What's the Conductivity of Gatorade?

Subject Area(s)	Science and Technology
Associated Unit	None
Associated Lesson	None
Activity Title	What's the Conductivity of Gatorade?
Header	Insert image 1 here, right justified

Image 1

ADA Description: Students measuring the conductivity of Gatorade

Caption: Image 1: none

Image file name: Students with conductivity meter_Img1.jpg

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Group Size	3-4
Expendable Cost per Group	$5
Grade Level	3
Time required	45 minutes

Summary

Using a conductivity meter constructed from the Basic stamp microcontroller, Parallax Board of Education and typical circuit elements, students measure the conductivity of various salt and water solutions. The conductivity of the salt solution is indicted by the number of LEDs (light emitting diodes) that are illuminated on the meter. Students will construct a calibration curve using known amounts of table salt dissolved in water, and their corresponding conductivity readings. This calibration curve will then be used to estimate the total equivalent amount of salt contained in Gatorade (or an unknown salt solution).

Engineering Connection

The concepts of electricity are a vital component of our industrial society. The efficient transport of electrons through electrolyte solutions is critical for applications such as fuel cells, water treatment facilities, electrochemical cells and batteries. Moreover, this activity reinforces the critical concepts of electrical engineering such as the relationship between electrical potential, current and resistance, as well as the typical circuitry components that represent these phenomena. For example, the concept of conductors is extended to ions that are dissolved in solution to illustrate why electrolytic solutions support the passage of a current.

The conductivity meter is constructed using the Basic Stamp microcontroller, and a 555 timer (in astable multivibrator mode, where the conductivity meter is modeled as one of the resistors). As the resistance of the solution changes with the addition of salt, the frequency of the 555 timer's output changes accordingly. The conductivity meter is programmed such that the output of the 555 timer controls the activation of the LEDs, where more LEDs are turned on with solutions of higher concentrations of salt.

Using the conductivity meter, students will record the conductivity of various solutions of water and known quantities of salt. Once completed, this calibration curve will be used to estimate the equivalent amount of salt that is contained in an unknown solution, for example Gatorade.

Engineering Category

Relates science concept to engineering

Relates math concepts to engineering

Keywords

Electricity, ions, current, charge, electrolyte, circuit, capacitor, resistor, microcontroller

Educational Standards

- New York Science, 2010, PS 4.1a: Observe, identify, and describe a variety of forms of energy: sound, heat, mechanical, chemical and electrical
- New York Science, 2010, PS 4.1d: Interaction of matter and energy

Pre-Requisite Knowledge

Basic understanding of circuits and electricity

Learning Objectives

After this activity, students should be able to:

- Use conductivity to estimate the amount of salt in Gatorade
- Explain how electricity travels through liquids

Materials List

Each group needs:

- Table Salt
- Water
- Cups
- Basic Stamp Conductivity Meter ($110 – see building instruction for further details)

Introduction / Motivation

There are many examples in our everyday life that use the properties of electricity. With our ever changing world, there is a push to make our conventional methods of producing and storing electricity more economical and environmentally friendly. Devices such as fuel cells and electric motors show promise for future applications such as automobiles. As such, developing media that can store, support and effectively propagate the flow of electrons is and will be a vital area of research for our society.

For electrons to pass through a liquid environment there must be charge carriers present in the solution to accept electrons from one electrode and deposit them at the other, thus completing the circuit. These charge carriers, known as ions, transition from a neutral state in solid form, to charged entities in solution. For example sodium chloride exists as a neutral crystal of sodium and chloride atoms in its solid form. When placed in water, the atoms of sodium and chloride begin to move away from each other as they interact with water molecules. In doing so, they no longer maintain a neutral state. Rather, they become charged ions, where the chlorine atoms adopt a negative charge and the sodium atoms take on a positive charge. It is the presence of these ions that allow electrons to be transferred from a solid conductor, such as metal wire, to an electrolytic solution.

However, when measuring electrical signals in a liquid environment certain precautions must be adhered to. In order for electrons to travel from a solid conductor (the conductivity probe in this case) to ions in solution, a chemical reaction must take place at the surface of each probe. The ions that are present in solution are mobile, and move about accepting electrons from one probe and depositing them on another, thus allowing a current to pass through the solution, completing the circuit. However, as the current continues to flow in the circuit in one direction, over time, there will be a depletion of ions in solution, as well as an accumulation of species at the surface of the probes, which would inhibit the flow of electrons. The surface of the probe becomes polarized leading to a diminished current flowing through the circuit.

