Electrolytes

Introduction

ELECTROLYTES are substances that, when dissolved in water, permit PASSAGE OF AN ELECTRICAL CURRENT THROUGH THE WATER. Electrolytes produce IONS when dissolved in water, and the positive and negative ionic particles carry the electrical charge of the current through the water. Various substances can behave as electrolytes.

All SALTS are electrolytes, assuming they dissolve to a great enough extent in water. Salts in the solid state consist of an extended lattice of alternating + and - ions, and when added to water, this lattice breaks up, releasing the individual ions into the solution for conducting the current. One of the most important medical determinations is a patient's "electrolyte balance." Nerve impulses are sent through the body by electrical currents, and if the levels of electrolytes are incorrect, such nerve impulses may be incorrectly transmitted.

All ACIDS (H^+ producers) and BASES (OH^- producers) are electrolytes. Some acids, such as HCl, ionize completely when dissolved, and conduct electrical currents very well. Some bases, such as NaOH, also ionize completely when dissolved, and also conduct currents very well. Acids/bases such as HCl and NaOH, which conduct electrical currents very well, are called STRONG electrolytes. Other acids, such as acetic acid, do NOT ionize very well when dissolved in water, but rather exist in solution mostly as the molecular species. Some bases, such as ammonia and organic derivatives of ammonia, likewise do not ionize very well in water. Acids/bases that do NOT ionize well will not conduct very much electrical current, and are called WEAK electrolytes.

Some species NEVER ionize when dissolved in water, and will not conduct an electrical current through water at all. These are referred to as NON-electrolytes. Such substances are typically nonpolar, covalently bonded molecules (most typically, ORGANIC chemical substances).

The extent to which a solution will conduct an electrical current depends on other factors also. For example, we may have a substance such as NaCl, which is considered a strong electrolyte. But if a solution of NaCl is VERY DILUTE, there is so much DISTANCE between sodium ions and chloride ions, that effectively, the solution will not conduct electricity very well.

We can also change the ability of a solution to conduct electricity by chemically reacting the dissolved electrolyte. For example, we would expect a solution of acetic acid to conduct electricity very poorly. But if we were to add some chemical reagent to the solution that caused a chemical reaction to occur, then the electrolytic properties of the resulting solution may change.

CHEMICALS

Calcium chloride, $CaCl_2$—no major health risks
Sodium chloride, NaCl—no major health risks
Ammonium chloride, NH_4Cl—toxic by ingestion
Sodium sulfite, Na_2SO_3—irritant
Glucose or dextrose, $C_6H_{12}O_6$—no major health risks
Sucrose, $C_{12}H_{22}O_{11}$—no major health risks
Ethanol, C_2H_5OH—flammable liquid and toxic
Methanol, CH_3OH—flammable liquid and toxic
Hydrochloric acid, HCl—toxic, corrosive, and may cause burns
Acetic acid, $HC_2H_3O_2$—corrosive, toxic and may cause burns
Ammonia, NH_3—toxic, corrosive, may cause permanent fogging of soft contact lenses, and respiratory irritant
Sodium hydroxide, NaOH—corrosive, toxic and may cause burns

Procedure—METHOD 1 MACROSCALE

CAUTION! THE MEASUREMENT OF THE ELECTRICAL CONDUCTIVITY OF SOLUTIONS QUITE NATURALLY INVOLVES THE USE OF ELECTRICAL CURRENT. THERE IS THEREFORE A HAZARD OF ELECTRICAL SHOCK IN THIS EXPERIMENT. FOLLOW ALL INSTRUCTIONS PROVIDED BY YOUR INSTRUCTOR EXACTLY. DO NOT PERFORM ANY UNSPECIFIED MANIPULATIONS OF THE INSTRUMENTS INVOLVED. DO NOT TOUCH ANY PARTS OF THE APPARATUS THAT MAY CARRY THE ELECTRICAL CURRENT. WEAR SAFETY GLASSES AT ALL TIMES!!

In this experiment, you will study electrical conductivity of solutions by a "lightbulb" method:

The apparatus is connected to the 110 volt wall current (DANGER). The circuit contains a lightbulb, two electrodes for dipping into the solution to be tested, and certain internal resistances to match the current to the solutions. When the electrodes are dipped into the solution to be tested, the extent to which the lightbulb glows is an indication of the conductive properties of the solution. If the lightbulb glows brightly, the solution is a strong conductor. If the lightbulb glows only dimly, the solution is a poor conductor. If the lightbulb does not glow at all, then the solution is a non-conductor.

