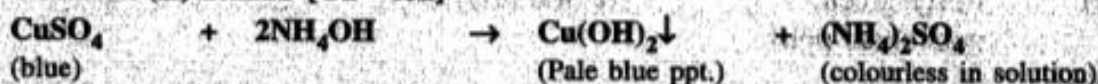
(B) IRON (III) SALTS [Fe^{3+} ion]



INSOLUBLE

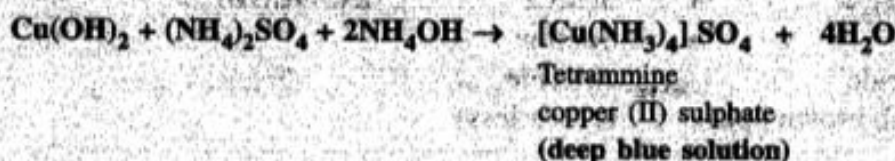


3. COPPER (II) SALTS [Cu^{2+} ion]



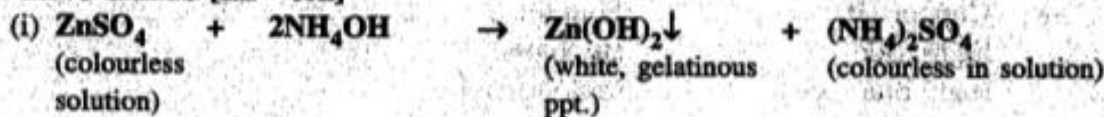
SOLUBLE

With excess of NH_4OH ppt. dissolves



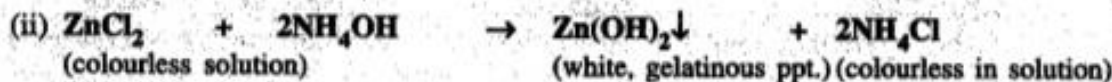
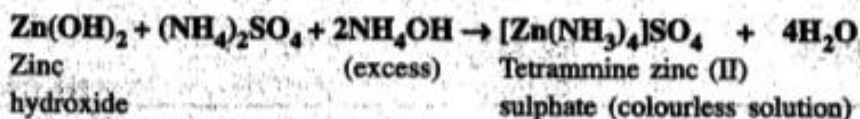
This reaction is a characteristic property of Cu^{2+} ion and is used for its detection in qualitative analysis.

4. ZINC SALTS [Zn^{2+} ion]

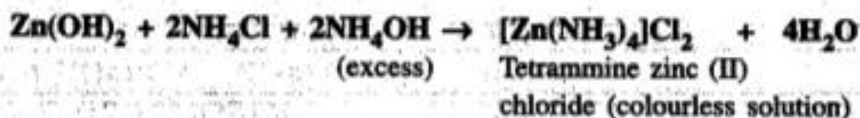


SOLUBLE

With excess of NH_4OH ppt. dissolves.



With excess of NH_4OH ppt. dissolves



5. LEAD SALTS [Pb^{2+} ion]



INSOLUBLE

• Action of ammonium hydroxide on

certain salt solutions:-

METAL	+	ALKALI	→	SALT	+	HYDROGEN
1. ZINC						
(i) Zn	+	2NaOH (Hot and conc.)	→	Na ₂ ZnO ₂ Sodium zincate (colourless)	+	H ₂
(ii) Zn	+	2KOH (Hot and conc.)	→	K ₂ ZnO ₂ Potassium zincate (colourless)	+	H ₂
2. ALUMINIUM						
Aluminium reacts only with boiling and dilute alkalis						
(i) 2Al + 2NaOH	+	2H ₂ O	→	2NaAlO ₂ Sodium aluminate (colourless)	+	3H ₂
(ii) 2Al + 2KOH	+	2H ₂ O	→	2KAlO ₂ Potassium aluminate	+	3H ₂
3. LEAD						
(i) Pb	+	2NaOH	→	Na ₂ PbO ₂ Sodium plumbite (colourless)	+	H ₂
(ii) Pb	+	2KOH	→	K ₂ PbO ₂ Potassium plumbite (colourless)	+	H ₂

- Action of alkalis on certain metals:-
- Oxides and hydroxides:-

- **OXIDES OF ALKALINE EARTH METALS - DEFINITION**

- All the elements of group 2 burns with oxygen gas to produce metallic oxide. The oxides of alkaline earth metals are less basic. Oxides become more basic on increas in electropositive character.

- **HYDROXIDES OF ALKALINE EARTH METAL - DEFINITION**

- Alkaline earth metals have tendency to form hydroxides which decrease as moving down in the group. All the hydroxides are basic in nature which decreases on moving down the group.

- **What are Oxides?**
- The classification of oxides is done into neutral, amphoteric and basic or acidic based on their acid-base characteristics.
- An acidic oxide is an oxide which when combined with water gives off an acid.

- A basic oxide is an oxide which when combined with water gives off a base.

AMPHOTERIC OXIDE / HYDROXIDE	OXIDE / HYDROXIDE	+ ALKALI	SALT	+ WATER
1. Zinc oxide / Zinc hydroxide	(i) ZnO (white)	+ 2NaOH	→ Na ₂ ZnO ₂ Sodium zincate (colourless, soluble)	+ H ₂ O
	Zn(OH) ₂	+ 2NaOH	→ Na ₂ ZnO ₂	+ 2H ₂ O
	(ii) ZnO (white)	+ 2KOH	→ K ₂ ZnO ₂ Potassium zincate (colourless, soluble)	+ H ₂ O
	Zn(OH) ₂	+ 2KOH	→ K ₂ ZnO ₂	+ 2H ₂ O
2. Aluminium oxide / Aluminium hydroxide	(i) Al ₂ O ₃ (white)	+ 2NaOH	→ 2NaAlO ₂ Sodium aluminate (white)	+ H ₂ O
	Al(OH) ₃	+ NaOH	→ NaAlO ₂	+ 2H ₂ O
	(ii) Al ₂ O ₃ (white)	+ 2KOH	→ 2KAlO ₂ Potassium aluminate (white)	+ H ₂ O
	Al(OH) ₃	+ KOH	→ KAlO ₂	+ 2H ₂ O
3. Lead oxide / Lead hydroxide	(i) PbO (yellow)	+ 2NaOH	→ Na ₂ PbO ₂ Sodium plumbite (colourless, soluble)	+ H ₂ O
	Pb(OH) ₂	+ 2NaOH	→ Na ₂ PbO ₂	+ 2H ₂ O
	(ii) PbO (yellow)	+ 2KOH	→ K ₂ PbO ₂ Potassium plumbite (colourless, soluble)	+ H ₂ O
	Pb(OH) ₂	+ 2KOH	→ K ₂ PbO ₂	+ 2H ₂ O

- When a substance reacts chemically, both as a base or acid it termed as an amphoteric solution.
- Neutral Oxide is one which neither has an acidic characteristic or a basic one.

- Metal Oxides have an oxidation number of -2 and generally comprise of an oxygen anion. The Earth's crust is mostly made up of oxides that are solid. Oxide coatings can get formed over pure elements too, for instance, a foil made of aluminum gets covered by a thin skin of Al_2O_3 , and this skin defends the rest of the foil from corrosion.

- **Classification Of Oxides**

- Depending upon nature and the properties exhibited by compounds, they are classified into
 - Acidic oxides
 - Basic oxides
 - Amphoteric oxides
 - Neutral oxides

- **Basic oxide:**

- Metals react with oxygen to give basic compounds of oxygen. These compounds are usually ionic in nature. Group 1, 2 and lanthanides form basic compounds of oxygen when they react with dioxygen. During the formation of these compounds, a large amount of energy is released. These compounds readily react with water except few exceptions.

- Examples: M_2O_3 , MO_2 , ThO_2

- $Na_2O + H_2O \rightarrow 2NaOH$

- **Acidic oxide:**

- Non-metals react with oxygen to form acidic compounds of oxides which are held together by covalent bonds. These compounds can also be called

as acid anhydrides. Acid anhydrides usually have a low melting and boiling point except for compounds like B_2O_3 and SiO_2 which have high melting points and form giant molecules.

- Examples: NO , CO_2
- $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$
- $\text{B}_2\text{O}_3 + \text{H}_2\text{O} \rightarrow 2\text{H}_3\text{BO}_3$
- **Amphoteric oxide:**
- Amphoteric oxides are compounds of oxygen which exhibits both acidic as well as basic characteristics. These oxides when reacting with acid undergoes a neutralization reaction to form water and salt. This exhibits the basic property of the compounds. Similarly reacts with the alkali to form

salt and water, exhibiting acidic property. Example: aluminium oxide

- Acidic characteristics:
- $\text{Al}_2\text{O}_3 + 6\text{HCl} \rightarrow 2\text{Al}^{3+} + 6\text{Cl}^- + 3\text{H}_2\text{O}$
- Basic characteristics:
- $\text{Al}_2\text{O}_3 + 2\text{OH}^- + 3\text{H}_2\text{O} \rightarrow 2[\text{Al}(\text{OH})_4]^-$
- **Neutral Oxides:**
- Some compounds react with oxygen to form oxides which do not exhibit acidic nor basic characteristics. Such compounds are called as neutral compounds of oxygen.
- Example: NO, CO.
- **QUESTIONS:-**

• Short Answer Questions

- Write the balanced equations for the reaction between aluminum oxide and sodium hydroxide.
- What do you observe when excess of NH_3 is passed through an aqueous solution of lead nitrate?
- From the list of metals given below, select a metal whose hydroxide is soluble in sodium hydroxide solution: Ca, Mg, Fe and Zn.
- Write balanced equations for (a) Al and (b) Zn, when warmed with caustic soda solution.
- What would you observe when NH_4OH solution is added to iron(III)sulphate solution?

- Write a balanced equation for the following: iron (III) chloride solution with NaOH solution.
- Long Answer Questions
- NaOH solution is added to the solutions containing the ions mentioned in List X. List Y gives the details of the precipitate. Match the ions with their coloured precipitates

- List

X

List

Y

- a. Pb^{+2}
 - i. Reddish brown
- b. Fe^{+2}
 - ii. White insoluble in excess
- c. Zn^{+2}
 - iii. Dirty green

- d. Fe^{+3}
 - iv. White soluble in excess
- e. Cu^{+2}
 - v. White soluble in excess
- f. Ca^{+2}
 - vi. Blue

- Write the equation for the following reactions:

- a. ZnO is treated with NaOH solution. b. NH_4Cl is heated with NaOH .

- Identify the substances P, Q and R in each case based in the information given below:

- The deliquescent salt P, turns yellow on dissolving in water, and gives a reddish brown

precipitate with NaOH solution.

- **The white crystalline solid Q is soluble in water. It liberates a pungent smelling gas when heated with sodium hydroxide solution.**
- **The pale green solid R turns reddish brown on heating. Its aqueous solution gives a white precipitate with barium chloride solution. The precipitate is soluble in mineral acids.**
- **Give one chemical test to distinguish between the following pairs of compounds iron (II) chloride, solution and iron (III) chloride solution.**

- Give one test each to distinguish between the following pairs of chemicals:

- Zinc nitrate solution and Calcium nitrate solution.

- Iron(III) chloride solution and copper chloride solution.

- The questions (a) and (b) given below refer to the following salt solutions listed A to F:

- A: $\text{Cu}(\text{NO}_3)_2$ B: FeSO_4 C: FeCl_3
D: $\text{Pb}(\text{NO}_3)_2$ E: MgSO_4 F: ZnCl_2

- Which salt solution becomes deep inky blue in colour when excess of ammonium hydroxide solution is added to it?

- Which salt solution gives a white precipitate with excess of NH_4OH solution?
- 7. NaOH solution is added first in a small quantity and then in excess to each of the aqueous salt solutions given below: CuSO_4 , $\text{Zn}(\text{NO}_3)_2$, $\text{Pb}(\text{NO}_3)_2$, CaCl_2 and $\text{Fe}_2(\text{SO}_4)_3$. Copy the following table.
- Also, write the color of the precipitate obtained in (A) to (E) and the nature of the precipitate (soluble or insoluble) in (F) to (J):

• Aqueous salt solution	• Ppt color	• Nature of ppt with
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	with littl e Na OH	excess NaOH (Solubl e or Insolub le)
• Copper(II)sulp hate	• A	• F
• Zinc nitrate	• B	• G
• Lead nitrate	• C	• H
• Calcium chloride	• D	• I
• Iron(III)sulphat e	• E	• J



- What do you observe when NH_4OH solution is added in excess to CuSO_4 solution?
- What do you observe when NaOH solution is added to Zinc sulphate solution is excess?
- a. How would you distinguish between Zn^{+2} and Pb^{+2} ions using NH_4OH solution?
- b. The following table shows the tests a student performed on aqueous solution of A and B. What are his observations?

• Test	• Observations	• Conclusions
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• To solution A, NaOH was added	•	• A contains Fe^{+3} ions
• To solution B, NH_4OH was added slowly till it was in	•	• B contains Cu^{+2} ions.

exces s		
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- State the effect of adding to small amount of
- (i) NaOH (ii) NH₄OH – followed by an excess of (a) Ca(NO₃)₂ (b) Zn(NO₃)₂ (c) Pb(NO₃)₂ solutions.