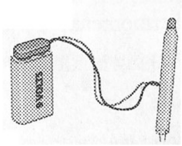
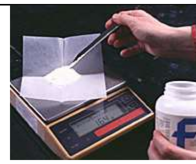
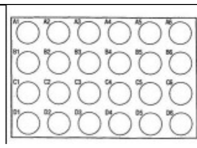
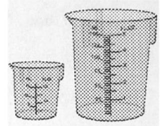
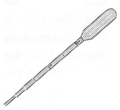
Electrical Conductivity of Solutions

Kit Lab Equipment:

 Safety goggles	 Conductivity apparatus	 Balance & weighing papers (slick magazine paper squares)
 Wash bottle	 24-well reaction plate	 150-mL beaker 50-mL beaker
 Graduated pipette		Dropping bottles of 0.1 *M* Hydrochloric acid, HCl(*aq*) Acetic acid, $HC_2H_3O_2(aq)$ Copper(II) nitrate, $Cu(NO_3)_2$

Student Supplied:

 Distilled water		
 Table sugar	 Table salt	 Baking soda to neutralize acid spills
 Drinking straw (not for drinking though)		

Background Information

Electrical conductivity is due to the movement of charged particles across a potential difference (voltage). In metals, conductivity is due to the movement of electrons which can readily move from one atom to another in a metal.

Most nonmetal elements and molecular compounds do not conduct electricity because their electrons are not free to move from one atom or molecule to another[1]. Pure water, H_2O, a molecular substance is a nonconductor.

Electrical conductivity can also be the result of the movement of ions.
Ionic compounds have ions that could conduct an electrical current, but as solids, these ions are locked into place. As a result, ionic compounds (all solids at room temperature) are nonconductors. When molten however, ionic compounds are excellent conductors because dissociated ions are free to move in the liquid.

Therefore, while pure water is a nonconductor, some aqueous solutions can have significant conductivity due to the movement of mobile positive ions (cations) and mobile negative ions (anions) which are provided by dissociation in water or produced by ionization reactions with water. The greater the ion concentrations, the better the solution will conduct electricity (the stronger the electrolyte). Electrolytes in biological systems are critical because of the movement of ions. Cells move ions to create electrical currents. Your consciousness and heartbeat are electrolytic in nature. EKG's and ECG's are used to monitor the electrochemical impulses of your body. Your mental operations in understanding electrolytes are a result of electrolytic movements.

[1] An important exception is carbon in the form of graphite which has mobile electrons.

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Aqueous solutes are classified as nonelectrolytes and electrolytes.

(1) Nonelectrolytes dissolve just having by having molecules dissolve without any chemical changes or chemical reactions.

Molecular oxygen dissolving: $O_2(g) \rightarrow O_2(aq)$

Glucose dissolving: $C_6H_{12}O_6(s) \rightarrow C_6H_{12}O_6(aq)$

(2) Electrolytes, when dissolved, have ions in solution that are formed two ways:

(a) Dissociation: Ions in an ionic compound separate from one another to make a solution.

Ionic compounds e.g. NaCl, $Mg(NO_3)_2$, $(NH_4)_2SO_4$

NaCl, sodium chloride, is a nonconducting ionic solid at room temperature. While it has ions, the ions are locked in the crystal lattice. As a soluble ionic compound, it becomes a strong electrolyte because its ions are free to move.

Sodium chloride dissociating: $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$

This reaction is complete. There is almost no NaCl(*aq*) only $Na^+(aq)$ and $Cl^-(aq)$.

(b) Ionization: Molecules can react with water to form ions in solution, hydrolysis.

Molecular substances e.g. HCl(*g*), $HC_2H_3O_2(l)$, $NH_3(g)$

HCl is a molecular substance. There is a covalent bond (shared pair of electrons) that forms molecules of H-Cl.

HCl, a gas at room temperature, will not conduct electricity nor would it if it were cooled to a liquid. However, HCl molecules react with water to make ions.

Molecular hydrogen chloride creating ions in the reaction with water:

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

To make the reaction simpler, H_2O is often removed from the equation to give:

$$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$$

Even though the simplified equation looks like HCl is dissociating, it is not. HCl must react with water to make these ions. HCl is a strong electrolyte so there is no unionized HCl(*aq*) left in solution.
HCl 100% reacts with water to make ions.

Acetic acid, a molecular substance, is a liquid at room temperature. It is soluble in water.

It can ionize with water also:

$$HC_2H_3O_2(l) + H_2O(l) \rightleftarrows H_3O^+(aq) + C_2H_3O_2^-(aq)$$

Again, written as a net reaction.

$$HC_2H_3O_2(aq) \rightleftarrows H^+(aq) + C_2H_3O_2^-(aq)$$

As a weak acid, acetic acid only partially ionizes and the double arrow indicates this. An acetic acid solution, $HC_2H_3O_2(aq)$, at the concentration of vinegar, will have less than one out of a hundred molecules ionized at any one time. This classifies acetic acid as a weak electrolyte. $HC_2H_3O_2(aq)$ is mostly $HC_2H_3O_2(aq)$ with small amounts of $H^+(aq)$ and $C_2H_3O_2^-(aq)$.

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Procedure:

1. **Wear safety goggles.**

   The reason for this is the use of the strong acid, HCl(*aq*). While the concentration is only 0.10 *M*, hydrochloric acid can cause eye damage, put holes in clothing and cause a burning sensation. Have some baking soda nearby to neutralize any acid spills.

