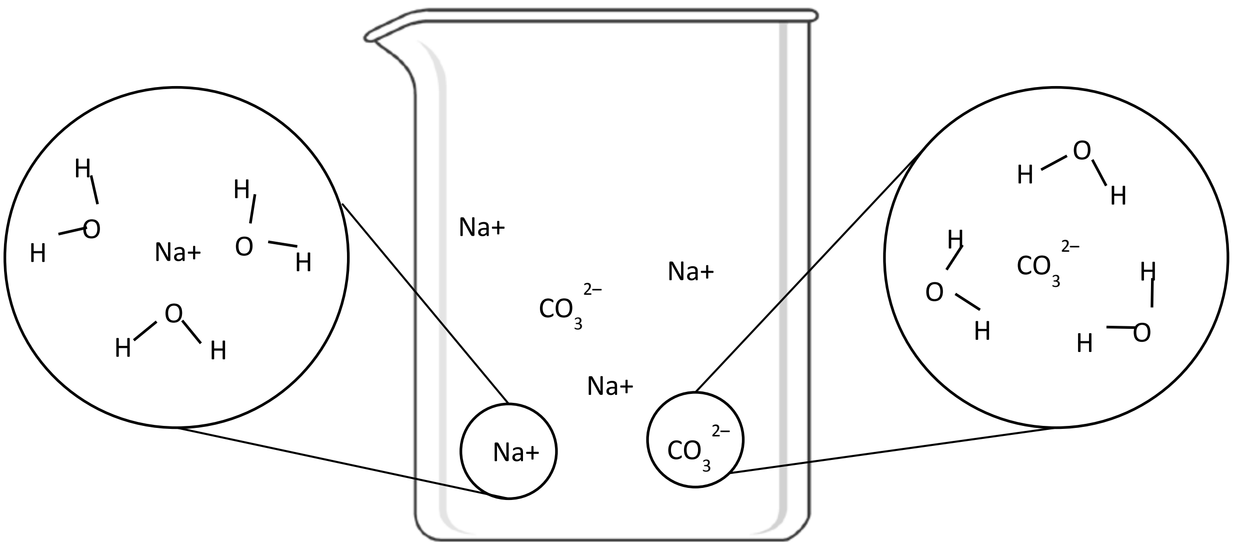
Experiment: Ionic Solutions (Electrolyte Solutions)*

Introduction

Molecular compounds are made up of molecules, while ionic compounds are made up of ions. Ions are different from molecules, as they have a charge. In an ionic compound, the number of positively charged cations and negatively charged anions are such that charges are balanced. For example, in the diagram below, note that there are two sodium cations (+1) to balance the charge of each carbonate anion (-2).

Many ionic compounds dissolve in water; many do not. If an ionic compound dissolves in water, it separates into individual charged ions. For example, when the soluble compound sodium carbonate dissolves in water, the partial negatively charged side of the polar water molecules surround the positively charged sodium ions, while the partial positively charged side of the polar water molecules surround the negatively charged carbonate ions. The resulting solution is composed of separate sodium ions and carbonate ions surrounded by water molecules.



The following chemical equation communicates how the soluble ionic compound, sodium carbonate, separates into sodium ions, and carbonate ions. The notation "(aq)" means "aqueous" or that the ion is dissolved in water. *Note that water is not written as a reactant, but over the reaction arrow.*

$$Na_2CO_3(s) \xrightarrow{H_2O} 2\ Na^{+}(aq) + CO_3^{2-}(aq)$$

Once ionic compounds are dissolved, the ions in solution may undergo further chemical reactions with other substances, including neutralization, precipitation, oxidation-reduction, and other reactions.

* Adapted with permission from Cascadia Community College

One technique that can be used to detect the presence of ions is conductivity, since charges in motion conduct electricity. Soluble ionic compounds form solutions containing mobile ions that conduct electricity and are therefore referred to as electrolytes. In contrast, insoluble ionic compounds do not conduct electricity and are called nonelectrolytes because no separate ions are formed in solution. Beyond being used to classify electrolytes and nonelectrolytes, conductivity is proportional to the concentration of ions, so it can also be used to determine the actual concentration of ionic compounds in water. Conductivity testing is simple, sensitive, and rugged/inexpensive equipment can be used. For these reasons it is used for a wide variety of field and industrial analyses.