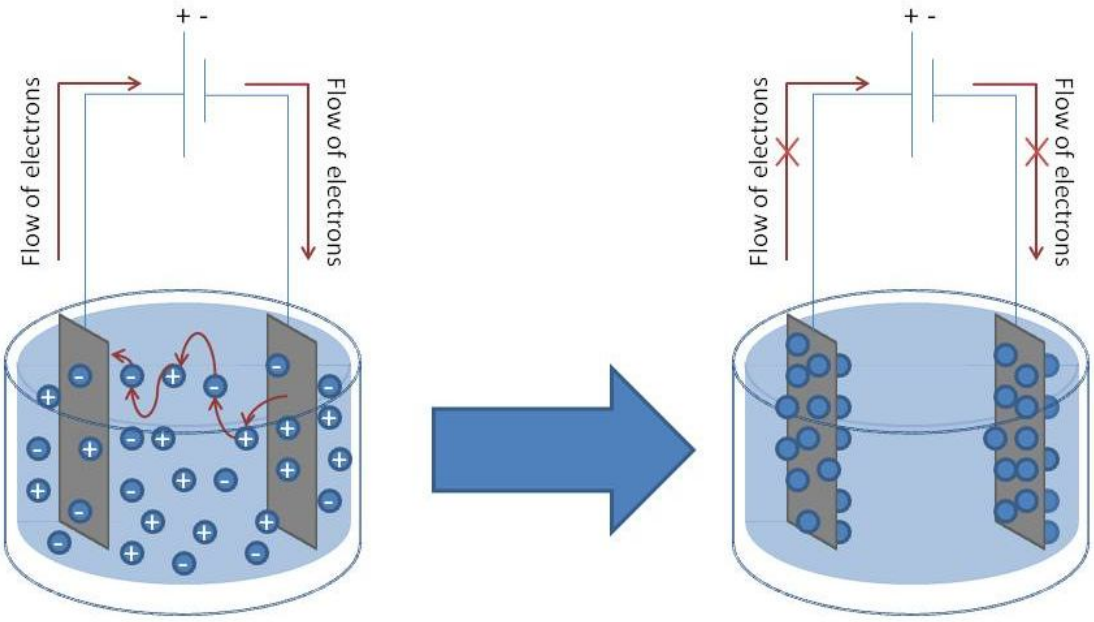

Figure 1

ADA Description: Electrode polarization.

Caption: Figure 1: As a direct current flows through the circuit, there is a depletion of ions at the surface of the probe. This causes polarization of the probe, leading to diminished current.

Image file name: Electrode Polarization_Fig1.jpg

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To overcome this phenomenon, an alternating signal is used to drive the current in opposite directions through the conductivity circuit. The Basic stamp conductivity meter uses an integrated circuit called the 555 timer to accomplish this.

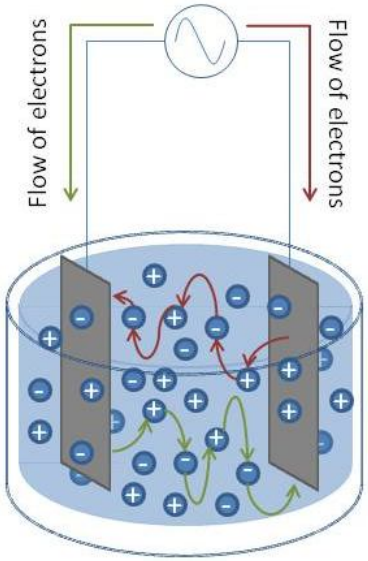

Figure 2

ADA Description: AC signal in an electrochemical cell.

Caption: Figure 2: Using an alternating voltage forces current to flow in both directions within the cell in a continuous manner.