Your instructor will give particular instructions for the method. FOLLOW THESE INSTRUCTIONS EXACTLY TO PREVENT ANY DANGER OF ELECTRICAL SHOCK TO YOURSELF.

USE SMALL AMOUNTS OF ALL SOLIDS

1. Electrolytic properties of NaOH, HCl, Na_2SO_3, $CaCl_2$, NaCl, and NH_4Cl

A. Fill a 150 mL beaker about half way with water. Add about a quarter of a teaspoon of sodium chloride ($NaCl$) and stir to dissolve. Test for conductivity.

Repeat, using two of the other salts that are available in the lab.

Dispose of the salt solutions ($NaCl$, $CaCl_2$, Na_2SO_3 and NH_4Cl in the WASTE SALT SOLUTIONS bottle.

B. Obtain about 50 mL of 3 M HCl in a beaker and test for conductivity.

C. Obtain about 50 mL of 3 M $NaOH$ in a beaker and test for conductivity.

Dispose of the HCl and NaOH solutions in WASTE ACID-BASE container.

2. Electrolytic properties of NH_3 and CH_3COOH

Retain both of these solutions for use in part 3.

A. Obtain about 50 mL of 3 M acetic acid in a beaker and test for conductivity.

B. Obtain about 50 mL of 3 M ammonia solution in a beaker and test for conductivity.

3. Reaction effects:

Add the ammonia solution from part 2 to the acetic acid solution from part 2.
Test for conductivity.

The product of this neutralization reaction is the SALT ammonium acetate.

Dispose of this solution in the WASTE ACID-BASE container.

4. Electrolytic properties of isopropyl alcohol and sugar (sucrose or dextrose)

A. Fill a 150 mL beaker about halfway with water. Add about a teaspoon of sugar (sucrose or dextrose) and stir to dissolve. Test for conductivity.

B. Repeat using half a beaker of water and a few mL of alcohol as solute.

Dispose of both of these solutions in the WASTE SUGAR/ALCOHOL bottle.

5. Dilution effects:

A. Place about 40 mL of water in a 150 mL beaker. Add a "pinch" of NaCl and stir to dissolve. Test for conductivity.

B. Add 100 mL of water to the beaker to dilute the solution. Stir to dissolve and test for conductivity.

C. Transfer the contents of your 150 mL beaker to a 600 mL beaker.
Add another 100 mL water, stir, and test for conductivity.

D. Repeat the process of adding water and testing for conductivity until the beaker has been filled to capacity.

Dispose of this solution by pouring it down the drain.

Procedure—METHOD 2 MICROSCALE

ABOUT THE FLINN CONDUCTIVITY APPARATUS

This apparatus is safe since only a 9-volt battery is used. No electric shock is possible. Two (2) light emitting diodes (LED's) are used to add a quantitative plus to the meter. One LED is green; the second is red. The green LED requires more voltage than the red LED.

This meter cannot be easily shorted out since an on-off switch has been provided to disconnect the circuit even during storage. The electrodes are easily interchanged or replaced.

The meter is sufficiently sensitive that it displays even low conductivity. Tap water shows a low to medium conductivity.

Very low or no conductivity will result in neither LED lighting. Low conductivity will give a dim light to the red LED and while the green remains off. A scale is affixed to the meter and is also shown on the next page.

CONDUCTIVITY CHART

Scale	Red LED	Green LED	Conductivity
0	Off	Off	Low or None
1	Dim	Off	Low
2	Medium	Off	Medium
3	Bright	Dim	High

4	Very Bright	Medium	Very High

USE SMALL AMOUNTS OF ALL SOLIDS

1. Electrolytic properties of NaOH, HCl, Na_2SO_3, $CaCl_2$, NaCl, and NH_4Cl

A. Half fill one well of a 24 hole well plate with distilled water. Add a small amount of NaCl to the well and stir with a stirring rod. Test for conductivity.

Repeat, using two of the other salts that are available in the lab

B. Add about 20 drops of 1.0 M HCl (hydrochloric acid) to a well and test for conductivity. Repeat the procedure using 1.0 M NaOH.

2. Electrolytic properties of NH_3 and CH_3COOH

A. Add about 20 drops of 1.0 M CH_3COOH (acetic acid) to a well and test for conductivity. Repeat this procedure with 1.0 M NH_3 (ammonia or ammonium hydroxide).