2. Set up your conductivity tester by attaching the harness to a 9 V battery and touch the electrodes to copper metal (the copper square in your lab kit, a coin, or copper wire) to observe the LED's maximum brightness with a good conductor of electricity. If you need to, dim the room so that you can see the LED glow.

3. Fill the clean, dry 50-mL beaker with distilled water and test its conductivity by placing the wire probes in the water. The LED should not light up. If it does glow, either your beaker was not clean or your distilled water was contaminated. Clean, dry and refill your beaker and test again for conductivity. If the water is still conductive, then you should get a new bottle of distilled water.

4. Using weighing paper (creased squares of slick magazine paper), tare the paper and mass 0.006 moles of sugar, sucrose, $C_{12}H_{22}O_{11}$, approximately 2 g. Check the conductivity of the solid by putting the dry probes into the pile of sucrose. Record your observations.

5. Pour the sucrose from the weighing paper into your 150 mL beaker. Tap the paper to assure that all the sugar was transferred. Add distilled water to make approximately 60 mL of solution using the gradations on the beaker as a guide and stir with the graduated pipette to dissolve. This will produce a 0.1 *M* solution. Check the conductivity of the solution by immersing the probes of the conductivity meter into the solution. Record your observations. Discard the solution and clean the beaker by rinsing with distilled water.

6. Using weighing paper, tare the paper and mass 0.006 moles of sodium chloride, NaCl, approximately 0.3 g.

8. Check the conductivity of the solid by putting the dry probes into the pile of sodium chloride. Record your observations.

9. Make a 0.1*M* sodium chloride solution by pouring the sodium chloride from the weighing paper into your 150 mL beaker. Add distilled water to make approximately 60 mL of solution using the gradations on the beaker as a guide. Test the solution's conductivity and record your observations. Discard the solution and rinse your beaker and meter probes with distilled water.

10. Using the dispensing bottles, put 5-drops of each solution into separate wells.

    B-1 HCl(*aq*) 0.1 *M* Hydrochloric acid
    B-2 $HC_2H_3O_2$ 0.1 *M* Acetic acid
    B-3 $Cu(NO_3)_2$ 0.1 *M* Copper(II) nitrate

11. Test the electrical conductivity of the solutions in the wells. Be sure that both electrodes are immersed in the solution. Record your observations. Rinse the electrodes with distilled water after each test.

12. Dump the solutions onto some newspaper sprinkled with baking soda. This will neutralize the small amount of acid. Discard the paper as solid waste. Do not try to rinse out the wells directly using a faucet. The stream of water can easily spray out the contents of the wells onto your hands and face! Instead submerge the 24-well plate in a container of soapy water and rinse with distilled water.

14. Clean and dry your 50-mL beaker. Add about 20 mL of distilled water, check the conductivity to be sure that the water and beaker were not contaminated. Using the straw, exhale through the water for at least one minute. You may use several breaths to do this. Check the conductivity and record your results.

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APLab.30	*Electrical Conductivity of Solutions*	*Date*

The purpose of this lab is to examine the conductivity of various solutions and substances.

The instructions for this lab can be found in my lab binder.
Give the experimental conductivity and explain the conductivity of these pure substances.

Reasons for good conduction of electricity:

(a) Electrons move from atom to atom in the substance
(b) Ionic compounds contain ions that can move

Reasons for nonconduction of electricity:

(c) Ionic compounds contain ions, but are locked in place
(d) Molecular compounds do not have ions or mobile electrons.

Table 2 Conclusions about pure substances		
Substance	*Conductivity (good, poor, none)*	*Reason for level of conductivity*
Cu(s)	*good*	*metals have mobile electrons*
H_2O *(l)*	*none*	*only has neutral molecules*
$C_{12}H_{22}O_{11}(s)$	*none*	*only has neutral molecules*
NaCl(s)	*none*	*ions are locked in place in the solid*

Write the equation for dissolving the pure substance in water as indicated by the LED observations and categorize the dissolving process as

(a) simple dissolving with no ion formation
(b) dissociation of ions into solution
(c) strong ionization reaction with water
(d) weak ionization reaction with water

Use the → to describe 100% (strong) or very soluble and $\rightleftarrows$ *to describe a small percent (weak) or slightly soluble.*

Table 3 Conclusions about Aqueous Mixtures			
Well	*Equation to form aqueous mixture*	*Conductivity (good, poor, none)*	*Category of dissolving process*
	$C_{12}H_{22}O_{11}(s) \rightarrow C_{12}H_{22}O_{11}(aq)$	*none*	*dissolving - no ion formation*
	$NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$	*good*	*dissociation of ions into solution*
B-1	$HCl(g) \rightarrow H^+(aq) + Cl^-(aq)$	*good*	*strong ionization rxn with water*
B-2	$HC_2H_3O_2(l) \rightleftarrows H^+(aq) + C_2H_3O_2^-(aq)$	*poor*	*weak ionization rxn with water*
B-3	$Cu(NO_3)_2(s) \rightarrow Cu^{2+}(aq) + 2\ NO_3^-(aq)$	*good*	*dissociation of ions into solution*

Anomalies from expected results and possible explanations:

I exhaled for a minute into a beaker with about 20-mL of distilled nonconductive water and checked its conductivity and noticed a dim LED glow indicating a weak electrolyte. I then found the pH which was close to 6. This indicated that the solution had hydrolyzed to make a weakly acidic solution. I speculated that the carbon dioxide in the exhaled air reacted with water to make hydronium ions.

$$CO_2(g) + 2H_2O(l) \rightleftarrows H_3O^+(aq) + HCO_3^-(aq)$$

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