ELECTRICAL CONDUCTIVITY

OBJECTIVES:

1. To observe the electrical conductivity of various pure liquids, ionic solids, metals and aqueous solutions using a conductivity probe and LED conductivity indicator.
2. To classify substances as strong, weak or nonelectrolytes.
3. To observe the changes in conductivity during the course of double displacement reactions.

DISCUSSION

1. Electrical conductivity of molten compounds

a. Ionic compounds, in the solid state, are composed of ions that are not free to move. The ions become mobile after the compound is heated to its melting temperature, becomes fluid, and the ions are freed from their positions in their crystalline lattice. The large number of mobile ions then causes the molten compounds to become good electrical conductors.

b. Covalent compounds do not conduct electricity even when molten because the resultant mobile particles are neutral molecules. Their movement cannot be used to carry an electric charge.

2. Electrical conductivity of metallic solids

Metals conduct electricity in the solid state because the valence electrons of the atoms generate a mobile "sea" of electrons.

3. Electrical conductivity of compounds in aqueous solutions

Water is a good solvent for many covalent and ionic compounds. Substances that dissolve in water to form electrically conducting solutions are **electrolytes**. Substances that dissolve to form nonconducting solutions are known as ***nonelectrolytes***. All soluble ionic compounds are electrolytes. Water molecules are able to pull the positively and the negatively charged ions away from each other in the solid state, and carry them along to be distributed throughout the solution.

$$\mathrm{NaCl\ (s)} \xrightarrow{H_2O} \mathrm{Na^+(aq)} + \mathrm{Cl^-\ (aq)}$$

Most covalent compounds are nonelectrolytes. When dissolved, molecules of covalent compounds are separated from each other by water molecules. The separated molecules are not charged species and will not conduct electricity. However, some covalent compounds actually react with water to form ions. The process of forming ions in this manner is known as ionization.

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

If all dissolved molecules react to form ions, the solution becomes strongly conducting and the solutes are referred to as ***strong electrolytes***. If only a fraction of the dissolved molecules ionizes the solution becomes weakly conducting and the compound is known as a ***weak electrolyte***.

$$\mathrm{HC_2H_3O_2\ (aq)} + \mathrm{H_2O\ (l)} \rightarrow \mathrm{H_3O^+\ (aq)} + \mathrm{C_2H_3O_2^-\ (aq)}$$

PROCEDURE:

1. SOLVENT EFFECT ON THE ELECTRICAL CONDUCTIVITY(**Demonstration by the instructor)**

Students are not allowed to do parts of the experiment designated as demonstration by the instructor.

a. The instructor will set-up the light- bulb conductivity apparatus as shown in the figure 1 below.

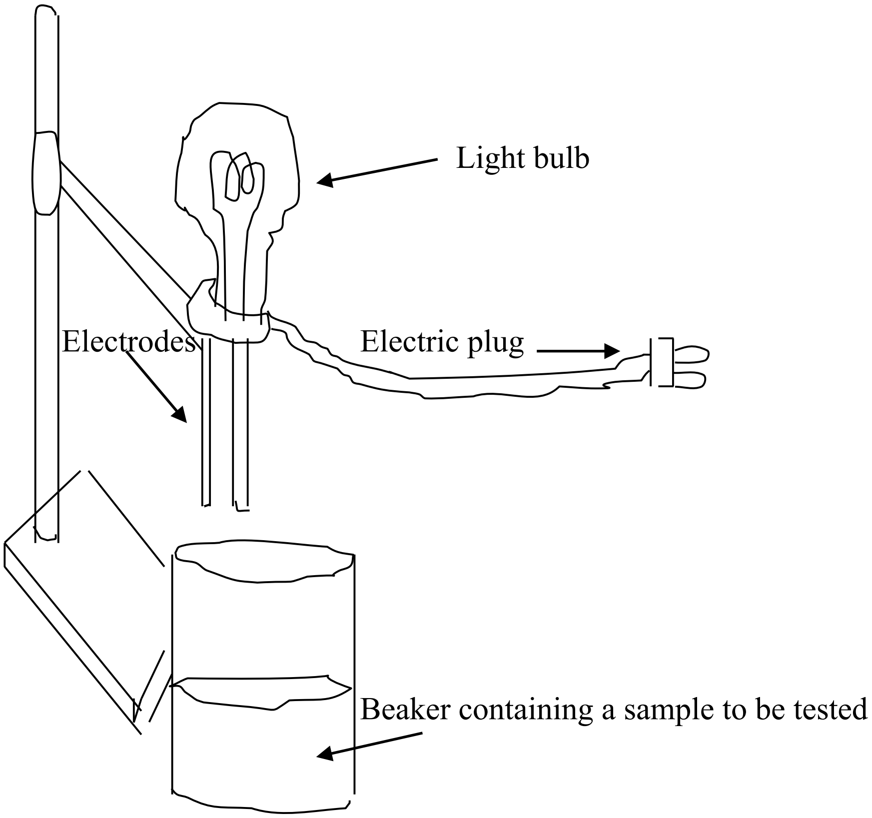

Figure 1: Light bulb conductivity apparatus

The conductivity apparatus consists of an electric lamp in series with open electrodes. The electrodes will fit inside a 50 ml beaker containing the liquid to be tested. The electrodes are to be rinsed thoroughly with distilled water between testing the different samples.

