EXPERIMENT 18

# The Conductivity of Solutions: A Demonstration

**Performance Goals**

**18–1** Describe how the conductivity of a solution may be tested.

**18–2** Basing your decision on conductivity observations, classify substances as strong electrolytes, weak electrolytes, or nonelectrolytes.

**18–3** Explain the presence or absence of conductivity in an aqueous solution.

## CHEMICAL OVERVIEW

Solutions of certain substances are conductors of electricity. The conductance is due to the presence of charged species (ions) that are free to move through the solution. If two metal strips, called *electrodes,* are connected to a current source (such as a battery or regular wall plug) and then immersed into a conducting solution, current will flow through the system. Ions will be attracted to the oppositely charged electrodes; i.e., positively charged ions, called *cations,* will flow to the negatively charged electrode (the *cathode),* and negatively charged *anions* will be attracted to the positively charged *anode.* Ions are already present in solid *ionic compounds,* but they are in fixed positions and hence cannot move. They are simply ''released'' from the crystal when the compound dissolves, and thereby become mobile. An example is sodium chloride, NaCl, which may be written $Na^+Cl^-(s)$ to emphasize its character as an ionic solid:

$$Na^+Cl^-(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq) \qquad (18.1)$$

With some *molecular compounds* (containing neutral molecules, instead of ions, in their pure state), ions are formed by reaction of the solute with water. For example, hydrogen chloride gas, HCl(g), reacts with water and yields hydrochloric acid:

$$HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq) \qquad (18.2)$$

In dilute hydrochloric acid, this reaction is virtually complete, and no appreciable number of neutral HCl molecules are present.

Solutions that contain a large number of ions are *good conductors.* The solutions, and the solutes that produce them, are called **strong electrolytes.** Hydrochloric acid is a strong acid. As stated above, its ionization is essentially complete, yielding a large number of ions. Similarly, if you dissolve solid potassium hydroxide, KOH, in water, ionization will be complete and the resultant solution will be a good conductor. There are relatively few strong acids and bases. All *soluble* salts completely ionize when dissolved in water and hence yield strongly conducting solutions.

When acetic acid is dissolved in water, an equilibrium is reached:

$$CH_3COOH(aq) + H_2O \rightleftarrows CH_3COO^-(aq) + H_3O^+(aq) \qquad (18.3)$$

Of the original neutral acetic acid molecules, only a small fraction ionizes. Hence, the resulting solution is a *poor conductor.* Most organic acids and bases ionize only to a small extent. Solutes that ionize only slightly and solutions that contain relatively few ions are referred to as **weak electrolytes.**

A third class of solutes includes molecular compounds that do not ionize when dissolved in water. The most minute solute particle remains a neutral molecule. Consequently, such solutions do not conduct an electric current. Solutes whose solutions are *nonconductors* are referred to as **nonelectrolytes.**

Solution conductivity can be detected by a conductivity-sensing apparatus such as the one shown in Figure 18–1. If the electrodes are immersed in a solution containing mobile ions, the ions conduct ''current,'' and the bulb lights. If the solution contains no ions, no current will flow, and the bulb does not light. The flow or non flow of current is therefore a clear indication of the presence or absence of ions. The intensity of light produced (which is proportional to the magnitude of current) is a qualitative measure of the number of ions present.

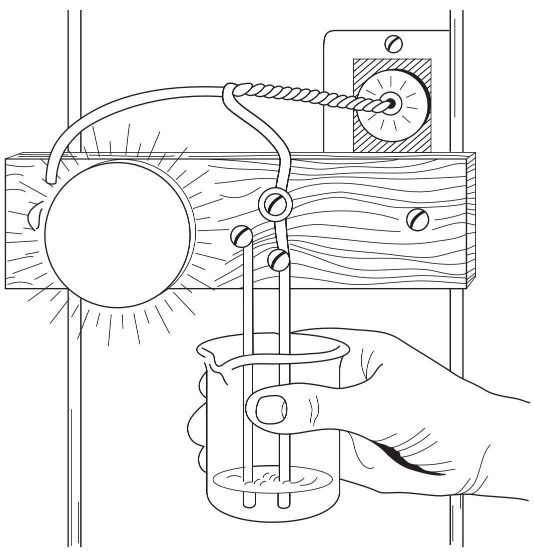

**Figure 18.1**
*Conductivity-sensing apparatus*

In this experiment, you will observe the conductivity of several solutions. You will be asked to make classifications, based on your experimental observations, of whether the substances tested are strong electrolytes, weak electrolytes, or nonelectrolytes.

