Chapter 18:

Qualitative Analysis

Short Questions (Exercise)

1 (i) How is ammonia detected by a litmus paper?

Ammonia gas turns moist red litmus paper blue because it is basic in nature.
Example: When ammonia gas is passed over red litmus, the blue color confirms its presence.

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1 (ii) How can you identify carbon dioxide?

Carbon dioxide is identified by bubbling it through limewater (calcium hydroxide solution), which turns milky due to the formation of calcium carbonate.
Example: $CO_2 + Ca(OH)_2 \rightarrow CaCO_3$ (white precipitate) + H_2O.

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1 (iii) How can you detect hydrogen gas?

Hydrogen gas is detected by bringing a burning splint near it, which produces a "pop" sound, indicating the presence of hydrogen.
Example: This test is commonly performed during electrolysis of water.

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1 (iv) How can you detect sulfur dioxide?

Sulfur dioxide is detected by its characteristic choking smell and by turning moist blue litmus paper red. It also decolorizes potassium permanganate solution (purple to colorless).
Example: $SO_2 + KMnO_4 \rightarrow Mn^{2+}$ (colorless) + SO_4^{2-}.

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1 (v) Differentiate between oxidizing and reducing flame.

- **Oxidizing Flame**: Contains excess oxygen and produces a blue color, used for oxidation reactions.
- **Reducing Flame**: Contains excess fuel and produces a yellow color, used for reduction reactions.

Example: The outer part of a Bunsen burner flame is oxidizing, while the inner part is reducing.

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2. What is the difference between qualitative and quantitative analysis?

- **Qualitative Analysis**: Identifies the components of a mixture or compound (e.g., identifying cations and anions).
- **Quantitative Analysis**: Measures the exact amount or concentration of components.
  Example: Identifying chloride ions is qualitative, while determining their concentration in ppm is quantitative.

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3. What is the origin of flame color?

The flame color originates from the excitation of electrons in metal ions. When the electrons return to their ground state, they release energy in the form of light of a specific wavelength.
Example: Sodium produces a yellow flame, while potassium gives a violet flame.

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4. Why does hydrogen gas produce a popping sound when exposed to a flame?

Hydrogen gas reacts explosively with oxygen in the air, producing water and releasing energy in the form of a popping sound.
Reaction: $2H_2 + O_2 \rightarrow 2H_2O$ + Energy.
Example: This test confirms the presence of hydrogen gas.

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5. Why does litmus paper turn white at the end after converting red?

Litmus paper turns white when exposed to a strong bleaching agent like chlorine gas, which removes the dye from the litmus paper.
Example: Bleaching powder releases chlorine gas that can turn litmus paper white.

Extera Short Questions (Topic Wise)

18.1: Identification of Cations

1. How are cations identified in qualitative analysis?

Cations are identified by adding specific reagents to a solution and observing the formation of precipitates or color changes. Different cations produce distinct reactions.
Example: Adding sodium hydroxide to a solution containing Fe^{3+} produces a reddish-brown precipitate of $Fe(OH)_3$.

2. What is the role of sodium hydroxide in cation identification?

Sodium hydroxide reacts with metal ions to form insoluble hydroxides, which precipitate out of the solution.
Example: $Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$ (a blue precipitate).

3. How is ammonium (NH_4^+) detected?

Ammonium ions are detected by heating the sample with sodium hydroxide. The release of ammonia gas, which turns moist red litmus paper blue, confirms its presence.
Example: $NH_4^+ + OH^- \rightarrow NH_3$ (gas) + H_2O.

4. Why is flame testing not used for all cations?

Flame testing is limited to cations that emit distinct colors in a flame. Non-metallic ions and some metals like Fe^{3+} are better identified using precipitation or other chemical reactions.
Example: Sodium (Na^+) produces a yellow flame, but iron (Fe^{3+}) does not show a specific color.