Caution: The instructor will put on a pair of rubber gloves before plugging the conductivity apparatus cord into the electrical outlet. The gloves are kept on through out the entire experiment and while the apparatus is plugged in. To prevent electric shock, the electrodes are not to be touched while the apparatus is plugged into the 110 volts. The apparatus is not to be left on unattended. In any lab experiment involving "live" contacts, the apparatus is to be disconnected from the source power except when actually making measurements.

b. Electrical conductivity of glacial acetic acid, $HC_2H_3O_2(l)$, no solvent present:
The instructor will test the electrical conductivity by using the light bulb conductivity apparatus. Students are not allowed to do this part of the experiment:

i. Approximately 15 ml of glacial acetic acid is poured into a 50 ml beaker.
Glacial acetic acid is a pure form of acetic acid (99.8%). It is called glacial because its freezing point (16.7 ºC) is only slightly below room temperature.

Caution:
Glacial acetic acid is corrosive and will burn the skin. If skin contact occurs, the contacted area should be washed with large amounts of water. It also has a strong odor and should be kept away from the nose while testing it. When finished, it is to be flushed with lots of water into the large sink before, while and after it is emptied.

ii. The conductivity is tested by raising the beaker up around the pair of electrodes. When a measurable number of movable ions are present, the light bulb will glow. A dim glowing light indicates a relatively small number of ions, while a bright glowing light indicates a relatively large number.

iii. Record your observation of the light bulb on table A, page 7.

c. Electrical conductivity of HCl in different solvents.
The instructor will test the electrical conductivity by using the light bulb conductivity apparatus. Students are not allowed to do this part of the experiment:

Caution: Toluene is flammable and quite volatile. The use of burners during this part of the experiment is prohibited. No student in the area is allowed to use the burner.

i. This part of the experiment will be done under the fume hood. The conductivity of a solution labeled “HCl in Toluene” will be tested. Note: Toluene is a nonpolar solvent. Then, about 10 ml of distilled water are added. The beaker is shaken gently to stir the solution. There will be two liquid layers in this mixture. The electrodes are placed so that they penetrate below the surface of the lower (water) layer, and the conductivity is tested again.

ii. Record your observation of the light bulb on table A, page 7.

All solutions containing toluene are disposed of in a special waste container, labeled ***Halogenated Hydrocarbon***, found under the fume hood.

2. <u>ELECTROLYTES</u>: (*strong, weak, or nonelectrolyte solutions*)

Each pair of students will check out from the instructor a Vernier conductivity probe and a LabQuest 2. The conductivity probe is sensitive and must be calibrated before using.

Before performing this part, you will need to calibrate the LabQuest 2 as follows:

1. Make sure to have a beaker of DI water ready (enough in small beaker so tip of electrode is immersed in DI water)
2. Plug in the power supply to the LabQuest 2.
3. Turn on the LabQuest 2.
4. On the sensitivity switch on the side of the LabQuest, move the switch to 0-2000 μS if this is not set here.
5. Connect the conductivity probe to the LabQuest.
6. Click on Sensors on the top of the screen.
7. Click Calibrate.
8. Select CH1: Conductivity 2000 MICS.
9. Click one point calibrate.
10. Immerse conductivity probe into beaker of DI water.
11. Enter in 0 for the Known value.
12. Press Keep (on bottom left of screen).
13. You will now return to the previous screen. Press OK (on bottom left of screen).
14. LabQuest will now show 0 μS/cm.
15. You are now ready to take conductivity measurements of your solutions.
16. Make sure you fill the spot plate all the way to the top without spilling solution all over the plate. This ensures that the electrode tip is in contact and immersed within the solution.
17. Conductivity may fluctuate. Choose the measurement that stays around a value that is constant.

