Conductivity: A Demonstration Lesson

Task

Introduction of the Problem/Context: In this activity, high school chemistry students begin to formulate a working definition for covalent (non-ionic) and ionic compounds by investigating patterns of conductivity with various liquids and aqueous solutions.

Selected GPS:

Co-Requisite: Characteristics of Science

Habits of Mind

- **SCSh1**: Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.
  a. Exhibit the above traits in their own activities.
  b. Recognize that different explanations often can be given for the same evidence.

- **SCSh3**: Students will identify and investigate problems scientifically.
  a. Suggest reasonable hypotheses for identified problems.
  e. Develop reasonable conclusions based on data collected.

- **SCSh4**: Students will use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.
  a. Develop and use systematic procedures for recording and organizing information.

Nature of Science

- **SCSh7**: Students will analyze how scientific knowledge is developed.
  e. Testing, revising, and occasionally rejecting new and old theories never ends.

Co-Requisite: Characteristics of Science

Content

SC3. Students will use the modern atomic theory to explain the characteristics of atoms.
e. Compare and contrast types of chemical bonds (i.e. ionic, covalent).

Classroom Materials: Lesson Outline

Conductivity

Grade Level/Subject: High School Chemistry

Overview: In this activity, students begin to formulate a working definition for covalent and ionic compounds by investigating patterns of conductivity with various liquids and aqueous solutions.

Key Objectives:

- To investigate a problem scientifically (GPS: SCSh3 a, e).
- To suggest reasonable explanations based of data collected (GPS: ScSh1 a, b).
- To keep detailed and accurate records of data collected (GPS: SCSh4 a).
- To understand analyze how scientific knowledge is developed and changes over time (GPS: SCSh7 e).
- To begin to formulate a working definition of ionic compounds (GPS: SC3 e).

Learning Outcomes:

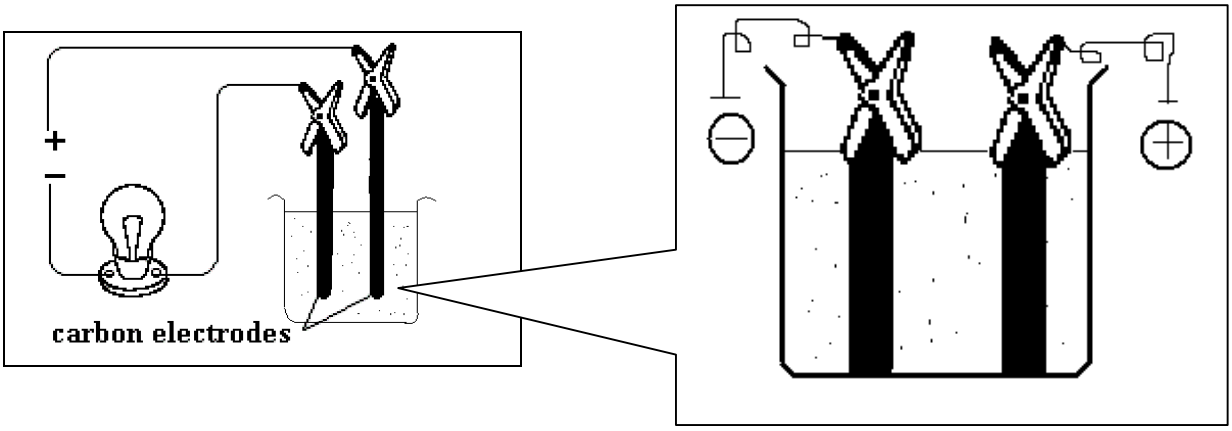
- Students will derive:
  → Working definitions of ionic versus covalent (and molecular) compounds.
- Students will be able to:
  → Predict a substance's electrical conductivity based on its chemical formula.
  →Explain the electrical conductivity of aqueous solutions of ionic compounds.
  →Distinguish between ionic and covalent compounds and explain the characteristics.
  →Explain why some covalent (molecular) substances conduct electricity when dissolved in water to form aqueous solution.
  →Relate the presence/absence of ions in solution with electrical conductivity.

Possible Materials:

- Beakers
- Distilled water
- Stirring Rods
- Ammonium chloride
- Ethyl alcohol (ethanol)
- Hydrochloric acid
- Sodium hydroxide
- Acetic acid /Vinegar (Hydrogen acetate)
- Ammonium hydroxide
- Protective eyewear (Goggles)
- Aprons
- Gloves
- Simple circuit (with bulb in circuit).
- Salt
- Sugar solution

Task:

- A simple circuit with a battery is used to compare the electrical conductivity of different solutions. Students observe and record the conductivity of various liquids and aqueous solutions. Based on the data collected, they begin to formulate a working definition for covalent, molecular and ionic compounds.