3. Reaction effects:

Add the 20 drops of the 1.0 M ammonia solution to the well containing the acetic acid solution. Test for conductivity.

The product of this neutralization reaction is the SALT ammonium acetate.

4. Electrolytic properties of isopropyl alcohol and sugar (sucrose or dextrose)

A. Half fill a well with distilled water. Add a small amount of sucrose or glucose to the water. Stir with a stirring rod. Test for conductivity.

B. Half fill a well with distilled water. Add 20 drops of isopropyl alcohol (rubbing alcohol) to the well. Mix and test for conductivity.

Dispose of the contents of your well plate into the beaker labeled HAZARDOUS WASTE, Electrolyte Solutions.

5. Dilution effects:

A. Place about 40 mL of water in a 150 mL beaker. Add a “pinch” of NaCl and stir to dissolve. Test for conductivity.

B. Add 100 mL of water to the beaker to dilute the solution. Stir to dissolve and test for conductivity.

C. Transfer the contents of your 150 mL beaker to a 600 mL beaker.
Add another 100 mL water, stir, and test for conductivity.

D. Repeat the process of adding water and testing for conductivity until the beaker has been filled to capacity.

Dispose of this solution by pouring it down the drain.

REMEMBER TO TURN IN THE YELLOW COPY OF YOUR LAB NOTEBOOK TO YOUR TA.

Electrolytes

Report Sheet (30 Points)

Name ______________________ Lab Day __________________

Instructor ________________________ Date _____________________

Record your observations as to the electrical conductivities of the samples you tested: (strong electrolyte, weak electrolyte, or non-electrolyte)

NaCl____

Na_2SO_3____

$CaCl_2$____

NH_4Cl ____

3 M HCl ____

3 M NaOH ____

3 M acetic acid ____

3 M ammonia ____

Upon mixing the acetic acid and ammonia_______________________________________

Sugar ____

Alcohol ____

Dilution Effects:

NaCl (before dilution) ____

After adding 100 mL H_2O ____

After adding 200 mL H_2O ____

After adding 300 mL H_2O ____

After adding 400 mL H_2O ____

After adding 500 mL H_2O ____

After adding 600 mL H_2O ____

Electrolytes

Post-Lab Questions (40 Points)

Name ________________________ Lab Day __________________

Instructor _________________________ Date _____________________

1. Although ammonia and acetic acid themselves are weak electrolytes, a mixture of these two solutions behaved as a strong electrolyte. Why?

2. Write the reaction that occurs when ammonia and acetic acid are mixed.

3. In one portion of this experiment you added a pinch of NaCl to a beaker, and you added progressively more and more water to the beaker. Explain why the light gets dimmer and dimmer.

4. You are given three bottles labeled a, b, AND c. The bottles contain pentane (C_5H_{12}, a liquid), calcium chloride ($CaCl_2$) solution, and aqueous ammonium hydroxide (NH_4OH, ammonia dissolved in water). Describe a procedure to identify which liquid would be in each bottle.

5. The device used in this experiment only measured the relative conductivity of the solution tested, that is, whether the solution contained a strong, weak or non-electrolyte. A more elaborate conductivity meter can determine a numerical value that can be related to the number of ions in solution. Arrange the following 0.1 M solutions in order of increasing conductivity and explain why you chose this order.

0.1 M $FeCl_3$ 0.1 M $MgCl_2$ 0.1 M NaCl 0.1 M glucose ($C_6H_{12}O_6$)

Electrolytes
Preliminary Questions (10 Points)

Name ________________________ Lab Day _________________

Instructor ___________________________ Date ____________________

1. Classify each of the following as STRONG, WEAK, or NON-ELECTROLYTES: nitric acid, sulfuric acid, potassium hydroxide, calcium hydroxide, methylamine (an ammonia derivative), benzoic acid, salicylic acid, glucose, and oxygen gas

   Nitric acid ______________________________

   Sulfuric acid ______________________________

   Calcium hydroxide ______________________________

   Potassium hydroxide ______________________________

   Methylamine (an ammonia derivative) ______________________________

   Benzoic acid ______________________________

   Salicylic Acid ______________________________

   Glucose ______________________________

Oxygen gas ____

2. Define the term weak electrolyte.

3. What is the proper disposal of the salt solutions in this experiment?