



# Teacher-to-Teacher

Video Series

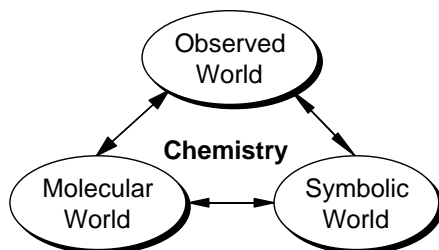
for Secondary Educators

## TITLE: Bridging the Gaps Between the Three Worlds of Chemistry

**PRIMARY SUBJECT AREAS:** Science

**GRADE LEVEL:** 10-12

**OVERVIEW:** Teaching chemistry has many challenges. Students sometimes struggle because of the use of abstract concepts, for example, tiny invisible particles, in constant motion and randomly colliding, to explain what we observe in beakers and flasks. The mental transition from this **observed world** (macroscopic) to the **molecular world** (microscopic) may be trivial, or even subconscious, for the experienced teacher, but can be troublesome for the novice. Furthermore, the use of symbols, formulas, and equations to represent and describe the behavior of these tiny particles creates a third world of chemistry, **the symbolic world**. As teachers of chemical principles, we make these transitions several times in one lesson, often without notice. It is a small wonder that students sometimes have difficulty with chemistry, particularly in the early stages of content development.



Acknowledging the transitions between the three worlds can be a useful approach to teaching introductory chemistry. It helps students form concrete mental images as they think about and construct their knowledge base for the behavior of matter.

In this lesson the use of lecture demonstrations as a tool for bridging the gaps between the three worlds of chemistry will be shown. We will see how using demonstrations provides opportunities for direct student observations and gives all students of the class a common, concrete experience with the subject matter. Finally, the use of a lecture demonstration as an assessment tool to evaluate students' conceptual understanding of chemical principles will be shown.

As a platform for this lesson, the general topic of solution chemistry, or more specifically, reactions that occur in aqueous solutions, has been chosen. Some of the chemical principles involved will be acids and bases, neutralization, indicators, electrolytes, conductivity, precipitation, and solubility.

The lesson will begin with a review of the electrical properties of aqueous solutions. Using a light-bulb conductivity tester, the relative conductivity of various solutions will be demonstrated. Observations will be explained on the molecular level and illustrated in the symbolic world with typical chemical formulas and equations. The concepts of strong electrolytes, weak electrolytes, and non-electrolytes will be developed on a need-to-know basis as the demonstrations are carried out.

Finally, the use of lecture demonstrations to assess conceptual understanding of solution chemistry will be discussed. Demonstration assessment is an excellent technique that not only provides a method of assessing student achievement, but aides in further development of conceptual understanding. Student responses involve written observations and explanations of events witnessed during a short lecture demonstration.

**APPROXIMATE DURATION:** approximately five 50-minute class periods

### **LOUISIANA CONTENT STANDARDS:**

#### **Physical Science**

##### **Benchmarks:**

- PS-H-D1 observing and describing changes in matter and citing evidence of chemical change.
- PS-H-D2 comparing, contrasting, and measuring the pH of acids and bases using a variety of indicators.
- PS-H-D3 writing balanced equations to represent a variety of chemical reactions.
- PS-H-D7 identifying important chemical reactions that occur in living systems, the home, industry, and the environment.

##### **Chemistry GLEs:**

- 31. Describe chemical changes and reactions using diagrams and descriptions of the reactants, products, and energy changes (PS-H-D1)
- 32. Determine the concentration of an unknown acid or base by using data from a titration with a standard solution and an indicator (PS-H-D2)
- 34. Describe chemical changes by developing word equations, balanced formula equations, and net ionic equations (PS-H-D3)
- 35. Predict products (with phase notations) of simple reactions, including acid/base, oxidation/reduction, and formation of precipitates (PS-H-D3)
- 36. Identify the substances gaining and losing electrons in simple oxidation-reduction reactions (PS-H-D3)
- 45. Give examples of common chemical reactions, including those found in biological systems (PS-H-D7)

**EDUCATIONAL TECHNOLOGY GUIDELINES:** N/A

**INTERDISCIPLINARY CONNECTIONS:** N/A

The demonstration assessment requires a brief written response by students.

