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Acidic, Basic, and Neutral Salts

Weak Acids and Bases

Introduction

A salt may be defined as the product of a neutralization reaction of an acid and a base. The prototype "salt," of course, is sodium chloride, or table salt. Sodium chloride, which is obtained by neutralization of hydrochloric acid and sodium hydroxide, is a neutral salt. Neutralization of any strong acid with a strong base always gives a neutral salt. In general, however, salts may be acidic, basic or neutral. An easy way to predict the acid–base properties of a salt is to consider the strengths of the "parent" acid and base that make up the salt. Let's investigate the pH of salts dissolved in water.

Concepts

- Strong vs. weak acid and bases
- Neutralization reactions
- Conjugate acid–base pairs
- Hydrolysis

Background

A Brönsted acid is considered a proton or hydrogen ion donor. When an acid dissolves in water, it donates hydrogen ions (H^+) to water molecules to form H_3O^+ ions. The general form of this ionization reaction is shown in Equation 1, where HA is the parent acid and A^- is its conjugate base after donating a hydrogen ion to water. The double arrows represent a reversible reaction.

$$HA(aq) + H_2O \rightleftarrows A^-(aq) + H_3O^+(aq) \qquad \textit{Equation 1}$$

Acids are classified as strong or weak acids based on the value of the equilibrium constant for Equation 1. Strong acids ionize completely in aqueous solution. The value of the equilibrium constant for a strong acid is significantly greater than one and Equation 1 is essentially irreversible—only H_3O^+ and A^- will be present in the solution of a strong acid. There are six common strong acids: $HClO_4$, HI, HBr, HCl, H_2SO_4, and HNO_3. *The conjugate base of a strong acid is neutral.*

In contrast to strong acids, weak acids ionize only partially in aqueous solution. The equilibrium constant for a weak acid is much less than one and Equation 1 is reversible—both HA and A^- will be present in the solution of a weak acid. *The conjugate base of a weak acid is basic.* An example of the conjugate base of a weak acid is acetate ion (Equation 2). The acetate ion is basic, and the pH of a solution of sodium acetate is approximately 8.

$$CH_3CO_2H + H_2O \rightleftarrows CH_3CO_2^- + H_3O^+ \qquad \textit{Equation 2}$$

Weak acid – acetic acid *Conjugate base – acetate ion*

A Brönsted base is a hydrogen ion acceptor. When a base dissolves in water, it removes hydrogen ions (H^+) from water molecules to form OH^- ions. The general form of this reaction is shown in Equation 3, where B is a parent base and HB^+ its conjugate acid after accepting a hydrogen ion from water.

$$B(aq) + H_2O(aq) \rightleftarrows BH^+(aq) + OH^-(aq) \qquad \textit{Equation 3}$$

Strong bases ionize completely in aqueous solution to produce OH^- ions, and their ionization reactions are irreversible. Alkali metal and alkaline earth metal hydroxides, such as NaOH, KOH, and $Ca(OH)_2$, are considered strong bases. *The conjugate acid of a strong base is neutral.* All other bases are weak bases—they are only partially ionized in aqueous solution, and both B and BH^+ will be present in the solution of a weak base. *The conjugate acid of a weak base is acidic.* An example of salt containing the conjugate acid of a weak base is ammonium chloride (Equation 4). The ammonium ion is acidic, and the pH of a solution of ammonium chloride is approximately 5.

$$NH_3(aq) + H_2O(aq) \rightleftarrows NH_4^+(aq) + OH^-(aq) \qquad \textit{Equation 4}$$

Weak base – ammonia *Conjugate acid – ammonium ion*

Any salt can be written as the product of the neutralization reaction of an acid and a base. The acid–base properties of a salt can be predicted by writing the formulas and analyzing the strength of the parent acid and base that can be used to make the salt. Neutralization of a strong acid and a strong base gives a neutral salt. Neutralization of a strong acid with a weak base gives an acidic salt, while neutralization of a weak acid with a strong base gives a basic salt.

Materials

Aluminum chloride, $AlCl_3{\cdot}6H_2O$, 1 g	Beaker, 500-mL
Ammonium chloride, NH_4Cl, 1 g	Beral pipet
Sodium bicarbonate, $NaHCO_3$, 1 g	Graduated cylinder, 25-mL
Sodium chloride, NaCl, 1 g	Hot plate (optional)*
Sodium phosphate, $Na_3PO_4{\cdot}12H_2O$, 1 g	Petri dishes, 5
Universal indicator solution, 7 mL	Spatulas
Water, distilled or deionized	Stirrers or wooden splints

**See the* Preparation *section.*

Safety Precautions

Aluminum chloride, ammonium chloride, and sodium phosphate are slightly toxic by ingestion and are body tissue irritants. Do not use anhydrous aluminum chloride in this demonstration-it is extremely water reactive and produces fumes of HCl when exposed to air. Universal indicator solution contains alcohol and is a flammable liquid. Wear chemical splash goggles, chemical-resistant gloves, and chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

Distilled water usually has a pH of about 5 due to the presence of dissolved carbon dioxide, which forms a weak acid, carbonic acid, in water. For best results, use freshly boiled distilled water in this demonstration so that the initial color of the universal indicator solution will be green, corresponding to neutral pH 7. Fill a 500-mL beaker about one-half full with distilled water. Add a boiling stone and heat the water to boiling on a hot plate at a medium-high setting. Boil the water for 10–15 minutes. Remove the beaker from the hot plate, cover the beaker, and allow to cool to room temperature.

Procedure

1. Add 5–7 mL of universal indicator to 250 mL of boiled, distilled water. The resulting solution should be green, pH 7. See the universal indicator color card for color comparisons. Adjust the amount of indicator added to obtain a visible, deep green color.
2. Pour about 20 mL of the prepared indicator solution into each of five Petri dishes.
3. Using a fresh spatula or wooden splint for each salt, add about 1 g (two scoops) of the appropriate salt to each Petri dish, in the following order:
   - Sodium chloride
   - Ammonium chloride
   - Sodium bicarbonate
   - Aluminum chloride
   - Sodium phosphate
4. Stir to dissolve each salt, and observe the color and appearance of the resulting solutions.
5. Compare the color of each solution with the colors on the universal indicator color chart, and record the pH of each salt solution. Identify the salts as acidic, basic or neutral.
6. For each salt, ask students to write out the parent acid and base that could be used to prepare the salt (by neutralization), and identify each as a strong or weak acid or base. Predict whether each salt should be acidic, basic or neutral based on the principles discussed in the *Background* section, and compare the predictions with the actual results.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The salt solutions may be rinsed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Tip

- A wide variety of salts, including sodium acetate, sodium sulfate, iron(III) chloride, sodium fluoride, and sodium carbonate, and calcium chloride, may be tested in this demonstration.

Discussion

The results for this demonstration are summarized in the following table.

Salt	Indicator Color/pH	Parent Acid	Parent Base	Acidic, Basic or Neutral
NaCl	Green/pH 7	HCl	NaOH	Strong acid and strong base = neutral salt
$AlCl_3$	Red/pH 4	HCl	$Al(OH)_3$	Strong acid and weak base = acidic salt
$NaHCO_3$	Blue/pH 9	H_2CO_3	NaOH	Weak acid and strong base = basic salt
NH_4Cl	Orange/pH 5	HCl	NH_3	Strong acid and weak base = acidic salt
Na_3PO_4	Purple/pH 10	H_3PO_4	NaOH	Weak acid and strong base = basic salt

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter.
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, chemical reactions.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Acidic, Basic, and Neutral Salts* activity, presented by Annis Hapkiewicz, is available in *Weak Acids and Bases,* part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Acidic, Basic, and Neutral Salts* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *Hydrolysis of Salts—Acidic, Basic or Neutral?—Chemical Demonstration Kit* available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
P6187	Hydrolysis of Salts —Acidic, Basic, or Neutral? A Colorful Overhead Demonstration
AP5367	Universal Indicator Overhead Color Chart
A0225	Aluminum Chloride, Reagent, 100 g
A0266	Ammonium Chloride, Reagent, 100 g
S0042	Sodium Bicarbonate, Reagent, 300 g
S0061	Sodium Chloride, Reagent, 500 g
S0101	Sodium Phosphate, Tribasic, 500 g
U0001	Universal Indicator Solution, 100 mL
GP3019	Petri Dishes, Borosilicate Glass, 100 × 15 mm

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