Molecular compounds are not made up of charged particles; therefore, they cannot conduct electricity and are nonelectrolytes, like insoluble ionic compounds. However, there is an important class of molecular compounds – even though not made up of ions – that can form ions via a chemical reaction when they dissolve in water. If each molecule separates into ions, the compound is called a "strong electrolyte", but if the molecules of a compound produce only a few ions, it is called a "weak electrolyte". Soluble ionic compounds are also considered "strong electrolytes."

For electrolytes, conductivity depends on concentration. In this lab you will measure the conductivity of a solution with some initial concentration, and then you will dilute the solution by adding solvent. The concentration of the original solution and diluted solution is determined by the following equations:

Original solution: the initial concentration, C_i

$$C_i = \frac{mass\ of\ dry\ NaCl\ (in\ grams)}{volume\ of\ solution\ (in\ Liters)}$$

Diluted solution: the final concentration, C_f

$$C_f V_f = C_i V_i$$

therefore, $C_f = C_i \frac{V_i}{V_f}$

where C_f and C_i are the final and initial concentrations,
V_i is the initial volume and V_f is the final volume. *(Notice that the units for V will cancel.)*

Objectives

In this experiment, you will

- ✓ Classify substances as strong, weak, or non-electrolytes.
- ✓ Use conductivity to observe the process of dissolving an ionic compound.
- ✓ Learn and practice the technique of dilution.
- ✓ Observe the relationship between concentration of an ionic substance and conductivity.

Hazards

☠ Hydrochloric acid can cause chemical burns on the skin and damage eyes. Wear goggles and wash your hands after using.

Procedure

Part A: Ionic Solutions

1. Obtain a large beaker and label it "Rinse". All subsequent rinses from Part A and B are to be collected in this rinse beaker, and then later emptied into the sink.
2. Obtain a LABQuest and conductivity probe (also used in Part B). Set up the LABQuest to recognize the conductivity probe. **Make sure the probe is set to read from 0-20,000 μS/cm.** (μS/cm=microSiemens per centimeter, a unit of conductivity). Thoroughly rinse the conductivity probe with distilled water into your waste beaker. Use a Kimwipe or paper towel to pat it dry. Hold the probe in the air and tap the display until you get an option to "zero". Select it. The reading in air should now read zero. This is called calibration.
3. There are six solutions circulating about the room. The order you use them does not matter. You will read the conductivity of each substance in its vial by submerging the probe into the liquid in the vial, and slightly stirring it until you get a stable reading. Make sure you rinse the probe with distilled water and pat it dry before/after every measurement so you avoid contamination of the sample vials. (Avoid getting water into the vial, as it dilutes the samples!) Rinsings go into the waste beaker.
4. Record the conductivity values you obtain for each of the solutions in your data table.
5. Rinse the probe thoroughly when finished. The rinses can be poured into the sink.

Part B: Conductivity Analyses

All wastes from this part **only** may be emptied into the laboratory sink. You may find it convenient to use a waste beaker, and then to empty this into the sink.

1. Obtain a LABQuest and conductivity probe. Set up the LABQuest to recognize the conductivity probe. Thoroughly rinse the conductivity probe with distilled water into a large waste beaker.
2. Place a dry, 250 mL beaker on a magnetic stirring plate and add a magnetic stirring bar. Clamp the conductivity probe so that it is near the wall of the beaker, and lowered almost to the bottom of the beaker.
3. Carefully measure 100mL of deionized water using a 100-mL graduated cylinder. Record the <u>actual</u> volume to the closest 0.1 mL. Pour this into the 250mL beaker.
4. Place the probe into the above beaker. (Using a 0-20,000 μS/cm range, it will likely read between 0 and 100 μS.) Calibrate the probe as you did earlier by setting this to zero. Record this value (0 μS/cm) in the data table for Part B.
5. Obtain a piece of weigh paper. Use your spatula to weigh out between 0.100 and 0.150 g sodium chloride (NaCl) onto the weigh paper. Record the <u>actual</u> mass. Do NOT return any NaCl to the original container to prevent contamination; put extra material into your waste container or give it to a classmate.
6. Slowly turn on the magnetic stirrer (NOT the heater). Make sure the stir bar does not hit the probe while it is stirring and set the speed so a small vortex can be seen in the distilled water.
7. On the LABQuest, click on the graphical display. Press "Start". (Ask your instructor or your lab

neighbors if you cannot find this.) Add the NaCl to the DI water in the beaker and watch the trace on the screen while the NaCl dissolves. Sketch this trace in the data section of the report sheet.

