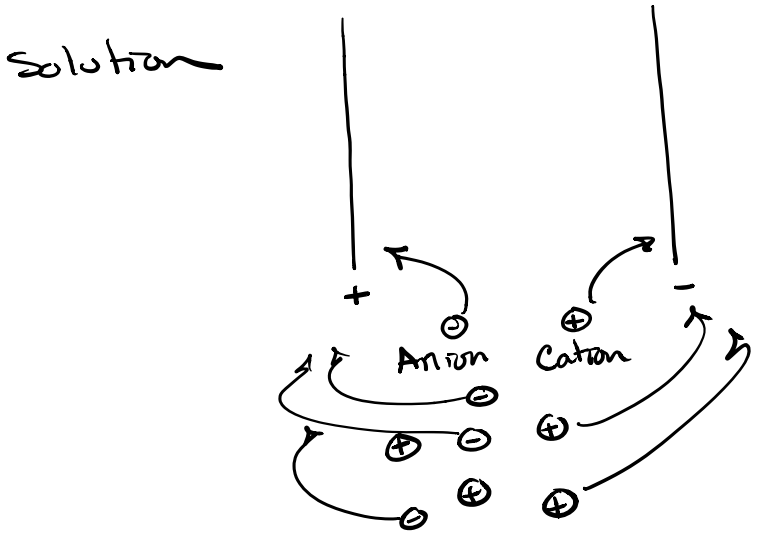
Electrolyte Lab

Electrolytic Solution – A solution which conducts electricity by having dissolved ions (Cations ⊕ & Anions ⊖)



Electrolyte – A compound that when dissolved in aqueous solution produces ions. (dissociates)

Two Types

A) Ionic compounds

B) Molecular Acids

Examples

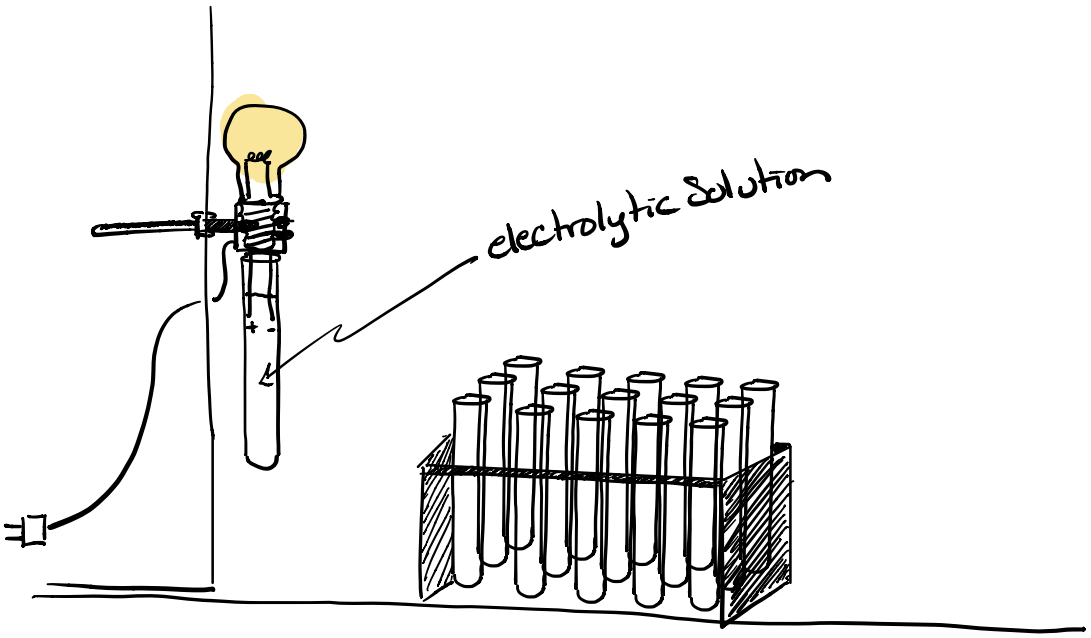
A) $NaCl_{(s)} \xrightarrow{H_2O} Na^+_{(aq)} + Cl^-_{(aq)}$

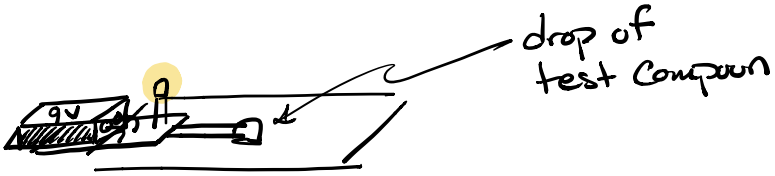
Electrolytic Solution

B) $HCl_{(g)} + H_2O_{(l)} \xrightarrow{H_2O} H_3O^+_{(aq)} + Cl^-_{(aq)}$

$HC_2H_3O_{2(l)} + H_2O_{(l)} \xrightarrow{H_2O} H_3O^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$