Image file name: AC signal in an electrochemical cell_Fig2.jpg

Vocabulary / Definitions

Word	Definition
Ion	an electrically charged atom or group of atoms formed by the loss or gain of one or more electrons
Electrolyte	a conducting medium in which the flow of current is accompanied by the movement of matter in the form of ions
Capacitor	a device for accumulating and holding a charge of electricity, consisting of two equally charged conducting surfaces having opposite signs and separated by a dielectric
Resistor	a device designed to introduce resistance to the flow of current into an electric circuit
Electron	an elementary particle that is a fundamental constituent of matter, having a negative charge of 1.602×10^{-19} coulombs, a mass of 9.108×10^{-31} kilograms, and spin of $^1/_2$, and existing independently or as the component outside the nucleus of an atom.
Conductivity	A measure of how well materials permit the passage of electricity

Procedure

Before the Activity

- Distribute the 5 salt packets to all groups of students.
- Each group should have a Basic Stamp conductivity meter. Make sure that the switch for the basic stamp is in the "0" (off) position

With Students

1. Turn on the Basic Stamp conductivity meter by moving the 3 position switch to the "1" position. The 5 LEDs will blink indicating that it is ready to be used. If the LEDs do not turn on, you may need to press the reset button.

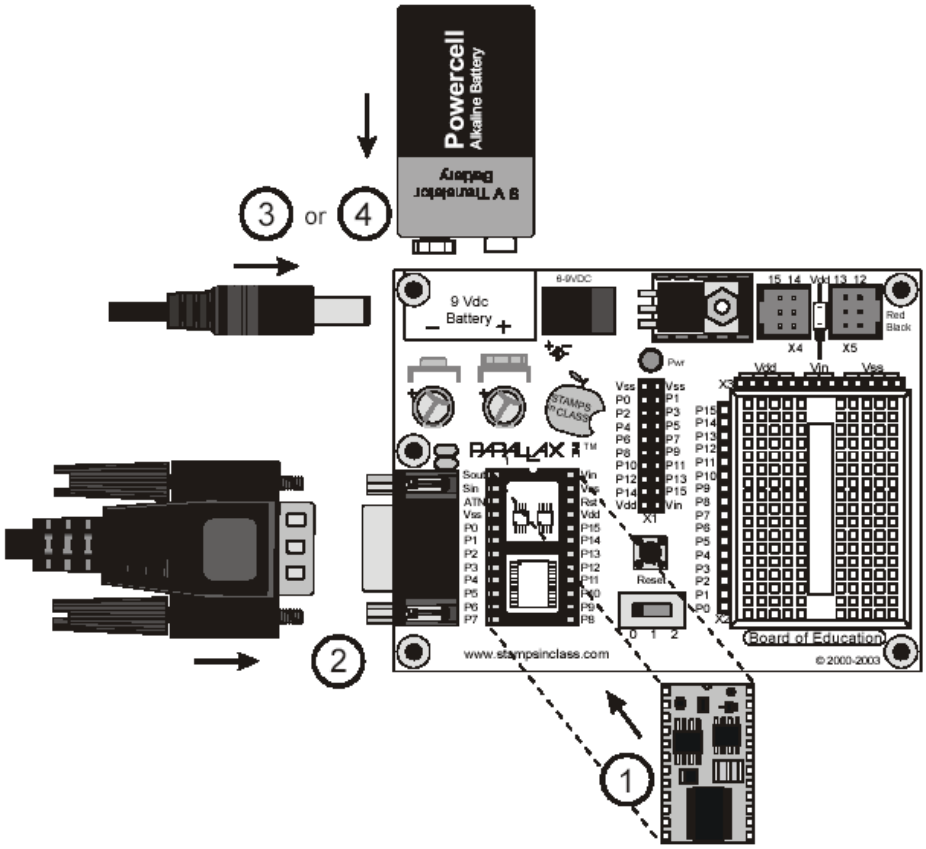

Figure 3

ADA Description: Board of Education. BASIC stamp Module, Battery and Serial Cable.

Caption: Figure 3: The Basic Stamp module (1) should be connected to the Board of education as shown. The reset switch is the round button in the middle of the board, directly above the 3-position switch (0-1-2).

Image file name: Board of Education_Fig3.png

2. Starting with tap water, fill a cup to half its capacity and immerse the conductivity probe (the two screws) up to about the blue cap and record the number of LEDs that are lit onto the worksheet. Add one packet of salt to the cup and stir.