## **OBJECTIVES:**

1. The student will differentiate between the observed world, the molecular world, and the symbolic world of chemistry.
2. The student will differentiate between weak, strong, and non-electrolytes and the electrical properties of aqueous solutions.
3. The student will describe the properties of acids and bases.
4. The student will predict the outcome of solution reactions.
5. The student will apply solubility rules to predict if precipitation will occur during a solution reaction.

## **LESSON MATERIALS AND RESOURCES:**

Light-bulb conductivity tester (Flinn Scientific), magnetic stirrer, various beakers, Spatula, table salt, sugar, water, 0.1 M HCl, 0.1M NaOH, vinegar, ammonia solution, 2 M H<sub>2</sub>SO<sub>4</sub>, saturated solution of barium hydroxide, and phenolphthalein

Attachments:

1. Procedure for Demonstration of Electrical Properties of Solutions
2. General Rubric for Demonstration Assessments
3. Procedure for Conductivity Titration Demonstration Assessment
4. Rubric for Conductivity Demonstration Assessment

## **TECHNOLOGY TOOLS AND MATERIALS:**

Hardware: Light-bulb conductivity tester, Magnetic stirrer

## **BACKGROUND INFORMATION:**

The high school students should be able to write and interpret simple chemical formulas, write and balance simple chemical reactions, and know standard solubility rules.

## **LESSON PROCEDURES:**

1. Introduction to Three Worlds of Chemistry
  - a. Explain the three worlds (See Overview)
2. Conductivity of Solutions Demonstrations (Attachment 1 for procedure)
  - a. Test salt, sugar, water, and solutions of each
  - b. Define electrolytes and nonelectrolytes
  - c. Give symbolic and molecular world descriptions
3. Weak and Strong Acids (See Attachment 1 for procedure)
  - a. Test HCl and Vinegar Solutions
  - b. Explain weak and strong acids
  - c. Give symbolic and molecular world descriptions
  - d. Define Arrhenius acids
4. Weak and Strong Bases (Attachment 1)
  - a. Test NaOH
  - b. Define Arrhenius bases
  - c. Test NH<sub>3</sub>
  - d. Give molecular and symbolic world descriptions

## 5. Demonstration Assessment

- a. Present to the students the general rubric (See Attachment 2)
- b. Perform the conductivity titration demonstration (See Attachment 3)
- c. After the students write their responses, present the specific rubric (See Attachment 4)

### **ASSESSMENT PROCEDURES:**

A Demonstration Assessment is conducted at the end of the lesson:

A short demonstration is shown to the students.

The students record their observations.

The students write a short narrative explaining their observations.

A scoring rubric is shown to the students.

The students may score their own responses or the instructor may collect the papers and assign a grade.

Conductivity Titration Demonstration Procedure (Attachment 3)

Rubric for Conductivity Titration Demonstration Assessment (Attachment 4)

### **ACCOMMODATIONS/MODIFICATIONS:**

Students with impaired vision would obviously be at a disadvantage on the demonstration assessment. One possible modification is for the instructor to describe verbally the events of the demonstration assessment as they occur. An aide or peer could sit beside the student and verbally describe what they see to the visually impaired student. It is also possible to videotape the demonstration assessment so that a student with vision or hearing impairments can view and listen to it closely.

### **REPRODUCIBLE MATERIALS:**

Script for Bridging the Gaps Between the Three Worlds of Chemistry

Attachments 1 - 4

Slides for Video Presentation in MS PowerPoint

### **EXPLORATION AND EXTENSION:**

There are infinite possibilities. This should be left to the teachers' discretion.

### **LESSON DEVELOPMENT RESOURCES:**

Deese, W.C., Ramsey, L.L., Walczyk, J., Eddy, D., "Using Demonstration Assessments to Improve Learning", *Journal of Chemical Education*, Vol. 77, 1511-1516, (Nov., 2000).

Johnstone, *JChemEd*, 1993, p.301.

Radford, D., Ramsey, L.L., and Deese, W.C., "Using Science Demonstrations to Assess Conceptual Understanding and Critical Thinking", *The Science Teacher*, Vol. 62, No. 7, 52-55, (Oct., 1995).

Summerlin, Borgford, and Ealy, *Chemical Demonstrations: A Sourcebook for Teachers Vol. 2*, American Chemical Society, Washington, DC, 1987.

**REFLECTIONS:**

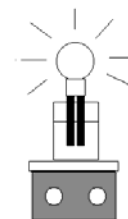
My students often struggle when attempting to articulate verbally or in writing their observations and their explanations. The demonstration assessment shown in this lesson is a fairly complex one involving many chemical concepts. It would be wise to provide students with experience writing observations and explanations with demonstration assessments that are related to fewer concepts before presenting this one.

I have found that acknowledging the three worlds of chemistry and pointing out to the students when you make a transition from one world to another during class is an excellent approach in introductory chemistry classes. It helps students organize their thoughts and relax some when first dealing with chemical formulas and equations. Also molecular diagrams are very helpful when describing the molecular world events.

**CONTACT INFORMATION:**

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**Attachment 1**  
**Conductivity of Solutions**  
by: William C. Deese



**Description:** The electrical properties of aqueous solutions are demonstrated using a light bulb conductivity tester.

**Materials:** 0.1M NaOH, 0.1M HCl, vinegar, ammonia solution, table salt, sugar. Several small beakers, spatula, stirring rod, light bulb conductivity tester.

**Procedure:**

1. Cover the bottom of one beaker with table salt (NaCl), cover the bottom of a second beaker with sugar ( $C_{11}H_{22}O_{11}$ ).
2. Test the conductivity of each by dipping the electrodes of the tester into the solids. (The bulb should not light.)
3. Fill a third beaker about 3/4 full with distilled water and test the conductivity. (The bulb should not light.)
4. Make a solution of table sugar by adding a scoop of sugar from the first beaker into the water. Test this solution. (The bulb should not light.)
5. Make a similar solution of table salt and test it. (The bulb should light brightly!)
6. Test the solutions of NaOH and HCl. (Both should light the bulb brightly.)
7. Test the solutions of vinegar ( $HC_2H_3O_2(aq)$ ) and ammonia ( $NH_3(aq)$ ). (Both should light the bulb, but it will be dim.)

*Be sure to rinse the electrodes with distilled water after each test.*

**Hazards:** Both hydrochloric acid and sodium hydroxide solutions are corrosive and can cause chemical burns to the skin and eyes. Wear eye protection at all times. Ammonia is toxic by ingestion and inhalation. Be sure the electrodes of the conductivity tester are covered for the prevention of electric shock.

**Clean up:**

1. The table salt, sugar, vinegar, and ammonia solutions can be flushed down the drain.
2. The HCl and NaOH solutions should be mixed and the mixture flushed down the drain.
3. Rinse the electrodes of the conductivity tester.

**Discussion:** Solutions that contain many ions conduct electricity well. In all cases when the bulb lights brightly, there are many ions in solution. All soluble salts separate into ions when they dissolve. All strong acids and bases separate into ions in solution. Soluble salts, strong acids and strong bases are said to be strong electrolytes. In the case of the dimly lit bulb, there are some ions in solution, but most of the solute molecules remain neutral. This indicates only partial disassociation into ions. Acetic acid and ammonia are said to be weak electrolytes. Sugar is a nonelectrolyte that doesn't ionize at all in solution.

## Attachment 2

### General Rubric for Demonstration Assessments

Deese, W. C., Louisiana Tech University

<b>Score</b>	<b>Accomplishments</b>
<b>0</b>	Makes no observations or inaccurate observations.
<b>1-4</b>	Makes accurate observations; but no accurate inferences.
<b>5-7</b>	Makes accurate observation, uses some appropriate vocabulary to draw some accurate inferences.
<b>8-10</b>	Makes accurate observations, accurate inferences, cites evidence, uses appropriate vocabulary.

**Attachment 3**  
**Conductivity Titration Demonstration**  
by: William C. Deese

**Description:** Electrodes from a conductivity tester are placed in a pink solution. The bulb becomes bright.  $\text{H}_2\text{SO}_{4(\text{aq})}$  is added in small amounts. The bulb of the conductivity tester grows dimmer until it goes out, the solution becomes cloudy, and the pink color fades. As more acid is added, the bulb becomes brightly lit again.

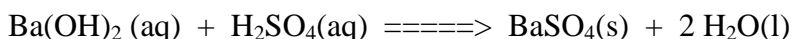


**Materials:** Conductivity tester, 2 M  $\text{H}_2\text{SO}_4$  in a dropping bottle, 400ml beaker, magnetic stirrer or stirring rod, saturated solution of  $\text{Ba}(\text{OH})_2$ , phenolphthalein.

**Procedure:**

- 1) Set up the conductivity tester and stir motor.
- 2) Pour about 200 ml of the barium hydroxide solution into the 400 ml beaker. Add a few drops of phenolphthalein indicator. The solution should be pink, and the light bulb should be bright. You are ready to begin the demonstration.
- 3) Add several drops of sulfuric acid solution to the beaker. The solution will become cloudy, and the bulb will gradually dim.
- 4) Continue adding acid and stirring until the bulb goes out. Addition of a few more drops of acid will cause the pink color of the indicator to change to colorless leaving a white suspension.
- 5) Continue to slowly add acid, and the bulb will gradually become bright.

**Discussion:** The bulb is glowing at first primarily due to the presence of barium and hydroxide ions. The reaction occurring in the beaker is the neutralization of barium hydroxide by sulfuric acid to produce water and the slightly soluble barium sulfate. The precipitation of barium sulfate and the formation of the weak electrolyte,  $\text{H}_2\text{O}$ , remove ions from solution causing the conductivity to decrease. Upon complete neutralization of the base, the phenolphthalein becomes colorless leaving a white suspension of barium sulfate. Further addition of the strong electrolyte, sulfuric acid, increases the conductivity until the bulb once again shines brightly.



**Hazards:** Sulfuric acid and barium hydroxide solutions are corrosive and should be handled with care. Eye protection should be worn at all times. Soluble barium compounds are toxic if ingested. Contact with the skin may produce minor irritations or allergic reactions. Be sure the electrodes of the conductivity apparatus are well protected in order to avoid electrical shock.

**Disposal:** The contents of the beaker should be neutralized with base and flushed down the drain. Unplug the conductivity apparatus and rinse the electrodes.

**Reference:** Summerlin, Borgford, and Ealy, Chemical Demonstrations: A Sourcebook for Teachers Vol. 2, American Chemical Society, Washington, DC, 1987.

**Attachment 4**  
**Rubric for Conductivity Titration Demonstration Assessment**  
 Deese, W. C., Louisiana Tech University

<b>Score</b>	<b>Accomplishments</b>
<b>0</b>	Makes no observations or inaccurate observations.
<b>1-4</b>	<p><b>Observations:</b></p> <p>A small amount of a colorless solution of dilute H<sub>2</sub>SO<sub>4</sub> was added to the pink Ba(OH)<sub>2</sub> solution. The light bulb became dimmer and the solution became cloudy. As more solution was added, more precipitate formed, and the light bulb grew dimmer until it went out. A few drops more acid were added, and the pink color disappeared leaving a white suspension. As still more acid solution was added, the bulb began to glow again until it was bright.</p>
<b>5-7</b>	<p><b>Explanation:</b></p> <p>The above plus:</p> <p>The acid neutralized the base and formed a precipitate. This reduced the number of ions in solution, which caused the bulb to dim. When all of the base was neutralized, the phenolphthalein changed from pink to colorless leaving a white mixture.</p>
<b>8-10</b>	<p>The above plus:</p> <p>The products of the reaction were the precipitate, barium sulfate and the weak electrolyte, water.</p> $\text{Ba(OH)}_2(\text{aq}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2 \text{H}_2\text{O}(\text{l})$ <p>After the equivalence point, addition of the strong acid, H<sub>2</sub>SO<sub>4</sub>, increased the conductivity until the bulb became bright again.</p>