You are now ready to perform taking conductivity measurements of solutions from table B page 7.

a. Take a clean spot plate to the reagent bench. Fill each separate well of the spot plate *all the way* to the top with each solution listed on table B-page 7.

b. Immerse the 'tip' of the conductivity probe in each solution to be tested. Before testing each solution, rinse the probes by immersing them in distilled water placed in a small beaker. To prevent contamination, do not allow a solution from one well to mix with a solution of another well. The measured conductivity (in units of μS/cm) of the tested solution will be recorded in table B, page 7 and will indicate one of the following types of electrical conductivity:

> *i. Strong conductor- very high measured conductivity values in the range of 1000 – 5000* μS/cm .
> *ii. Weak conductor- low to high measured conductivity values in the range of 100 – 1000* μS/cm .
> *iii. Non-conductor- essentially zero or very low conductivity values in the range of 0 – 100* μS/cm .

c. Record the measured conductivity value for each of the solutions from the LabQuest 2 as described above onto table B, page 7 .

d. Classify each solution as *weak*-, *strong*-, or as a *non-electrolyte* based on your measurement and the ranges given above.

e. Write the formulas of all solute particles (ions and/or molecules) present, listing the most abundant kind of particle first.

Dispose of your solutions by pouring them in the sink and washing them down with water.

3. EFFECT OF MIXING REAGENTS

a. Take a clean spot plate to the reagent bench. Fill each separate well of the spot plate *all the way* to the top with each of the solutions listed in part 3(a) on page 8. For the pairs of reagents listed, you will test the conductivity of each solution separately by using the conductivity probe. Then, you will mix the pair of solutions by using a clean medicine dropper to transfer the contents of one well into the other. Measure the conductivity after mixing. You should be able to recognize the changes in the number of ions present.

i. Record your observations.

ii. Write molecular-, total ionic-, and net ionic equations

iii. Explain the observed electrical conductivity by listing the formulas of the ions present in solution after the reaction has taken place. *Note: The ions listed as products in the total ionic equations are responsible for the observed electrical conductivity. These include the spectator ions(ions that do not participate in the chemical reactions) and the ions produced in the chemical reactions.*

Dispose of the solutions by pouring them in the sink and washing them down with water.

b. Again take a clean spot plate to the reagent bench. Fill each separate well of the spot plate *all the way* to the top with each of the solutions listed in part 3(b) on page 8. Measure the conductivity and proceed as you did in part 3(a) above.

Dispose of the calcium chloride/sodium carbonate mixture in a special waste container labeled: $CaCO_3$ *waste.*

4. DETECTING THE END POINT OF AN ACID-BASE REACTION BY MEASURING THE ELECTRICAL CONDUCTIVITY

Take a clean spot plate to the reagent bench. Fill a separate well of the spot plate *all the way* to the top with 0.10 M $Ba(OH)_2$. Into another well of the spot plate fill *all the way* to the top with 0.10 M H_2SO_4. Measure the conductivity of each solution by using the conductivity probe. Record your observations. Now, in a clean *small beaker* fill it with 5 mL of 0.10 M H_2SO_4, place the conductivity probe into the solution and then slowly add the 0.10 M $Ba(OH)_2$ solution drop by drop. Mix well after the addition of each drop by gently swirling the beaker. Monitor the electrical conductivity until the conductivity measurement shows no conductivity. Show the non-conducting mixture with your measured conductivtiy to your instructor and get his/ her initial on page 9. Write your explanation on page 9 based on the chemical equations for the reaction.

Now add more drops of $Ba(OH)_2$ to the non-conducting mixture until the electrical conductivity is resumed. Explain in terms of the ions present.

Dispose of the Barium mixture in a special waste container labeled: $BaSO_4$ *waste*

5. CONDUCTIVITY OF WATER

a. Test the conductivity of water, using the conductivity probe. Notice that the conductivity you will observe for tap water is due to the presence of dissolved minerals.

b. Record the response of the conductivity probe on table C, page 9.

6. CONDUCTIVITY OF IONIC COMPOUNDS AND METALS

Test the conductivity of solids listed on page 10 using the LED conductivity indicator. Be sure that “both” probes are dry and in contact with the material being tested. To dry the probes, blot the excess water with a tissue. Record the response of the LED on table D, page 10.

Report- Electrical Conductivity

Name____________________________________
Last First
Instructor's initial ___________

1. SOLVENT EFFECT ON THE ELECTRICAL CONDUCTIVITY

Table A

sample	**LED response: bright blinking, dim no blinking, or none**	**Conclusion: electrical conductor or none conductor**
Glacial acetic acid, $HC_2H_3O_2$ (l)		
HCl in toluene		
HCl in water layer present under toluene (after mixing).		

