Determine Whether Aqueous Solutions Of The Following Salts Are Acidic, Basic Or Neutral. Provide The

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Understanding the nature of aqueous salt solutions—whether they are acidic, basic, or neutral—is fundamental in chemistry. This classification hinges on the properties of the ions produced when salts dissolve in water. When salts dissolve, they dissociate into their constituent ions, which can interact with water molecules to influence the solution's pH. Some salts produce ions that react with water to generate hydrogen ions (H^+), making the solution acidic; others produce hydroxide ions (OH^-), rendering it basic; while some ions do not significantly affect the hydrogen ion concentration, resulting in a neutral solution. This article delves into the principles and methods used to determine the acidity, basicity, or neutrality of aqueous salt solutions, supported by illustrative examples.

Fundamental Concepts in Salt Hydrolysis

What Is Hydrolysis?

Hydrolysis refers to the chemical reaction where ions derived from a salt interact with water, leading to the formation of either H^+ or OH^- ions, which in turn affect the pH of the solution. The nature of these ions and their interactions depend on the origins of the salt—specifically, the acids and bases from which the salt is derived.

Sources of Salts and Their Impact on pH

Salts originate from the reaction of an acid with a base:
- Strong acid + strong base: produces a neutral salt
- Strong acid + weak base: produces an acidic salt
- Weak acid + strong base: produces a basic salt
- Weak acid + weak base: may produce an acidic, basic, or neutral salt, depending on the relative strengths

The dissociation and hydrolysis behavior of the ions determines the pH of the solution.

Determining the Nature of Salt Solutions

Step-by-Step Approach

To classify a salt's aqueous solution, follow these steps:

1. Identify the ions present in the salt (cation and anion).
2. Determine the origin of these ions—are they from strong or weak acids/bases?
3. Assess the hydrolysis potential of each ion in water.
4. Predict the overall effect on pH based on the hydrolysis tendencies.

Key Factors to Consider

- Whether the cation is from a strong or weak base.
- Whether the anion is from a strong or weak acid.
- The relative strengths of the acid and base involved in the salt's formation.

Analysis of Common Salts and Their Aqueous Behavior

Salts from Strong Acid and Strong Base

These salts tend to produce neutral solutions because their ions do not hydrolyze significantly.

- **Example:** Sodium chloride ($NaCl$)
- **Reasoning:** Na^+ comes from $NaOH$ (a strong base), Cl^- from HCl (a strong acid). Neither ion hydrolyzes appreciably.
- **Result:** The solution is neutral with pH ≈ 7.

Salts from Strong Acid and Weak Base

These salts tend to produce acidic solutions because the conjugate acid of the weak base hydrolyzes in water, releasing H^+ ions.

- **Example:** Ammonium chloride (NH_4Cl)
- **Reasoning:** NH_4^+ is the conjugate acid of NH_3 (weak base), which hydrolyzes to produce H^+ ions.
- **Result:** The solution is acidic with pH < 7.

Salts from Weak Acid and Strong Base

These salts produce basic solutions because the conjugate base of the weak acid hydrolyzes in water, generating OH^- ions.

- **Example:** Sodium acetate (CH_3COONa)
- **Reasoning:** CH_3COO^- is the conjugate base of acetic acid, which hydrolyzes to produce OH^-.
- **Result:** The solution is basic with pH > 7.

Salts from Weak Acid and Weak Base

The pH of these solutions depends on the relative strengths of the weak acid and weak base. The dominant hydrolysis determines whether the solution is acidic, basic, or neutral.

- **Example:** Ammonium acetate (NH_4CH_3COO)
- **Analysis:** Both ions can hydrolyze; the dominant effect depends on their respective acid/base strengths.
- **Result:** The solution may be slightly acidic, basic, or neutral.

Practical Examples and pH Predictions

Example 1: Sodium Nitrate ($NaNO_3$)

$NaNO_3$ is derived from NaOH (strong base) and HNO_3 (strong acid).

- Both ions are from strong electrolytes.
- Hydrolysis is negligible.

- **Conclusion:** The solution is neutral with pH ≈ 7.

Example 2: Potassium Hydroxide and Nitric Acid Salt (KNO_3)

KNO_3 forms from KOH (strong base) and HNO_3 (strong acid).

- Same reasoning as above.
- **Conclusion:** Neutral solution with pH ≈ 7.

Example 3: Ammonium Sulfate $(NH_4)_2SO_4$

Derived from ammonia (weak base) and sulfuric acid (strong acid).

- Ammonium ion (NH_4^+) hydrolyzes, releasing H^+.
- Sulfate ion (SO_4^{2-}) from a strong acid does not hydrolyze.
- **Conclusion:** The solution is acidic with pH < 7.

Example 4: Sodium Carbonate (Na_2CO_3)

Formed from NaOH (strong base) and carbonic acid (weak acid).

- Carbonate ion (CO_3^{2-}) hydrolyzes to produce OH^-.
- Na^+ does not hydrolyze.
- **Conclusion:** The solution is basic with pH > 7.

Special Cases and Considerations

Polyvalent Ions

Some ions, such as Al^{3+} or Fe^{3+}, can hydrolyze extensively, producing acidic solutions even if originating from salts of strong acids or bases. These ions can cause solutions to be strongly acidic.

Buffering Effects

In some cases, the solution may contain multiple ions that interact, leading to buffering and stabilization of pH, complicating the straightforward classification.

Experimental Determination

While theoretical predictions are useful, empirical measurement of pH using a pH meter provides definitive classification.

Summary Table