## SAFETY PRECAUTIONS

Do not, at any time, handle the conductivity-testing apparatus unless specifically directed by your instructor. Never touch both electrodes at the same time; if the apparatus is plugged in, a severe electrical shock may result.

## PROCEDURE

The instructor will set up a conductivity-sensing apparatus. This apparatus will be used to test the conductivity of several solutions. Classify each solution in the following list as a good conductor, a poor conductor, or a nonconductor, and record your classification in the space provided on the work page. Also, answer the corresponding questions in the Discussion section of the work page as the experiment progresses.

1. Deionized water
2. Tap water

Explain the difference between the conductivities of deionized water and tap water.

3. Solid NaCl
4. 1.0 M NaCl (salt of a strong acid and strong base). NaCl is an ionic solid.

Explain why solid NaCl did or did not conduct. Would you predict that molten NaCl (pure NaCl in liquid state) would or would not conduct? Why?

5. Glacial acetic acid, $CH_3COOH$ or $HC_2H_3O_2$ (pure acetic acid, no water present)
6. 1.0 M $HC_2H_3O_2$

How would you explain the difference in conductivity between pure acetic acid and dissolved acetic acid?

7. 1.0 M HCl

Compare the conductivities of Solutions 6 and 7. Explain the difference between the two acids.

8. 1.0 M NaOH
9. 1.0 M $NH_3$(aq) (also referred to as $NH_4OH$)

How would you explain the difference in the observed conductivities?

10. 1.0 M $NaC_2H_3O_2$ (salt of a weak acid and strong base)
11. 1.0 M $NH_4C_2H_3O_2$ (salt of a weak acid and weak base)
12. 1.0 M $NH_4Cl$ (salt of a strong acid and weak base)

Did you find any substantial difference between the conductivities of these solutions? Did they differ from the conductivities of 1.0 M NaCl? Did you find that it made a difference in conductivity whether the soluble salt was formed from a weak or strong acid and a strong or weak base?

**13.** Solid dextrose (sugar), $C_6H_{12}O_6$

**14.** 1.0 M dextrose (sugar)

Based on the conductivity of the sugar solution, would you classify it as a molecular solution or an ionic solution? Does it behave like pure water did, or is it similar to a salt solution? Explain your answer. Would you predict that molten sugar is a good conductor, weak conductor, or nonconductor?

**15.** $BaSO_4$ in water

**16.** Equal volumes of 1.0 M $BaCl_2$ and 1.0 M $Na_2SO_4$

Was there any visible evidence of a chemical reaction? Write the conventional equation as well as the net ionic equation for the reaction. Based on your observations for Species 3 and 15, explain the conductivity behavior of the mixture.

*Name* *Date* *Section*

# Experiment 18

## Advance Study Assignment

1. What is the difference between a strong electrolyte and a weak electrolyte?

2. What do we mean by ionic compound and molecular compound?

3. How does a conductivity-sensing device, such as the one used in this experiment, indicate whether a solution contains ionic or molecular species?

