Blowing Out a Light Bulb

Properties of Solutions

Introduction

The ionic theory of solutions was a critical discovery in the history of physical chemistry. Following the conductivity of the solution can both review students as to what is happening in solutions on a molecular level, as well as provide visual cues to different chemical reactions.

Concepts • Ionic theory of solutions • Electrical conductivity • Acid–base theory Materials Beaker, 100-mL Beaker, 50-mL Electrical conductivity apparatus (Flinn AP5355 or similar) Household vinegar

Safety Precautions

Limewater solutions are strongly basic. Avoid contact of all chemicals with eyes and skin. Follow all laboratory safety guidelines. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information. Remember to wash hands thoroughly with soap and water before leaving the laboratory. Also take precautions with the electrical conductivity apparatus. Do not touch the leads of the apparatus while it is plugged into an outlet.

Procedure

- 1. Place approximately 50 mL of saturated calcium hydroxide solution (limewater) into a 100-mL beaker and approximately 37.5 mL of vinegar into a 50-mL beaker. Record your observations of the solutions. The solutions should be clear and colorless.
- 2. Rinse the electrodes with distilled water and then immerse the electrodes of the conductivity solution into the beaker of vinegar. Plug the apparatus into the outlet and observe. Record your observations of its conductivity. The light bulb should glow dimly.
- 3. Unplug the apparatus and remove it from the vinegar solution. Rinse the electrodes with distilled water and then immerse the electrodes of the apparatus in the limewater solution. Plug the apparatus into the outlet and observe. Record your observations of its conductivity. The light bulb should glow more brightly than before.
- 4. Place a straw in the limewater solution, and exhale into the limewater solution (adding carbon dioxide which forms carbonic acid) for approximately 2 minutes. Record your final observations of the appearance of the resulting solution and its conductivity. Within 1–2 minutes the light bulb should dim significantly as the solution clouds.
- 5. After the light bulb has gone "out," add the vinegar to the limewater solution. Record your final observations of the appearance of the resulting solution (vinegar and limewater + carbonic acid) and its conductivity. The solution should clear and the light bulb should glow brightly.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. All remaining solutions may be disposed of according to Flinn Suggested Disposal Method #26b. Excess limewater solution can be stored for future use.



Discussion

The electrical conductivity of an aqueous solution is dependent on the number of dissolved ions present. The addition of a soluble ionic compound to water will cause a light bulb conductivity device to glow brightly, as the aqueous ions act as a "liquid wire" to freely carry charge from one electrode to the other. Solutes that do not dissociate completely, such as acetic acid, will cause such an apparatus to glow dimly as only a small fraction of possible ions are present due to the nature of the weak acid. Although calcium hydroxide is considered by many to be an "insoluble" salt, its solubility product constant, K_{sp} , is 5.5×10^{-5} , meaning that in a saturated solution such is found in limewater still has a significant concentration of ions (approximately 0.07 M), which is 10 times the concentration of ions in a vinegar solution. This results in the light bulb glowing slightly brighter in the limewater solution than the vinegar.

When one blows into the limewater solution, carbon dioxide is forced into the solution, forming carbonic acid. The acid neutralizes the hydroxide in limewater forming insoluble calcium carbonate:

$$\begin{split} & \text{CO}_2(\text{g}) \ + \ \text{H}_2\text{O}(\text{l}) \ \rightarrow \ \text{H}_2\text{CO}_3(\text{aq}) \\ & \text{H}_2\text{CO}_3(\text{aq}) \ + \ \text{Ca}(\text{OH}), (\text{aq}) \ \rightarrow \ \text{Ca}\text{CO}_3(\text{s}) \ + \ 2\text{H}_2\text{O}(\text{l}) \end{split}$$

As the ions in the solution are "tied-up" in the calcium carbonate, the loss of ions increase the resistance of the solution, resulting in the light bulb being extinguished. One can show that weak acids are as effective as strong acids in dissolving carbonates by combining the vinegar with the solid calcium carbonate. The reaction of the acid with the calcium carbonate will produce an aqueous solution of calcium acetate. The production of the strong electrolyte results in the light bulb glowing brightly again.

Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K-12 Evidence, models, and explanation Content Standards: Grades 5-8

Content Standard A: Science as Inquiry Content Standard B: Physical Science, properties and changes of properties in matter, motions and forces, transfer of energy

Content Standards: Grades 9–12

Content Standard A: Science as Inquiry

Content Standard B: Physical Science, structure of atoms, structure and properties of matter, chemical reactions, motions and forces, conservation of energy and increase in disorder, interactions of energy and matter

Sample Data Table

	Observations
Calcium hydroxide (limewater solution)	Clear colorless solution
Vinegar (acetic acid)	Clear colorless solution
Conductivity of vinegar (acetic acid)	Poor—light bulb glows dimly
Conductivity of calcium hydroxide	Better—light bulb flows brighter than in vinegar
Calcium hydroxide + carbonic acid (after 2 minutes)	Cloudy solution
Conductivity of calcium hydroxide + carbonic acid (after 2 min- utes)	Low—light bulb will dim significantly
Vinegar + reaction mixture (limewater + carbonic acid)	Clear colorless solution
Conductivity of vinegar + reaction mixture	Good—light bulb glows brightly

Answers to Questions

1. Write the balanced equation for calcium hydroxide in equilibrium with its ions. *Note:* The presence of ions accounts for the conductivity of calcium hydroxide.

 $Ca(OH)_2(aq) \rightleftharpoons Ca^{2+}(aq) + 2OH^{-}(aq)$

2. Write the balanced equation for the reaction of carbon dioxide and water to form carbonic acid. H₂CO₃.

 $CO_2(g) \ + \ H_2O(l) \ \rightarrow \ H_2CO_3(aq)$

3. Write the balanced equation for the double-replacement reaction of calcium hydroxide and carbonic acid.

 $H_2CO_3(aq) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + 2H_2O(l)$

4. Refer to your Table of Solubilities. Write (s) after the product in the above equation that is the precipitate.

 $CaCO_3(s)$

5. For conductivity to occur, in an aqueous solution, there must be moving, charged particles—ions. When the reaction between calcium hydroxide and carbonic acid is complete, there is (**high/ no**) conductivity. Explain why this occurs in terms of ions.

The calcium ions and carbonate ions react to form a solid that does not contain accessible ions.

6. Write the balanced equation for the double-replacement reaction between vinegar and calcium carbonate. *Hint:* Vinegar is acetic acid, HCH₃COO. Refer to your Table of Solubilities. Write (s) after the product in the above equation which has low solubility.

 $2HCH_3COO(aq) + CaCO_3(s) \rightarrow Ca(CH_3COO)_2(aq) + H_2CO_3(aq)$

7. Write the following completed statement: When the vinegar reacts with the calcium carbonate, the resulting solution has (high /no) conductivity. Explain (using complete sentences) why this occurs in terms of ions.

The CaCO₃(s) and vinegar react to form calcium ions, acetate, ions, carbonate ions, and hydrogen ions.

Reference

Summerlin, L; Borgford, C.; Ealy, J. Chemical Demonstrations: A Sourcebook for Teachers Vol. 2; Amer. Chemical Soc: Washington D.C., 1988.

Flinn Scientific—Teaching Chemistry[™] eLearning Video Series

A video of the *Blowing Out a Light Bulb* activity, presented by Kathleen Dombrink, is available in *Properties of Solutions*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for Blowing Out a Light Bulb are available from Flinn Scientific, Inc.

Catalog No.	Description
AP5355	Conductivity Tester
GP9035	Soft Glass Stirring Rod
AP1819	Straws, Plastic
AP6025	Straws, Plastic Drinking
L0021	Limewater Solution, 500-mL

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

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Data Table

	Observations
Calcium hydroxide (limewater solution)	
Vinegar (acetic acid)	
Conductivity of vinegar (acetic acid)	
Conductivity of calcium hydroxide	
Calcium hydroxide + carbonic acid (after 2 minutes)	
Conductivity of calcium hydroxide + carbonic acid (after 2 min- utes)	
Vinegar + reaction mixture (limewater + carbonic acid)	
Conductivity of vinegar + reaction mixture	

Questions

- 1. Write the balanced equation for calcium hydroxide in equilibrium with its ions. (Note: The presence of ions accounts for the conductivity of calcium hydroxide.)
- 2. Write the balanced equation for the reaction of carbon dioxide and water to form carbonic acid. H₂CO₃.
- 3. Write the balanced equation for the double-replacement reaction of calcium hydroxide and carbonic acid.
- 4. Refer to your Table of Solubilities. Write (s) after the product in the above equation that is the precipitate.
- 5. For conductivity to occur, in an aqueous solution, there must be moving, charged particles—ions. When the reaction between calcium hydroxide and carbonic acid is complete, there is (**high/no**) conductivity. Explain why this occurs in terms of ions.
- 6. Write the balanced equation for the double-replacement reaction between vinegar and calcium carbonate. *Hint:* Vinegar is acetic acid, HCH₃COO. Refer to your Table of Solubilities. Write (s) after the product in the above equation which has low solubility.
- 7. Write the following completed statement: When the vinegar reacts with the calcium carbonate, the resulting solution has (high/no) conductivity. Explain (using complete sentences) why this occurs in terms of ions.