Immerse the conductivity probe again and record the number of LEDs that are lit. Repeat this process, adding one packet of salt to the cup at a time, until all LEDs all 5 LEDs are lit. Make sure that the depth at which the conductivity probe is immersed in the solution is the same every time.

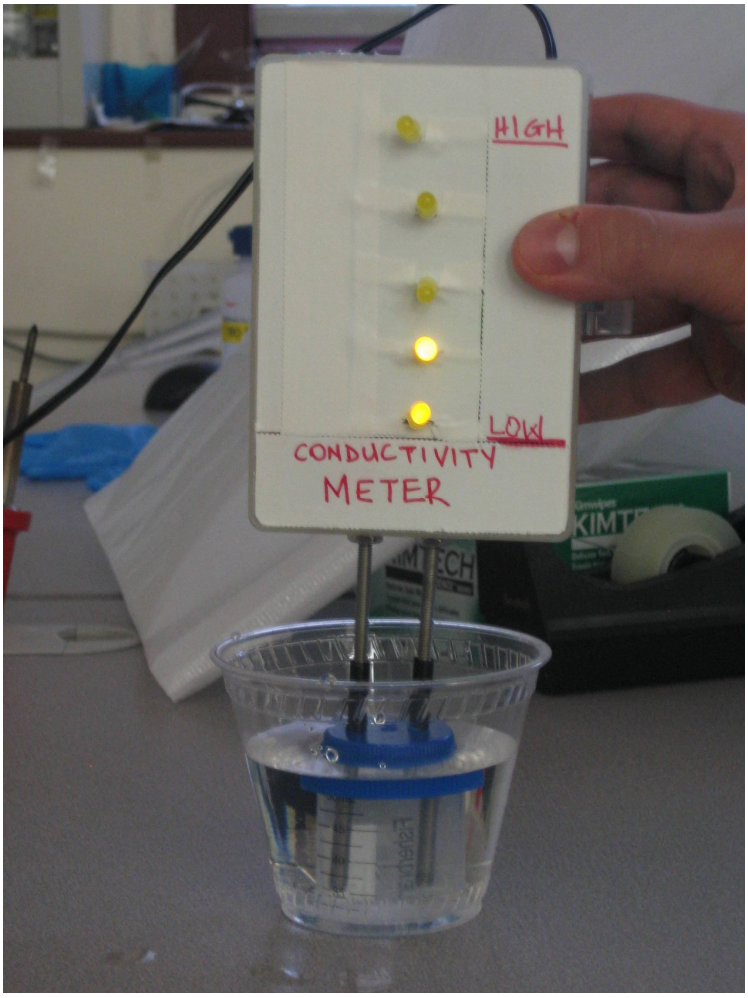

Image 2

ADA Description: The Basic Stamp Conductivity Meter

Caption: Image 2: The conductivity meter in use. The number of activated LEDs is directly proportional to the amount of salt present in solution.

Image file name: Conductivity Meter_Img_2.bmp

3. Once a complete table of conductivity readings for various packets of salt has been compiled, plot these data points. Use the graph on page 2 of the worksheet.
4. Using a ruler, draw a best fit line that is equidistant to all points on the graph. This graph will serve as your conductivity calibration curve.

5. Pour some Gatorade (or any unknown salt solution that is within the calibration range of the meter) into a cup, to about the same level as the water in step 2. Immerse the conductivity probe, and measure its conductivity.
6. Using the conductivity calibration curve constructed in step 4, estimate the equivalent packets of salt that is contained in Gatorade.

Assessment

Activity Embedded Assessment

Analysis

Students should be evaluated on the collection of data for the calibration curve. All curves should be linear with a positive slope. Students should be able to deduce how many equivalent "packets of salt" are contained in an unknown solution.

Attachements

What's the conductivity of Gatorade – Worksheet.doc
What's the conductivity of Gatorade – Conductivity Meter Building Instructions.doc
What's the conductivity of Gatorade – Program.bs2

Activity Extensions

None

Additional Multimedia Support

None

References

1. Dictionary.com. Dictionary.com, LLC. Accessed August 2, 2009 (Source of some vocabulary definitions, with some adaption) http://dictionary.reference.com/
2. Parallax.com. Parallax inc. Accessed August 2, 2009 http://parallax.com/

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