*Name* ______ *Date* ______ *Section* ______

# Experiment 18

## Work Page

| *Number* | *Substance* | *Conductor (Good, poor, nonconductor)* | *Electrolyte* | | |
|---|---|---|---|---|---|
| | | | *Strong* | *Weak* | *Non* |
| 1. | Deionized water | | | | |
| 2. | Tap water | | | | |
| 3. | Solid NaCl | | | | |
| 4. | 1.0 M NaCl | | | | |
| 5. | Glacial $HC_2H_3O_2$ | | | | |
| 6. | 1.0 M $HC_2H_3O_2$ | | | | |
| 7. | 1.0 M HCl | | | | |
| 8. | 1.0 M NaOH | | | | |
| 9. | 1.0 M $NH_3$ | | | | |
| 10. | 1.0 M $NaC_2H_3O_2$ | | | | |
| 11. | 1.0 M $NH_4C_2H_3O_2$ | | | | |
| 12. | 1.0 M $NH_4Cl$ | | | | |
| 13. | Solid dextrose | | | | |
| 14. | 1.0 M dextrose | | | | |
| 15. | $BaSO_4$ in water | | | | |
| 16. | 1.0 M $BaCl_2$ and 1.0 M $Na_2SO_4$ | | | | |

## Discussion

1; 2: Explain the difference between the conductivities of deionized water and tap water.

3; 4: Did solid NaCl conduct? Yes __________ No __________. Explain why or why not.

Would you predict that molten NaCl would __________ or would not __________ conduct? Explain your reasoning.

5; 6: Explain the reason for the difference in conductivities.

6; 7: The acid having higher conductivity is _______________. Give an explanation for the difference.

8; 9: Compare the two bases and explain the difference in conductivities.

_______________ _______________ _______________
*Name* *Date* *Section*

# Experiment 18

## Work Page

10–12: Were the conductivities different? Yes ____________ No _____________. Give reasons for your observations.

13; 14: Sugar dissolved in water gives an ionic ________________ a molecular _______________ solution, which resembles water _______________ a salt solution ______________. Molten sugar would be a good _____________ weak _____________ non _____________ conductor.

15; 16: Evidence of a chemical reaction: _______________________________________________________.

Conventional equation: _______________________________________________________.

Net ionic equation: _______________________________________________________.

Explanation for conductivity behavior:

Name ______________ Date ______________ Section ______________

# Experiment 18

## Report Sheet

| Number | Substance | Conductor (Good, poor, nonconductor) | Electrolyte | | |
|---|---|---|---|---|---|
| | | | Strong | Weak | Non |
| 1. | Deionized water | | | | |
| 2. | Tap water | | | | |
| 3. | Solid NaCl | | | | |
| 4. | 1.0 M NaCl | | | | |
| 5. | Glacial $HC_2H_3O_2$ | | | | |
| 6. | 1.0 M $HC_2H_3O_2$ | | | | |
| 7. | 1.0 M HCl | | | | |
| 8. | 1.0 M NaOH | | | | |
| 9. | 1.0 M $NH_3$ | | | | |
| 10. | 1.0 M $NaC_2H_3O_2$ | | | | |
| 11. | 1.0 M $NH_4C_2H_3O_2$ | | | | |
| 12. | 1.0 M $NH_4Cl$ | | | | |
| 13. | Solid dextrose | | | | |
| 14. | 1.0 M dextrose | | | | |
| 15. | $BaSO_4$ in water | | | | |
| 16. | 1.0 M $BaCl_2$ and 1.0 M $Na_2SO_4$ | | | | |

## Discussion

1; 2: Explain the difference between the conductivities of deionized water and tap water.

3; 4: Did solid NaCl conduct? Yes _______________ No _______________. Explain why or why not.

Would you predict that molten NaCl would _____________ or would not ____________ conduct? Explain your reasoning.

5; 6: Explain the reason for the difference in conductivities.

6; 7: The acid having higher conductivity is __________. Give an explanation for the difference.

8; 9: Compare the two bases and explain the difference in conductivities.

______________________________ ____________ ____________
*Name* *Date* *Section*

# Experiment 18

## Report Sheet

10–12: Were the conductivities different? Yes __________ No __________. Give reasons for your observations.

13; 14: Sugar dissolved in water gives an ionic __________ a molecular __________ solution, which resembles water __________ a salt solution __________. Molten sugar would be a good __________ weak __________ non __________ conductor.

15; 16: Evidence of a chemical reaction: ______________________________.

Conventional equation: ______________________________.

Net ionic equation: ______________________________.

Explanation for conductivity behavior: