Electrolyte Challenge: Orange Juice Vs. Sports Drink

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Experimental Procedure

Making a Simple Conductance Sensor

1. Cut a 5 cm (2 inch) piece from the drinking straw.
2. Cut two pieces of copper wire, each about 12 cm (5 inches) long.
3. Wrap the two pieces of wire around each end of the straw, leaving 5 cm tails of wire, as shown in Figure 1.
    a. Make sure you wrap the wires snugly around the straw so they do not slide back and forth.
    b. **Caution:** Make sure the two wires **do not touch**. The conductance sensor will not work if the wires touch, and touching wires will blow the fuse in your multimeter.

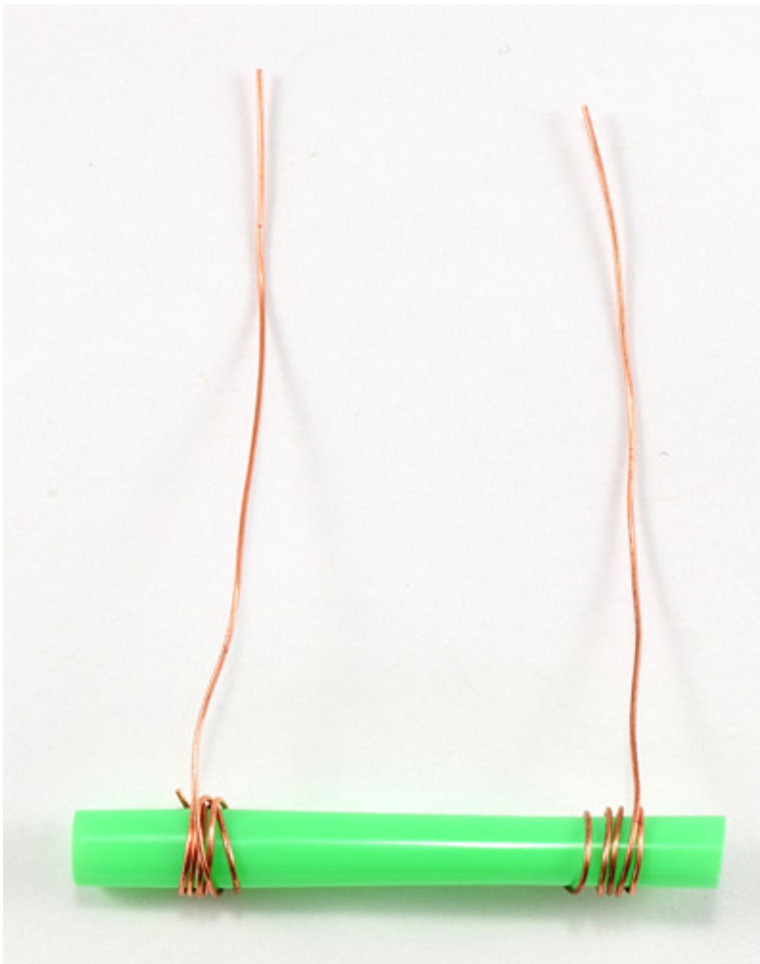

Figure 1. The conductance sensor consists of a non-conducting core (a piece of disposable drinking straw) with copper wire wrapped around the ends. The ions in the solution complete the circuit, enabling current to flow between the copper wires.

Making a Conductance Measuring Circuit

1. Connect the multimeter probes as shown in Figure 2.
    a. For now, make sure your multimeter is off.
    b. Plug the black probe into the port labeled "COM".

c. