#19 Measuring Conductance Using a Probe Interfaced with LabQuest

Purpose: Conductance of aqueous solutions is measured using a probe interfaced with a computer. The conductance values will be used to estimate the total dissolved solids (TDS) in drinking water, to compare solutions of ionic and covalent compounds, and to find the number of ions produced for each formula unit of an ionic compound.

Introduction

Conductance is defined as the reciprocal of electrical resistance. The unit for resistance is the ohm. The unit for conductance, once known as the mho (ohm, spelled backwards), is now called the *siemen*, abbreviated with a capital S. Since the siemen is a very large unit, conductance of aqueous solutions is measured in microsiemens, µS (micro is 1 millionth, 10^{-6}).

Total Dissolved Solids

The conductance of a water sample is commonly used as a "watchdog" environmental test to find the concentration of total dissolved solids (TDS) in a water sample. Note that the conductivity does not indicate the specific ions present, just the total from all dissolved solids. Conductivity in µS is roughly twice the concentration of TDS in mg/L. For instance, an upper limit often placed on TDS in drinking water is 1100 mg/L which would have a conductivity of about 2200 µS.

Ionic vs. Covalent Compounds

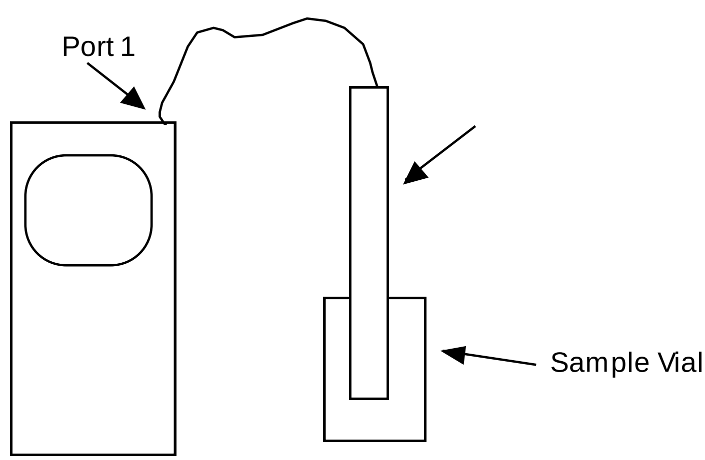
Conductance can be used to make a qualitative observation of the difference between solutions of ionic and covalent compounds. Solutions of ionic compounds have much greater values of conductance than solutions of covalent compounds.

Ions per Formula Unit

Conductance measurements can be used to follow breakdown of ionic compounds by finding the number of ions that an ionic substance produces per formula unit. For example, NaCl produces two ions per unit, Na^+ and Cl^-.

Apparatus

The probe will be connected to the LabQuest device as shown below.



Procedure

Part A Setting up the Computer-Interfaced Probe

1. Plug in the LabQuest. Connect the conductance probe to analog Channel 1.

2. Set the probe to the 0 to 20,000 range. (0 to 10,000 mg/L TDS)

3. The conductance values will be dispkayed on the LabQuest screen.

Part B Measuring Conductance

1. Samples are provided in 20 mL plastic vials.

2. Rinse the tip of the probe with distilled water and then pat dry. (Remember to do this each time you prepare to test a new sample.) Insert the probe in the sample solution so that the electrode surfaces are completely submerged in the liquid. (See diagram apparatus section). Hold onto the probe as you work, or the vial will topple.

Note: See Part C for instructions on which samples to test.

3. Gently swirl the probe and wait for the reading to stabilize. If the number varies, record the range of values.

CAUTION: Avoid scratching the inside electrode surface of the elongated cell.

4. When you are finished with the probe, rinse it with distilled water and blot dry with a Kimwipe. The probe can be stored dry.

Part C Testing Samples

1. Total dissolved solids in drinking water can readily be estimated from conductance. Test samples of tap water and bottled water. Record in Data sheet C.1. One half the conductance measurement in µS can be used to estimate mg TDS per liter of water.

2. Solutions of ionic compounds have much higher conductance than solutions of covalent compounds. Samples available for testing include: Distilled water, aqueous glucose ($C_6H_{12}O_6$), aqueous sucrose ($C_{12}H_{22}O_{11}$) , KCl(aq), NaI(aq). Record in Data sheet C.2.

3. To determine the number of ions produced when an ionic compound dissociates in dilute solution, test 0.005 M NaCl, $CaCl_2$ and $AlCl_3$. Results will indicate the number of ions produced per formula unit for each compound. Record in Data sheet C.3.

Data and Results (Measuring Conductance)

Name(s) ____

Part C.1 Total Dissolved solids in Drinking Water

Water sample	Conductance microsiemens (µs)	TDS (mg/L)
H_2O, tap water		
H_2O, spring water		

Part C.2 Comparing Solutions of Ionic vs. Covalent Compounds

Compound Name	Formula	Conc'n Molarity (M)	Conductance (µs)	Type of compound: covalent or ionic
H_2O, distilled				
Sodium iodide				
Potassium chloride				
Sucrose				
Glucose				

Part C.3 Finding Number of Ions/Formula Unit

Compound formula	Name	No of ions/ formula unit	Conc'n (M)	Conductance (µs) measured	Conductance (µs) literature
NaCl					
$CaCl_2$					
$AlCl_3$					

Questions:

1. If the maximum level of TDS permitted in drinking water is 1000 mg/L, what is the approximate conductance in µS of the water?
2. Compare conductance of ionic and covalent compounds from Part C.2.
3. Show that the conductance values in Part C.3 indicate approximately the number of ion produced for the 3 compounds tested. You can use the literature values listed in the table since they are more accurate than the ones measured with the Vernier probe.
4. The simple relationship of conductance to TDS works best in very dilute solutions, that is conductance in µS is about twice the TDS in mg/L. Can you think of a reason for this?