Explain the effect of solvent on the conductivity of:

Glacial acetic acid ____

HCl in toluene ____

HCl in water layer after mixing (The electrodes should touch the water layer at the bottom)

____

2. ELECTROLYTES : Classification of substances (strong, weak, or nonelectrolyte)

Table B

Sample	Conductivity (μS/cm)	*Strong, weak, or non-electrolyte*	Formulas of all solute particles present
0.10 M NaCl			
Saturated $Ca(OH)_2$ (aq)			
0.10 M HCl			
0.10 M NaOH			
0.10 M $HC_2H_3O_2$			
0.10 M $NaC_2H_3O_2$			
Sucrose solution, $C_{12}H_{22}O_{11}$ (aq)			

Instructor's approval________

Exercise: Complete the following statements:

a. Soluble ionic compounds are classified as ____________ (*strong, weak, or nonelectrolytes*)

b. List all ionic compounds tested that are strong electrolytes:______, ______, _______, _______

c. List all covalent compounds tested that are strong electrolytes: ________

d. List all covalent compounds that are weak electrolytes:___________.

e. List all covalent compounds tested that are nonelectrolytes _______,

f. Why does 0.10 M acetic acid exhibit different conductivity from that of glacial acetic acid?
____

3. ELECTRICAL CONDUCTIVITY WHEN REAGENTS ARE MIXED

a.	0.10 M $HC_2H_3O_2$	0.10 M NH_3	After mixing
Conductivity (µS/cm)			
Strong, weak, or non-electrolyte			

Molecular equation:

Total ionic equation:

Net-ionic equation:

Write the formulas of the ions conducting electricity: _____________________________________

Instructor's approval________

b.	0.10 M $CaCl_2$	0.10 M Na_2CO_3	After mixing
Conductivity (µS/cm)			
Strong, weak, or non-electrolyte			

Molecular equation:

Total ionic equation:

Net-ionic equation:

Write the formulas of the ions conducting electricity: ____________________________________

Instructor's approval________

4. DETECTING THE END POINT OF AN ACID-BASE REACTION BY MEASURING THE ELECTRICAL CONDUCTIVITY

	0.10 M H_2SO_4	0.10 M $Ba(OH)_2$	After mixing
Conductivity (µS/cm)			
Strong, weak, or non-electrolyte			

Molecular equation:

Total ionic equation:

Net-ionic equation:

Write your explanation for the lack of electrical conductivity based on the above chemical equations for the reaction.

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Instructor's approval________

Now add more drops of $Ba(OH)_2$ to the non-conducting mixture until the electrical conductivity is resumed. Explain in terms of the ions present.

____

> Dispose of $BaSO_4$ in a special waste container labeled "*$BaSO_4$ WASTE*".

5. ELECTRICAL CONDUCTIVITY OF WATER:

Table C

	Conductivity (µS/cm)	*Strong, weak, or non-electrolyte*
Distilled water		
Tap water		

Explain your observation to the conductivity response when the electrical conductivity of distilled water is tested.

____

6. ELECTRICAL CODUCTIVITY OF IONIC COMPOUNDS AND METALS USING LED CONDUCTIVITY INDICATOR

Table D

	LED response: bright, dim, or none	Conclusion: electrical conductor, or non conductor
NaCl crystals. (Probes must be dry)		
Copper metal		
Zinc metal		
Tin metal		

Instructor's approval________

a. Why is the electrical conductivity of NaCl (s) different from that of 0.10 M NaCl?

____

____

b. Explain the reason for the electrical conductivity of metals.

____

____

EXERCISE:

A. For each of the following substances, write the formula(s) of the principal, more abundant, molecular or ionic species present in an aqueous solution of each substance.

	Write ***only*** the formulas of the ions or molecules which are ***abundant***		Write ***only*** the formulas of the ions or molecules which are ***abundant***
NaOH		$Pb(NO_3)_2$	
$KC_2H_3O_2$		C_2H_6O	
$H_2C_2O_4$		$BaCl_2$	
KHS		H_2S	
HI		NH_3	
HNO_2		$NH_4C_2H_3O_2$	

B. Write molecular, total, and net-ionic equations. Then predict if the mixtures would conduct electric current and write the formulas of ions conducting electricity.

1. Silver nitrate reacting with hydrobromic acid
Molecular equation:

Total-ionic equation:

Net-ionic equation:

Any electrical conductivity?_______. List the ions conducting the electric current______________

2. Potassium chloride reacting with magnesium nitrate.
Molecular equation:

Total-ionic equation:

Net-ionic equation:

Any electrical conductivity?_______. List the ions conducting the electric current______________

3. Sodium acetate reacting with hydrochloric acid.

Molecular equation:

Total-ionic equation:

Net-ionic equation:

Any electrical conductivity?_______. List the ions conducting the electric current______________

4. Potassium hydroxide reacting with hydrosulfuric acid

Molecular equation:

Total-ionic equation:

Net-ionic equation:

Any electrical conductivity?_______. List the ions conducting the electric current______________