

TWO SAFE STUDENT CONDUCTIVITY APPARATUS

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Testing the conductivity of solutions can give important insights into the nature of the solutions and the particles in the solution. Traditionally, conductivity devices used to test the conductivity of a solution or solid usually consist of expensive devices such as volt-ohm meters or specific conductivity meters. Less expensive devices using one or several 120-volt light bulbs can be constructed that use the brightness of the bulb(s) to indicate the conductivity. These latter devices present a danger in that they usually utilize exposed electrodes presenting a possibility of electric shock or electrocution at 110-volt and up to 15 amps current. Although commercial versions use shielded electrodes, the high voltage and current remain.

Russo(1) showed how to construct a simple and safe conductivity apparatus using a blinking light emitting diode (LED) and a 9-volt battery. This apparatus is safe, due to the low voltage, thus eliminating any possibility of electric shock. The apparatus is portable so it can be used in any classroom or on a field trip. Further, the apparatus is inexpensive enough to provide sufficient quantities of the apparatus for a class. The only drawbacks were that it provides a crude quantitative measurement of conductivity and that blinking-type LED's can malfunction easily.

Willis(2) made the device a bit more quantitative by using two LED's, one red and one green. Willis noted that the green LED requires a slightly higher voltage than the red LED and increased that further using a 100 ohm resistor in series with the green LED.

Katz, attempted to duplicate Willis' apparatus, but found that the red LED was easily shorted out. Katz modified the circuit by adding a 1000 ohm resistor along with a switch to prevent shorting the electrodes during storage. Katz also provided for replaceable or interchangeable electrodes by using screw terminals for attaching the electrodes which are fitted with spade lugs on one end. (Heavy pencil leads, 1 mm diameter or larger, can be substituted for the copper electrodes.)

A schematic of the conductivity tester is shown in Figure 1 and a parts list is given in Table 1. The prototype was constructed on a predrilled circuit board, but any construction technique can be used. For student use, the switch can be omitted and the circuit can be taped onto a strip of wood with black plastic electrical tape. The use of a suitable enclosure will protect the apparatus circuitry from accidental damage.

This apparatus is sufficiently sensitive that it displays low conductivity for water solutions of ethanol (70% by volume) and 2-propanol (70% by volume). Local tap water shows a medium conductivity. The conductivity scale is given in Table 2.¹

A second conductivity apparatus also designed by Willis and modified by Katz uses a high-brightness LED and a pulsing piezo buzzer to provide both visual and audio responses. This apparatus is suitable for classroom demonstration use as well as student use. Katz added a 1000 Ω resistor to reduce the sensitivity to allow the tester to be silent at the equivalence point of a barium hydroxide-sulfuric acid titration. A schematic of the pulsing conductivity apparatus is shown in Figure 2 and a parts list is given in Table 3.

These conductivity apparatus can be used in a conductivity experiment such as the one contained in this paper. Students test the conductivity of a wide variety of metallic elements such copper, aluminum, iron, tin, magnesium, or chromium; nonmetals such as sulfur, or carbon (charcoal); and metalloids such as silicon, graphite, or arsenic (lump). It is suggested that elements be available in screw cap vials so they can be tested in the vial without handling. Proper precautions should be given to the students for any elements that may be hazardous.

Students can test the conductivity of solid compounds, both organic and inorganic, that may be soluble, slightly soluble, or insoluble in water. Proper precautions should be given for any compounds that may be hazardous.

Liquids suitable for testing are dilute acids, acetic acid (glacial can be used), ammonia, alcohols, and low volatile hydrocarbons. Proper precautions should be given for any liquids that are hazardous or flammable.

The titration of 0.1 M barium hydroxide with 0.1 M sulfuric acid works well with either conductivity apparatus. It is suggested that the solution be tested using litmus paper (or other suitable test paper) rather than phenolphthalein solution as the alcoholic solution is a weak conductor.

A MICROSCALE CONDUCTIVITY LAB

Objective

The object of this investigation is to determine the conductivity of some elements, compounds, and -solutions.

Safety

Most of the substances used in this investigation are not harmful. Your instructor will inform you of any materials that will require caution in handling. Be sure to wash your hands after handling the substances.

Disposal

Your instructor will inform you of any materials that will require disposal special containers.

Preparation and Clean Up

It is essential that your well plate and beakers be clean for this experiment. Wash your apparatus well with soap or detergent. Rinse well with tap water. Rinse three times with distilled or deionized water.

The electrodes of the conductivity tester must be rinsed with distilled water between tests to insure accurate results.

Procedure

Obtain a conductivity apparatus-, a 24-well plate, 6 small beakers (20 or 50 mL), a stirring rod, and four droppers. Samples of elements and compounds will be provided.

1. Conductivity of Solids

- a. Obtain samples of several elements. Check each one for conductivity. Where do these elements occur on the periodic table? Based on their positions on the periodic table, would you expect them to be conductors? non-conductors?
- b. Obtain samples (about 0.1 gram) of several compounds in separate well of the well plate. Test each compound for conductivity. Save these compounds for Part 3 of the experiment.