Instructor's Guide
#19 Conductance

Part C.1 Total Dissolved solids in Drinking Water

Water sample	Conductance microsiemens (µs)	TDS (mg/L)
H_2O, tap	*540 - 570*	*270 - 285*
H_2O, spring water	*200-220*	*100-110*

Part C.2 Comparing Solutions of Ionic vs. Covalent Compounds

Compound Name	Formula	Conc'n Molarity (M)	Conductance (µs)	Type of compound: covalent or ionic
Water, distilled	*H_2O*	---	*20 - 34*	*covalent*
Sodium iodide	*NaI*	*0.1*	*9140 – 9170*	*ionic*
Potassium chloride	*KCl*	*0.1*	*11,900*	*ionic*
Sucrose	*$C_{12}H_{22}O_{11}$*	*0.1*	*20 – 40*	*covalent*
Glucose	*$C_6H_{12}O_6$*	*0.1*		*covalent*

Part C.3 Finding Number of Ions/Formula Unit

Compound formula	Name	No of ions/ formula unit	Conc'n (M)	Conductance (µs) measured	Conductance (µs) literature
NaCl	*sodium chloride*	*2*	*0.005*	*650 – 680*	721
$CaCl_2$	*calcium chloride*	*3*	*0.005*	*1090 – 1110*	1251
$AlCl_3$	*aluminum chloride*	*4*	*0.005*	*1680 - 1700*	1650

Questions:

1. If the maximum level of TDS permitted in drinking water is 1000 mg/L, what is the approximate conductance in µS of the water?
2. Compare conductance of ionic and covalent compounds from Part C.2.
3. Show that the conductance values in Part C.3 indicate approximately the number of ion produced for the 3 compounds tested. You can use the literature values listed in the table since they are more accurate than the ones measured with the Vernier probe.
4. The simple relationship of conductance to TDS works best in very dilute solutions, that is conductance in µS is about twice the TDS in mg/L. Can you think of a reason for this?

---

1. *The conductance is twice the concentration in mg/L or about 2000 µS.*

2. *Ionic compounds have much higher conductance than covalent ones.*

3. *To set up the ratios of conductances assign '4' to $AlCl_3$.*

For $CaCl_2$: $\frac{\text{Conductance } AlCl_3}{\text{Conductance } CaCl_2} = \frac{4}{x}$ $\quad \frac{1650}{1251} = \frac{4}{3.03}$ $\quad x = 3.03$

For $NaCl_2$: $\frac{\text{Conductance } AlCl_3}{\text{Conductance } NaCl} = \frac{4}{x}$ $\quad \frac{1650}{721} = \frac{4}{1.74}$ $\quad x = 1.74$

The ratio of the number of ions predicted for $AlCl_3$ and $CaCl_2$ is 4 to 3 as expected.
You can round the number for NaCl to 2.

4. *In dilute solutions the ions are far apart and thus do not interact with each other, allowing the simple relationship (Conductance µS = 2 x TDS mg/L) holds.*
This is similar to the simple ideal gas law, PV = nRT, which works best at high temperature and low pressure when gas molecules are far apart and interactions between molecules can be neglected.

Equipment and Materials per group **Time:** 60 min

Items	**Number**	**Comment**
LabQuest	1	
Conductance probes	1	
Solutions	1 ea	Tap water, spring water, distilled water, sodium iodide (0.1M), potassium chloride (0.1M), sucrose (0.1M), glucose (0.1M), sodium chloride (0.005M), calcium chloride (0.005M), aluminum chloride (0.005M)
250-mL beakers	1	for rinse water
Kimwipes	1	
Wash bottle	1	Distilled water
Safety glasses	1 per student	

Instructor's Guide (cont'd)
#19 Conductance

Ideas/ Information

1. Other samples to test include pond or river water, commercial brands of bottled water, and drinks such as Gatorade.
2. From measuring its conductance it can be seen that aluminum chloride is an ionic compound. This is the case although the electronegativity difference for Al and to Cl bonds is less than 2. The criterion of > 2 for ionic compounds has exceptions.
3. Solutions can be prepared by adding grams (*g*) of the compound to a volumetric flask and then diluting with distilled water to the mark on the flask.

Compound	Molarity (mol/L)	*g* compound for 1 L solution	*g* compound for 500 mL solution
sodium iodide	0.1	15	7.50
potassium chloride	0.1	7.45	3.73
sucrose	0.1	34.2	17.1
glucose	0.1	18	9
sodium chloride	0.005	0.29	0.145
calcium chloride*	0.005	0.74	0.37
aluminum chloride*	0.005	1.21	0.60

* calcium chloride is the dihydrate: $CaCl_2 \cdot 2H_2O$

* aluminum chloride is the hexahydrate: $AlCl_3 \cdot 6H_2O$