Procedure

- To test the conductivity of the liquids, the ends of the carbon electrodes are immersed in distilled water, sodium chloride (salt) solution, sugar solution, ethyl alcohol (ethanol), acetic acid (vinegar) and 2M solutions of hydrochloric acid, sodium hydroxide, ammonium hydroxide, ammonium chloride and ethanoic acid (acetic acid/vinegar) respectively.

(NB: The electrodes must be washed thoroughly after testing each solution)

- Solutions of acids, alkalis and metallic salts are generally good conductors. Solutions of sugar ($C_{12}H_{22}O_{11}$) and alcohol (CH_3CH_2OH) are non-conductors. Solutions of covalent (non-polar) molecular substances in water are generally non-conductors. However, some molecular gases such as Hydrogen chloride (HCl) and Ammonia (NH_3) dissolve in water to form solutions that conduct electricity due to the presence of ions. Ethanoic acid ionizes only partially (1%) and is mostly molecular. Therefore it conducts electricity to a small extent

- When testing distilled water for conductivity the bulb does not light. However, when small crystals of sodium chloride (salt) are gradually into the water and stirred gently, there is light from the light bulb as the salt dissolves. Students should also try testing the conductivity of tap water, sea water and water from a borehole if available.

Sample Questions:

- What does conductivity tell us about the nature of the chemical substances?
- What does it mean if a substance is ionic?
- Does distilled water conduct electricity? How about tap water? Why or why not?
- What happens when salt is added to water? Why?
- When combined with water, do all ionic and non-ionic substances conduct electricity?

Analysis

1. Based on the formula and observations, determine whether each of the substances used in this activity/experiment is covalent, molecular or ionic.

2. Look carefully at your results. Are there any patterns? How can they be summarized to give a wider definition of ionic and non-ionic compounds?

3. Make general statement on the solubility and conductivity for both covalently and ionically bonded compounds.

4. Explain the reasons for testing electrical conductivity of solutions with a metal in their bond structure and solutions with ALL nonmetals in their bond structure.

Assessment Ideas:

- Teacher observation: are the objectives being met?
- Write a detailed summary that discusses what was done in this activity and the conclusions you can draw from the data.
- Student journals or science notebooks: is there evidence of student learning?
- Teacher-constructed test, based on observations made and discussed.

Extension Ideas:

- Allow students to predict and test the conductivity of various other substances.
  Examples: Soda, Bleaching solution (e. g. Clorox), Orange/lemon juice, peanut oil, methylated spirit, liquid paraffin, milk.

- Have students modify the experimental set-up to rule out flawed observations.
  Suggestions: Use of voltmeter/ammeter in the circuit instead of an electric bulb.
  Allow longer experimental time for ions to flow to opposite electrodes.

Sample Question for Further Discussion

- The equations 1 - 6 below represent the ionization of different substances in water:

1. $NaOH_{(aq)} ===> Na^+_{(aq)} + OH^-_{(aq)}$

2. $NH_4OH_{(aq)} <=====> NH_4^+_{(aq)} + OH^-_{(aq)}$

→Which substances in equation 1 and 2 above is a better conductor of electricity? Why?

3. $NH_4Cl_{(aq)} ===> NH_4^+_{(aq)} + Cl^-_{(aq)}$

4. $NaCl_{(aq)} ===> Na^+_{(aq)} + Cl^-_{(aq)}$

→Explain why both substances in equation 3 and 4 above would be classified as ionic even though one has no metal in the bond structure.

5. $CH_3COOH_{(aq)} <=====> CH_3COO^-_{(aq)} + H^+_{(aq)}$

(Ionization of Ethanoic acid)

$$CH_3COOH + H_2O \underset{\text{approx 99\%}}{<=====>} H^+(aq) + CH_3COO^-(aq) \quad \text{approx 1\%}$$

6. $HCl_{(aq)} ===> H^+_{(aq)} + Cl^-_{(aq)}$

(Ionization Hydrochloric acid)

$$HCl + H_2O \underset{0\%}{=====>} H^+(aq) + Cl^-(aq) \quad 100\%$$

→How does the percent (%) ionization in water affect the conductivity each of the two substances? On the basis of this would both be classified as ionic, covalent or molecular? Why?

- Consider the following case scenarios:

Students in a Chemistry class dissolved common salt (NaCl) and sugar ($C_{12}H_{22}O_{11}$) in separate beakers containing distilled water and tested their electrical conductivity. They found that the salt solution conducted electricity where as the sugar solution did not.

They also tested the conductivity of tap water and rain water and found that tap water conducted electricity while distilled water did not.

→Explain the difference in electrical conductivity for each pair of liquid/solution.