Testing For Electrolytic Solutions





outcomes

Bright LED ⇒ Strong Electrolyte

Dim LED ⇒ Weak Electrolyte

No light ⇒ non Electrolyte

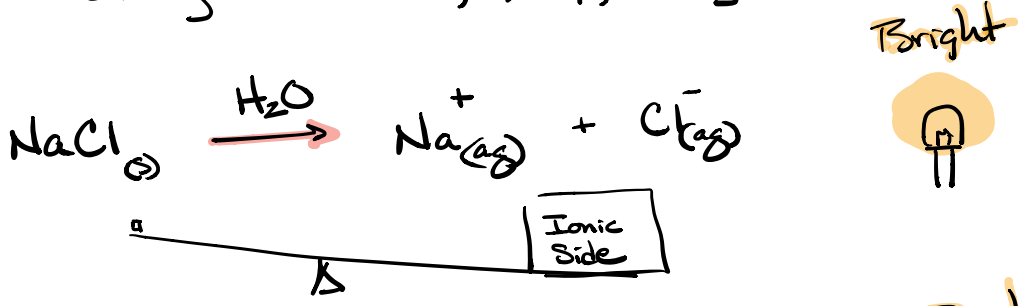
Strong Electrolyte → An an ionic compound or molecular acid that dissociates completely to produce many ions in solution

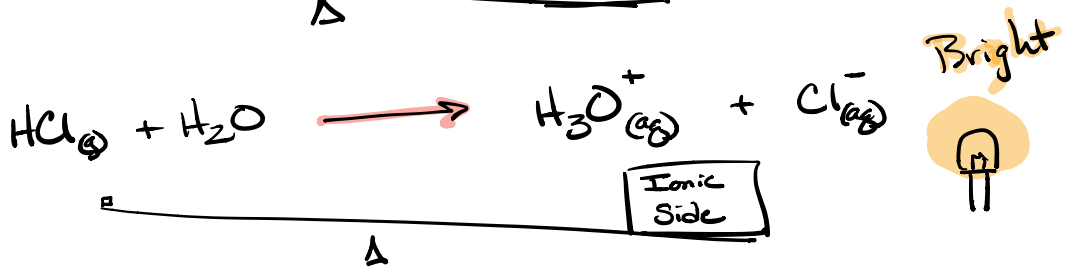
Cations & Anions that are always soluble

Group 1A & ammonium Na^+, K^+, Li^+, NH_4^+

Always Soluble anions NO_3^-, $C_2H_3O_2^-$

Strong Acid HCl, H_2SO_4, HNO_3





A weak electrolyte produces Some ions in Solution

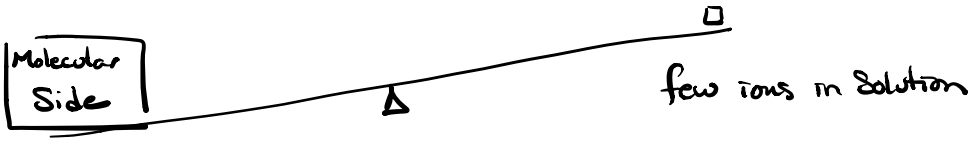
- Slightly soluble salts
- weak acids & bases

$PbCl_{2(s)} \overset{H_2O}{\rightleftharpoons} Pb^{2+}_{(aq)} + 2Cl^-$

Dim light

$HC_2H_3O_{2(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_2H_3O_2^-{}_{(aq)}$

Dim light



$NH_{3(l)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-_{(aq)}$

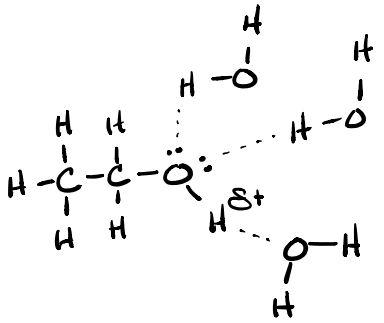
Dim light

A Nonelectrolyte does not produce ions when placed in aqueous solution.

$CH_3CH_2OH_{(l)} \xrightarrow{H_2O} CH_3CH_2OH_{(aq)}$

ethanol

No light ⇒ nonelectrolyte



dissolves through H-bonding & does not dissociate

Activity 19 – Electrolytes

Goals

- Observe and distinguish the conductive nature of solutions.
- Classify substances as strong, weak or non- electrolytes using conductivity.
- Understand the role of electrolytes in electrical systems.
- Design a valid experiment and evaluate the results.