This is now your **original NaCl solution**.

8. When the conductivity becomes almost constant, record the final conductivity value. Click "Stop", remove the probe, and rinse it with distilled water into the waste beaker.
9. Remove your NaCl solution from the stirring plate, remove the spin bar with tweezers and rinse the bar with distilled water. **SAVE your solution** for the following steps:
10. Pour between 20 and 25 mL of the original NaCl solution into a 50 mL graduated cylinder. Read and record this volume as the "initial" volume (V_i) of the original NaCl solution to the nearest 0.1 mL. Then add deionized water to the cylinder to a total volume of between 40 and 45 mL. Record the "final" volume (V_f), to the nearest 0.1 mL. Pour the diluted solution into a new, dry 100 mL beaker. *(Why a dry beaker?)*

    This is now your diluted NaCl solution.

11. Immerse the conductivity probe in the diluted solution and record the displayed conductivity value.
12. Discard the NaCl solutions and rinses in the sink. Rinse all of the glassware and the conductivity probe and put the equipment away. Return the magnetic stir bar to your instructor.

Report
Ionic Solutions

Name ____________________Section______

Lab Partner ___________________________

Data

Part A: Ionic Solutions

	Compound	Conductivity Values (µS) (Record data for all trials.)	Strong, Weak, or Nonelectrolyte?	Many, few or no ions produced in water?
1	NaCl sodium chloride			
2	$CaCl_2$ calcium chloride			
3	HCl hydrochloric acid			
4	CH_3COOH ($C_2H_4O_2$) acetic acid			
5	$HOCH_2CH_2OH$ ($C_2H_6O_2$) ethylene glycol			
6	CH_3OH methanol			

Part B: Conductivity Analyses

Data for the Original & Diluted NaCl Solutions (use significant figures!)

total volume of DI water for original NaCl solution, in mL	mL
total volume of DI water for original NaCl solution, in L	L
mass of dry NaCl used for original NaCl solution	g
calculated concentration of original NaCl solution (C_i) $C_i = \frac{mass\ of\ dry\ NaCl\ (in\ grams)}{volume\ of\ solution\ (in\ Liters)}$	g/L
volume of <u>original</u> NaCl solution used ("initial" volume, V_i)	mL
volume of <u>diluted</u> NaCl solution obtained ("final" volume, V_f)	mL
calculated concentration of diluted NaCl solution (C_f) *Since* $C_f V_f = C_i V_i \rightarrow C_f = C_i \left(\frac{V_i}{V_f}\right)$	g/L

Reproduce the conductivity trace observed on the LabQuest when the NaCl was dissolved in the DI water. A rough sketch is sufficient, but label the x and y axes correctly.

Describe in words what this graph shows.

Conductivity Data

Sample	Concentration (NaCl, g/L)	Conductivity (μS/cm)
deionized water	0	
original NaCl solution (C_i)		
diluted NaCl solution (C_f)		

Calibration Plot

Make a graph of the concentration (x axis) and conductivity (y axis) for distilled water and the two NaCl solutions. On your graph, make sure to **label the axes correctly and include units.**

(NOTE: This graph should result in a straight line!)

Complete the calibration plot by drawing a single straight line that best fits the points. (Do not connect the dots!) You can use this calibration plot to determine the concentration of any NaCl solution based on its measured conductivity or predict the expected conductivity of a solution with a known NaCl concentration.