2. Conductivity of Liquids and Solutions

- a. Obtain some distilled or deionized water in a clean beaker. Add about 1 mL in a clean well of the well plate. Test the water for conductivity.
- b. Place about 1 mL of distilled water in a clean well of the well plate. Add some salt (sodium chloride) to the distilled water. Test the solution for conductivity.
- c. Place about 1 mL of tap water in a clean well of the well plate. Test the tap water for conductivity.
- d. Add about 1 mL of distilled or deionized water to each of wells containing the solid compounds from Part 2, step b. Stir. Test each solution for conductivity.
- e. Obtain about 1 mL each of several liquids in clean wells of the well plate. Test each liquid for conductivity. Test to see if conductivity changes upon dilution by adding 1 to 2 mL of distilled water, a few drops at a time to each liquid.

3. A Conductivity Titration(3)

- a. Obtain a few mL of a solution of 0.1 M barium hydroxide, $\text{Ba}(\text{OH})_2$. Add 20 drops to one well of a 24 well plate. Test the conductivity of the solution.
- b. Obtain a few mL of a solution of 0.1 M sulfuric acid, H_2SO_4 . Add 20 drops to one well of a 24 well plate. Test the conductivity of the solution.
- c. Add sulfuric acid dropwise, stirring after each drop, to the solution of barium hydroxide. Continue adding the sulfuric acid until the solution tests acid to litmus paper. Note any changes that occur in the solution. Monitor the conductivity of the solution.
- d. If desired, add barium hydroxide solution dropwise, stirring after each drop, to the solution in the well plate until it tests basic to litmus paper. Monitor the conductivity of the solution.
- e. Steps c and d, above can be repeated, monitoring the conductivity of the solution.

Literature Cited

- (1) Russo, T., *J. Chem. Educ.*, **1986**, 63 (11), 981.
- (2) Willis, C., unpublished manuscript.
- (3) Alyea, H. N.; Dutton, F. B., *Tested Demonstrations in Chemistry*, 6th Ed., Journal of Chemical Education, 1965. (Also compiled in *J. Chem. Educ.*, **1955**, 32, pages unnumbered.)

Footnotes

- ¹A commercial version of this conductivity apparatus is available as catalog no. AP1493 from Flinn Scientific Inc., P.O. Box 219, 131 Flinn Street, Batavia, IL 60510.

Table 1. Parts list for the conductivity apparatus.

Component description
Red LED, 60mW, 20mA (Radio Shack #276-041 or equivalent)
Green LED, 75mW, 25mA (Radio Shack #276-022 or equivalent)
Resistor, 100 ohm, 1/2W (Radio Shack #271-012 or equivalent)
Resistor, 1 Kohm, 1/2W (Radio Shack #271-023 or equivalent)
Switch, spst 0.3A at 125V (Radio Shack #275-406 or equivalent)
Battery, 9V, alkaline
Battery snap connector for 9-volt battery (Radio Shack #270-325)
Electrodes: 12 or 14 gauge copper wire.

Figure 1. Schematic of two LED conductivity apparatus.

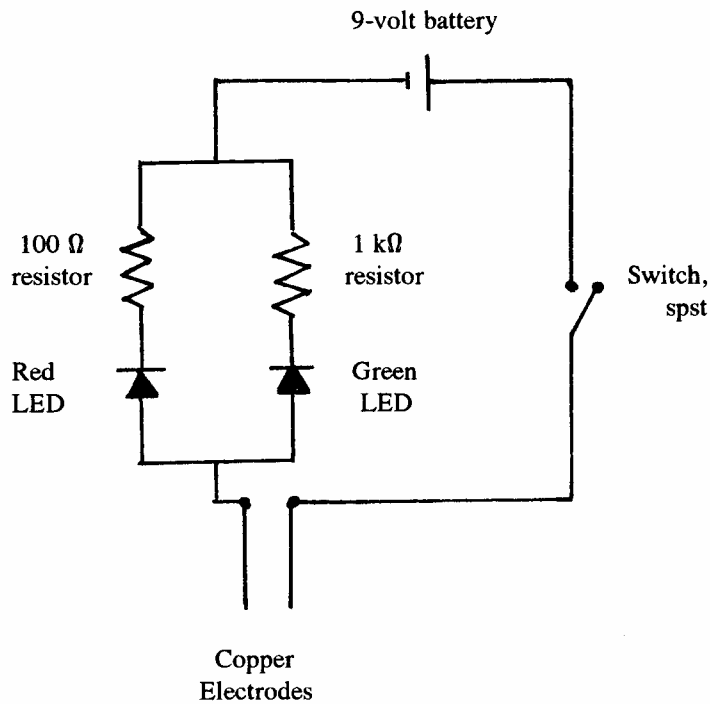


Table 2. Conductivity scale for conductivity measurements.

Scale	Red LED	Green LED	Conductivity
0	Off	Off	Low or none
1	Dim	Off	Low
2	Medium	Off	Medium
3	Bright	Dim	High
4	Very bright	Medium	Very high

Table 3. Parts list for the audio-visual pulsing conductivity apparatus.

Component description

High-brightness red LED, 100mW, 50mA (Radio Shack #276-066 or equivalent)
Resistor, 100 ohm, 1/2W (Radio Shack #271-012 or equivalent)
Pulsing piezo buzzer, 3-28 volts DC, 12 mA, 2.8 kHz (Radio Shack #273-066 or equivalent)
Switch, spst 0.3A at 125V (Radio Shack #275-406 or equivalent)
Battery, 9V, alkaline
Battery snap connector for 9-volt battery (Radio Shack #270-325)
Electrodes: 12 or 14 gauge copper wire.

Figure 2. Schematic of audio-visual pulsing conductivity apparatus.

