Study Notes: Analytical Chemistry - Qualitative Analysis

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1. Introduction to Qualitative Analysis

Qualitative analysis is a branch of analytical chemistry that identifies the presence of specific ions or functional groups in a sample. It is typically used to determine the chemical composition of a substance without quantifying the amount.

2. Confirmatory Tests for Different Groups of Cations

2.1 Group I Cations (Pb^{2+}, Cu^{2+})

2.1.1 Potassium Chromate Test

- **Procedure**: Add potassium chromate solution to the sample.
- **Observation**: A **yellow precipitate** of **$PbCrO_4$** forms if Pb^{2+} is present.
- **Reaction**:

$$Pb^{2+} + CrO_4^{2-} \rightarrow PbCrO_4(s)$$

2.1.2 Potassium Thiocyanate Test

- **Procedure**: Add potassium thiocyanate solution to the sample.
- **Observation**: A **blood-red color** forms due to the formation of **$Fe(SCN)_3$**.
- **Reaction**:

$$Fe^{3+} + SCN^{-} \rightarrow Fe(SCN)_3$$

2.1.3 Ammonia Test

- **Procedure**: Add ammonia solution to the sample.
- **Observation**: A **blue precipitate** of **$Cu(OH)_2$** forms if Cu^{2+} is present.
- **Reaction**:

$$Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2(s)$$

2.2 Group II Cations (Zn^{2+}, Ni^{2+})

2.2.1 Sodium Hydroxide Test

- **Procedure**: Add sodium hydroxide solution to the sample.
- **Observation**: A **white precipitate** of **$Zn(OH)_2$** forms if Zn^{2+} is present.
- **Reaction**:

$$Zn^{2+} + 2OH^- \rightarrow Zn(OH)_2(s)$$

2.2.2 Ammonia Test

- **Procedure**: Add ammonia solution to the sample.
- **Observation**: A **blue precipitate** of **$Ni(OH)_2$** forms if Ni^{2+} is present.
- **Reaction**:

$$Ni^{2+} + 2OH^- \rightarrow Ni(OH)_2(s)$$

2.3 Group III Cations (Mg^{2+})

2.3.1 Phenolphthalein Test

- **Procedure**: Add phenolphthalein solution to the sample.
- **Observation**: A **pink color** forms due to the formation of **$Mg(phen)_2$**.
- **Reaction**:

$$Mg^{2+} + 2phen \rightarrow Mg(phen)_2$$

3. Tests for Specific Functional Groups

3.1 Alcohol Test

3.1.1 Lucas Test

- **Procedure**: Add Lucas reagent (concentrated HCl and $ZnCl_2$) to the sample.
- **Observation**: A **cloudy or turbid solution** indicates the presence of **alcohols**.
- **Reaction**:

$$RCH_2OH + HCl \rightarrow RCH_2Cl + H_2O$$

3.1.2 Victor Meyer Test

- **Procedure**: Add Victor Meyer reagent (KBr, H_2SO_4) to the sample.
- **Observation**: A **red color** forms if the alcohol is **primary**, **violet** if **secondary**, and **no color** if **tertiary**.
- **Reactions**:
- Primary:

$$RCH_2OH + KBr + H_2SO_4 \rightarrow RCH_2Br + KHSO_4 + H_2O$$

- Secondary:

$$RCH(OH)R^{'} + KBr + H_2SO_4 \rightarrow RCHBrR^{'} + KHSO_4 + H_2O$$

3.2 Aldehyde Test

3.2.1 Tollens' Test

- **Procedure**: Add Tollens' reagent ($AgNO_3$ in NH_3) to the sample.
- **Observation**: A **silver mirror** forms if the compound is an **aldehyde**.
- **Reaction**:

$$RCHO + 2[Ag(NH_3)_2]^{+} + 3OH^{-} \rightarrow RCOO^{-} + 2Ag(s) + 4NH_3 + H_2O$$

3.3 Ketone Test

3.3.1 Iodoform Test

- **Procedure**: Add iodine and NaOH to the sample.
- **Observation**: A **yellow precipitate** of **CHI_3** forms if the compound is a **methyl ketone**.
- **Reaction**:

$$RCOCH_3 + 4I_2 + 6NaOH \rightarrow RCOONa + CHI_3 + 5NaI + 5H_2O$$

4. Summary of Key Tests and Observations

Test	Cation/Group	Reagent	Observation	Result
Potassium Chromate	Pb^{2+}	K_2CrO_4	Yellow precipitate	Presence of Pb^{2+}
Potassium Thiocyanate	Fe^{3+}	KSCN	Blood-red color	Presence of Fe^{3+}
Sodium Hydroxide	Zn^{2+}	NaOH	White precipitate	Presence of Zn^{2+}
Ammonia	Ni^{2+}	NH_3	Blue precipitate	Presence of Ni^{2+}
Phenolphthalein	Mg^{2+}	Phenolphthalein	Pink color	Presence of Mg^{2+}
Lucas Test	Alcohol	HCl, $ZnCl_2$	Cloudy or turbid solution	Presence of alcohol
Tollens' Test	Aldehyde	$AgNO_3$ in NH_3	Silver mirror	Presence of aldehyde
Iodoform Test	Methyl Ketone	I_2, NaOH	Yellow precipitate	Presence of methyl ketone

5. Conclusion

Qualitative analysis is a fundamental technique in analytical chemistry that allows for the identification of specific ions and functional groups in a sample. The methods described above provide a structured approach to determining the composition of unknown substances, using a combination of chemical reagents and observable changes. Each test is designed to detect specific ions or functional groups, making it a powerful tool for both educational and practical applications.