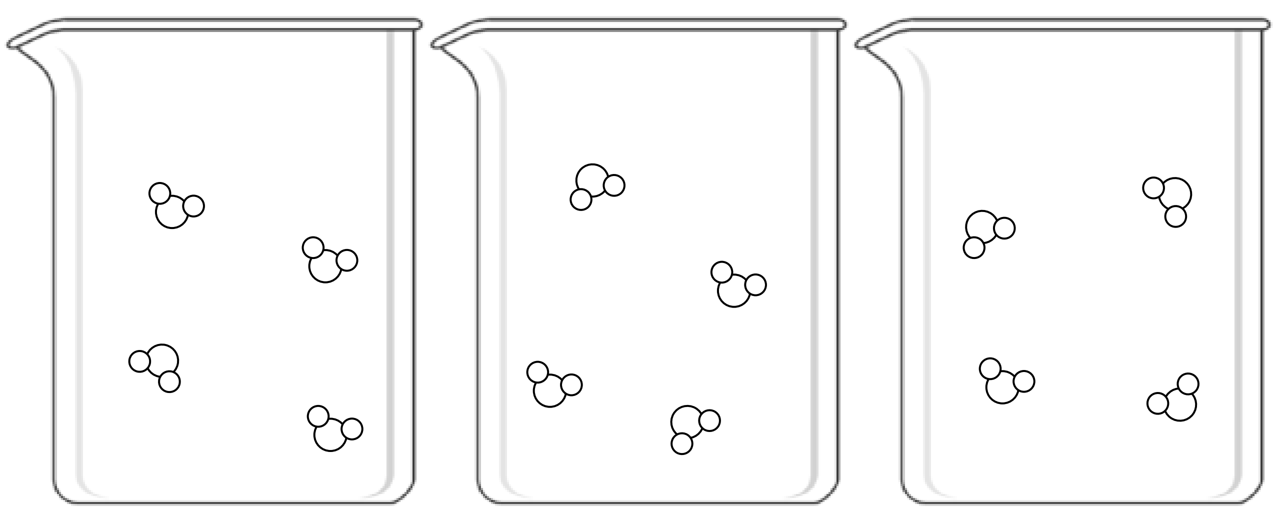
Post-lab Questions

1. HCl is a covalent (molecular) compound in the gas phase. Does your data indicate that HCl behaves as molecules or ions when dissolved in water? Explain your conclusion.

2. Write a chemical equation that communicates what solid $CaCl_2$ forms when dissolved in water. Use physical states in your equation as appropriate: (s), (l),(aq)

3. The following are beakers of water. Fill in the ions or molecules present when each of the following substances is dissolved in water. Use spheres to represent atoms/ions/molecules, and include a legend or labels with their chemical formula. (Look at the example on pg. 1.) Use at least 4-5 spheres (molecules or ions) for each drawing.

HBr (a strong electrolyte) HF (a weak electrolyte) CH_3OH (a non-electrolyte)



4. Using your graph, estimate the conductivity of a 2.4L solution that has 1.5g of NaCl dissolved in it?

    a. Estimated conductivity: ______________________ include units!

    b. Describe how you obtained the result.

5. If you measured the conductivity of pond water and found it was 2000 μS/cm, what concentration of NaCl would you expect?

    a. Estimated concentration: ______________________ include units!

    b. Let's say a 1%(m/v) NaCl solution is "salty" (2.5g NaCl in 250 mL water). Would the water in the pond taste "salty"? State "yes" or "no", and **<u>EXPLAIN</u>**. Show your work.

Prelab Name ____________________Section______

Ionic Solutions

1. Define the following terms (in your own words). Make sure you cite any sources used (provide author & title & pg number or website).
   a. nonelectrolyte

   b. strong electrolyte

   c. weak electrolyte

2. Predict whether each of the following is ionic or covalent (molecular). Circle your answers.

a. Water, H_2O	ionic compound	covalent compound
b. Sodium chloride, NaCl	ionic compound	covalent compound
c. Calcium carbonate, $CaCO_3$	ionic compound	covalent compound
d. Hydrogen chloride, HCl	ionic compound	covalent compound
e. Glycerol, $C_3H_8O_3$	ionic compound	covalent compound

3. Nitrate is a polyatomic ion with a charge of -1. Its ionic formula is NO_3^{-1}.
   Strontium is a Group 2 atom that forms a cation with a charge of +2. Its ionic formula is Sr^{2+}.

   a. Write the correct chemical formula for the ionic compound strontium nitrate.

   b. On page 1, the dissociation of sodium carbonate is written as this equation:

   $$Na_2CO_3(s) \rightarrow 2\ Na^{+}(aq) + CO_3^{2-}(aq)$$

   Write a chemical equation for the dissociation of strontium nitrate in water.
   (Hints: *Water is not a reactant! Use the example of sodium carbonate as a guide.*)

4. Calcium chloride is $CaCl_2$. Which equation best describes calcium chloride when it dissociates?

   a. $CaCl_2\ (s) \rightarrow Ca^{2+}\ (aq) + Cl_2^{2-}\ (aq)$

   b. $CaCl_2\ (s) \rightarrow Ca^{2+}\ (aq) + Cl_2^{1-}\ (aq)$

   c. $CaCl_2\ (s) \rightarrow Ca^{2+}\ (aq) + 2\ Cl^{1-}\ (aq)$