18.2: Identification of Anions

1. How are carbonate ions (CO_3^{2-}) identified?

Carbonate ions react with dilute acids to produce carbon dioxide gas, which turns limewater milky.
Example: $CO_3^{2-} + 2H^+ \rightarrow CO_2$ (gas) + H_2O.

2. How is the presence of sulfate ions (SO_4^{2-}) tested?

Adding barium chloride to a solution containing sulfate ions forms a white precipitate of barium sulfate, confirming their presence.
Example: $SO_4^{2-} + Ba^{2+} \rightarrow BaSO_4$ (white precipitate).

3. What test is used to detect chloride ions (Cl^-)?

Adding silver nitrate to a solution containing chloride ions forms a white precipitate of silver chloride, which is soluble in ammonia.
Example: $Cl^- + Ag^+ \rightarrow AgCl$ (white precipitate).

4. How is nitrate (NO_3^-) identified?

Nitrate ions are identified by heating the sample with sodium hydroxide and aluminum powder, which releases ammonia gas.
Example: $NO_3^- + 8Al + 5OH^- + 18H_2O \rightarrow 3NH_3\,(gas) + [Al(OH)_4]^-$.

18.3: Flame Tests

1. What is a flame test?

A flame test is a qualitative analysis technique in which a metal salt is heated in a flame, and the color emitted helps identify the metal ion.
Example: Sodium produces a yellow flame.

2. How does the flame color indicate the presence of specific cations?

Each cation emits light of a specific wavelength when heated, producing a distinct color in the flame.
Example: Potassium produces a violet flame, while calcium gives an orange-red flame.

3. What is the flame color for copper ions (Cu^{2+})?

Copper ions produce a green-blue flame in the flame test.
Example: Copper salts, like copper sulfate, exhibit this color.

4. Why is platinum or nichrome wire used in flame tests?

Platinum or nichrome wires are used because they do not produce any flame color themselves and are resistant to heat, ensuring accurate results.
Example: Dipping the wire in concentrated HCl cleans any residue before the test.

Extera Long Questions (Topic Wise)

1. Identification of Cations in Qualitative Analysis

Definition of Cations

Cations are positively charged ions formed by the loss of electrons. Identifying cations is a critical step in qualitative analysis to determine the components of a compound.

Methods for Identifying Cations

1. **Precipitation Reactions**:
   Specific reagents, like sodium hydroxide or ammonium hydroxide, react with cations to form precipitates of distinct colors.
   - **Example**: Fe^{3+} reacts with sodium hydroxide to form a reddish-brown precipitate of $Fe(OH)_3$.
2. **Ammonium Detection**:
   Ammonium ions (NH_4^+) are detected by adding sodium hydroxide and heating the mixture. The release of ammonia gas confirms the presence of ammonium.
   - **Example**: $NH_4^+ + OH^- \rightarrow NH_3$ (gas) + H_2O.
3. **Flame Tests for Alkali and Alkaline Earth Metals**:
   Some cations emit specific colors when heated in a flame.
   - **Example**: Sodium (Na^+) produces a yellow flame, and potassium (K^+) produces a violet flame.
4. **Complex Ion Formation**:
   Reactions with ligands, such as ammonia or cyanide, produce colorful complexes.
   - **Example**: Cu^{2+} forms a deep blue complex with ammonia: $[Cu(NH_3)_4]^{2+}$.

Applications

- Cation identification is widely used in industries like metallurgy, water treatment, and environmental analysis.
- **Example**: Detecting toxic metals like lead (Pb^{2+}) in drinking water.

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2. Identification of Anions in Qualitative Analysis

Definition of Anions

Anions are negatively charged ions formed by the gain of electrons. Identifying anions is essential in analyzing salts and other ionic compounds.

Methods for Identifying Anions

1. **Carbonate Ions (CO_3^{2-})**:
   Carbonate ions react with dilute acids to produce carbon dioxide gas, which turns limewater milky.
   - **Example**: $CO_3^{2-} + 2H^+ \rightarrow CO_2$ (gas) + H_2O.
2. **Sulfate Ions (SO_4^{2-})**:
   Adding barium chloride or barium nitrate to a solution containing sulfate ions forms a white precipitate of barium sulfate.
   - **Example**: $SO_4^{2-} + Ba^{2+} \rightarrow BaSO_4$ (white precipitate).
3. **Chloride Ions (Cl^-)**:
   Chloride ions react with silver nitrate to form a white precipitate of silver chloride, which is soluble in ammonia.
   - **Example**: $Cl^- + Ag^+ \rightarrow AgCl$ (white precipitate).
4. **Nitrate Ions (NO_3^-)**:
   Nitrate ions release ammonia gas when heated with sodium hydroxide and aluminum powder.
   - **Example**: $NO_3^- + Al + OH^- \rightarrow NH_3$ (gas) + $[Al(OH)_4]^-$.

Applications

- Anion analysis is crucial in environmental studies, agriculture, and food testing.
- **Example**: Testing for nitrate levels in groundwater to prevent pollution.

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3. Flame Tests: Principles and Applications

Definition of Flame Tests

Flame tests are a quick qualitative method to identify metal ions based on the color they emit when heated in a flame. The colors result from the excitation of electrons and their return to the ground state, releasing energy as light.

Flame Colors for Common Cations

1. Sodium (Na^+): Yellow flame.
2. Potassium (K^+): Violet flame.
3. Calcium (Ca^{2+}): Orange-red flame.
4. Copper (Cu^{2+}): Green-blue flame.

Steps in Flame Testing

1. Clean a platinum or nichrome wire by dipping it in concentrated HCl and heating it in a flame until no color is seen.
2. Dip the cleaned wire into the sample solution or powder.
3. Hold the wire in the flame and observe the color produced.

Advantages and Limitations

- **Advantages**:
    1. Quick and easy to perform.
    2. Requires minimal equipment.
- **Limitations**:
    1. Mixtures of cations can obscure individual flame colors.
    2. Not all cations produce distinctive colors.

Applications

- **Forensics**: Identifying unknown substances.
- **Industries**: Testing purity of salts and compounds.
  Example: Identifying potassium in fertilizers using its violet flame color.

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18.1: Identification of Cations

1. **What are cations?**
   a) Positively charged ions ✔
   b) Negatively charged ions
   c) Neutral particles
   d) Atoms without charge

2. **Which reagent is commonly used to test for Fe^{3+} ions?**
   a) Silver nitrate
   b) **Sodium hydroxide** ✔
   c) Hydrochloric acid
   d) Ammonium chloride

3. **What color precipitate is formed when copper (Cu^{2+}) reacts with sodium hydroxide?**
   a) White
   b) Yellow
   c) **Blue** ✔
   d) Red

4. **How is the ammonium ion (NH_4^+) detected?**
   a) By producing a blue precipitate
   b) By heating and detecting ammonia gas ✔
   c) By forming a green complex
   d) By adding H_2SO_4

5. **What is the flame color for sodium (Na^+)?**
   a) Violet
   b) **Yellow** ✔
   c) Green
   d) Red

6. **Which ion gives a green precipitate with sodium hydroxide?**
   a) Fe^{3+}
   b) Fe^{2+} ✔
   c) Cu^{2+}
   d) Zn^{2+}

7. **What is the test for calcium ions (Ca^{2+})?**
   a) Add dilute HCl
   b) **Flame test for orange-red color** ✔
   c) Add silver nitrate
   d) Heat with sodium hydroxide