Pre-lab Questions *(answer these on a separate sheet using complete sentences)*

1. Define the term electrolyte.
2. Are all electrolytes the same in their ability to conduct electricity? Explain.
3. How can you detect electrical conductivity?
4. Does your body conduct electricity? If so, give your reasoning or evidence.
5. Go to your refrigerator, kitchen cupboard or bathroom cabinet and identify three to five electrolytes. This does not require any special equipment, only an understanding of bonding in compounds and what happens when they dissolve in water.
6. Turn to the materials section of this lab. Classify the compounds as either ionic or molecular/covalent. Provide the missing formulas.

Concepts to Review

Ionic and molecular/covalent compounds
Molarity
Nomenclature
Observation vs. Conclusion
Solutions

Introduction

The most common use of the word electrolyte is found in the description of modern sports drinks. These beverages are said to replace the vital components lost in our sweat during physical exertion. In general, **electrolytes** are anything that, when dissolved in water, produce an electrically conductive solution. It was the discovery that some solutes conduct electricity when dissolved in water that won Svante Arrhenius the Nobel Prize in chemistry in 1903.[1] The concept that matter could fall apart in aqueous solution and form ions seemed to contradict the atomic theory and was initially not accepted. Today an understanding of electrolytes is foundational to understanding biochemistry, electrochemistry and a whole host of other disciplines.

A simple experiment can be done with an open circuit and an energy source (electricity from an outlet or a battery). If the electrodes of the open circuit are placed in a solution (and they themselves are not touching), the solution itself may be conductive. A critical component to this circuit is some means to "see" the completion of the circuit. Light emitting devices (LEDs) are included to give visual evidence of electrical conductivity to the observer; when the circuit is completed a light turns on.

Most batteries contain some kind of electrolyte. The lead batteries in most automobiles contain a sulfuric acid solution. Hybrid cars use two types of batteries, both a high voltage nickel metal hydride (NiMH) battery to provide a variety of advanced capabilities, but also the traditional lead-acid battery for starting in cold weather and powering other auxiliary loads.[2]

In today's experiment, several stock solutions of the same molarity will be tested. Based on their ability to complete an open circuit and turn on an LED to some degree, you will classify a substance as an **electrolyte**

[1]Beaty, W. Ridiculed Discoverers, Vindicated Mavericks. http://www.amasci.com/weird/vindac.html#j1 (accessed 6/16/07)
[2] Johnson Controls Hybrid Technology. http://www.johnsoncontrols.com/publish/us/en/hybrid_technology.html (accessed 6/16/07)

or a **nonelectrolyte**. From this experiment you will also be able to distinguish within the class of electrolytes which ones are **strong** and which are **weak**.

Since you will be asked to distinguish between strong and weak electrolytes, pay very close attention to the intensity of the light emitted in the conductivity experiments. The distinction between strong electrolytes, weak electrolytes and nonelectrolytes may be made apparent in the optional exercise using Hot Wheels cars that depend on electrolytes as fuel. When using stock solutions as fuel for Hot Wheels, make sure the experiments are consistent and reproducible (*precise*) so that the comparisons will be valid (*accurate*).

Safety

Act in accordance with the laboratory safety rules of Cabrillo College.
Wear safety glasses at all times.
Avoid contact with all chemical reagents and dispose of reactions using appropriate waste container.

Materials

Compounds for Part A

Calcium chloride
Sodium hydrogen sulfate
Sodium hydroxide
Sodium phosphate
Copper (II) sulfate
Zinc chloride
Sodium carbonate
Sodium hydrogen carbonate
Iron (III) chloride
Aluminum chloride

Compounds for Part B

Hydrogen peroxide
Hydrochloric acid (HCl(aq))
Ethanol ($CH_3CH_2OH(l)$)
Methanol ($CH_3OH(l)$)
2-Propanol ($CH_3CH(OH)CH_3(l)$)
Ammonia

Equipment required: Glass slide, Hot plate, Hot Wheels racer, Conductivity apparatus

Experimental Procedure

A. Conductivity Tests

1. Place one drop of the first ten solutions (calcium chloride, zinc chloride, sodium hydrogen sulfate, sodium carbonate, sodium hydroxide, sodium hydrogen carbonate, sodium phosphate, iron (III) chloride, copper (II) sulfate, aluminum chloride) onto 1 or 2 glass slides.
2. Use the conductivity apparatus to test for conductivity. Record your observations
3. Carefully place the glass slide onto a hot plate. Begin heating at a low setting, only increasing to higher settings if the solutions do not change or evaporate in a timely fashion. Avoid inhaling any vapors that may be coming off of the slide.
4. After evaporation of the solutions, carefully take the slide off the hotplate. Handle with tweezers or other tools only, as the slide is hot and can burn the skin. Test the resulting residue for conductivity. Record you observations. Clean and dry the apparatus after each measurement.
5. When the slide is cool, clean thoroughly and proceed.