8. **Which metal ion forms a white precipitate with sodium hydroxide but dissolves in excess?**
   a) Fe^{2+}

b) Cu^{2+}

c) **Zn^{2+}** ✔

d) Pb^{2+}

9. **What is the color of the flame produced by potassium (K^+)?**

a) Yellow

b) Green

c) **Violet** ✔

d) Red

10. **What happens when Al^{3+} reacts with ammonium hydroxide?**

a) No reaction

b) **White precipitate forms, dissolving in excess** ✔

c) Green precipitate forms

d) Reddish-brown precipitate forms

18.2: Identification of Anions

11. **How are carbonate ions (CO_3^{2-}) tested?**

a) Add HCl and look for bubbles of hydrogen gas

b) Add HCl and test for carbon dioxide gas ✔

c) Add NaOH and heat

d) Perform a flame test

12. **What is the result of adding barium chloride to a solution containing sulfate ions (SO_4^{2-})?**

a) No reaction

b) **A white precipitate of $BaSO_4$ forms** ✔

c) A yellow solution forms

d) Green precipitate forms

13. **What test is used to identify chloride ions (Cl^-)?**

a) Add barium chloride

b) Add silver nitrate to form a white precipitate ✔

c) Heat with sodium hydroxide

d) Test with flame

14. **What happens when nitrate ions (NO_3^-) are heated with sodium hydroxide and aluminum powder?**

a) Carbon dioxide gas is released

b) **Ammonia gas is released** ✔

c) A white precipitate forms

d) A green solution is formed

15. **Which anion forms a yellow precipitate with silver nitrate?**

a) Cl^-

b) SO_4^{2-}

c) **I^- (Iodide)** ✔

d) NO_3^-

16. **What is the test for phosphate ions (PO_4^{3-})?**
    a) Add barium chloride
    b) Add ammonium molybdate and heat ✔
    c) Perform flame test
    d) Add hydrochloric acid

17. **Which gas is produced when sulfite ions (SO_3^{2-}) react with acids?**
    a) Carbon dioxide
    b) **Sulfur dioxide** ✔
    c) Ammonia
    d) Hydrogen gas

18. **How are halide ions identified?**
    a) Using flame tests
    b) **Reacting with silver nitrate** ✔
    c) Adding sodium hydroxide
    d) Adding barium chloride

19. **What happens when bromide ions (Br^-) react with silver nitrate?**
    a) No precipitate forms
    b) **A cream precipitate forms** ✔
    c) A yellow solution forms
    d) A white precipitate forms

20. **What color precipitate does lead nitrate form with iodide ions (I^-)?**
    a) White
    b) Yellow ✔
    c) Red
    d) Blue

18.3: Flame Tests

21. **What is a flame test used for?**
    a) Identifying anions
    b) **Identifying metal cations** ✔
    c) Measuring solubility
    d) Testing for precipitates

22. **What is the flame color of lithium (Li^+)?**
    a) Yellow
    b) **Crimson red** ✔
    c) Blue
    d) Violet

23. **Which ion produces a green flame?**
    a) Potassium
    b) Sodium
    c) **Copper (Cu^{2+})** ✔
    d) Magnesium

24. **Why is platinum or nichrome wire used in flame tests?**
    a) It reacts with the metal ion
    b) It does not interfere with the flame color ✔
    c) It gives a green flame itself
    d) It absorbs heat

25. **Which flame color indicates the presence of barium (Ba^{2+})?**
    a) Red
    b) **Green** ✔
    c) Yellow
    d) Violet

26. **What is the limitation of flame tests?**
    a) They are too expensive
    b) They cannot detect any ions
    c) **The colors of some ions may overlap** ✔
    d) They require large amounts of the sample

27. **Which flame test color is observed for strontium (Sr^{2+})?**
    a) Yellow
    b) **Red** ✔
    c) Green
    d) Blue

28. **Why is hydrochloric acid used in flame tests?**
    a) To create gas bubbles
    b) **To clean the wire and enhance the flame color** ✔
    c) To create a white precipitate
    d) To dissolve metal ions

29. **What is the flame color for magnesium (Mg^{2+})?**
    a) Green
    b) Red
    c) **No distinct color** ✔
    d) Yellow

30. **Which element gives a golden-yellow flame?**
    a) Potassium
    b) **Sodium** ✔
    c) Calcium
    d) Barium