B. Conductivity Tests Continued

1. Place one drop of the remaining solutions onto 1 or 2 glass slides.
2. Use the conductivity apparatus to test for conductivity. Record your observations
3. Carefully place the glass slide onto a hot plate. Keep the heat on a low setting, being very cautious to not inhale any vapors coming off the slide. Only increase the heat if the solutions refuse to evaporate. Do not overheat!
4. After evaporation of the solutions, carefully take the slide off the hotplate. Handle with tweezers or another tool as it is hot and requires caution. Test the residue for conductivity. Record you observations. Clean and dry the apparatus after each measurement.
5. When the slide is cool, clean it thoroughly and return it to Reagent Central.

C. Hot Wheel Fuel Cell (Optional – May be done as Demonstration)

6. Get a Hot Wheel car from the cart or your instructor. Important features include a fuel cell on the top and back of the car, a start button on the top of the car and a switch on the bottom of the car. The switch has three settings, from left to right, (1) on, using fuel cell, (0) off and (2) on, using batteries (Figure 1). Familiarize yourself with the car. Remove the fuel cell. Can you make the car run without it? How? Now fill the fuel cell with DI water and replace the fuel cell. Observe the behavior of the car when you have the switch in all three positions. These cars can travel up to 50 ft. using the fuel cells so be careful where you point them. What did you observe? Add a pinch of "salt" to the DI water in the fuel cell and test the three switch positions again. What did you observe?

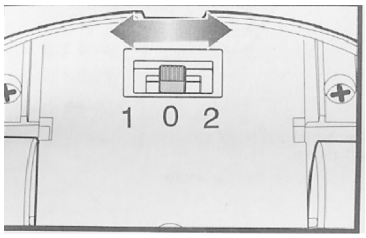


Figure 1. Switch on the underside of Hot Wheel car.

7. Once you are familiar with how the car works, test the hydrochloric acid, sodium hydroxide, ammonia and acetic acid solutions for "fuel efficiency". (They are all of the same molarity). This will require you to design an experiment that is as precise and accurate as possible. You are not confined to the geography of the lab space. Record your procedure and results.
8. Clean the "fuel cell" on your car (and the car itself if need be) and return it as soon as possible to the cart. Thoroughly clean your work area, making sure that all solutions have been removed using a damp towel and that the surfaces are also dried.

Activity 19 – Electrolytes

Name_____

Section_____ **Date**_____

Exercises A and B. Conductivity Tests

1. Complete the following data table based on your experimental results.

In solution — without water

Name and Formula	Appearance of Detector when Solution is Tested (**B**right, **D**im or **N**one)	Appearance of Detector when Dry Residue is tested (**B**right, **D**im or **N**one)
Calcium Chloride $CaCl_2$	Bright	None (No light)
Sodium hydrogen Sulfate $NaHSO_4$	Bright	
Sodium Hydroxide $NaOH$	Bright	
Sodium Phosphate Na_3PO_4	Bright	
Copper(II) Sulfate $CuSO_4$	Bright	
Zinc Chloride $ZnCl_2$	Bright	
Sodium Carbonate Na_2CO_3	Dim	
Sodium Hydrogen Carbonate $NaHCO_3$	Dim	
Iron(III) Chloride $FeCl_3$	Bright	
Aluminum Chloride $AlCl_3$	Bright	
Hydrogen Peroxide H_2O_2	None	
Hydrochloric acid HCl	Bright	
Ethanol CH_3CH_2OH	None	
Methanol CH_3OH	None	
2-propanol (rubbing alcohol) $CH_3\underset{OH}{C}HCH_3$	None	
Ammonia NH_3	Dim	

Group A Materials

Group B Materials

Structural differences (types of compounds)

* 2. What are the differences between the first group of solutions tested and the second?

* 3. Classify all of the reagents in used as strong electrolyte, weak electrolyte or non-electrolyte by writing the **name** of the reagent in the appropriate column:

Strong Electrolyte	***Weak Electrolyte***	***Non-electrolyte***

~~**Exercise C. Hot Wheel Fuel Cell**~~

~~1. Describe what you observed regarding the Hot Wheels car. Why was this toy included in this experiment?~~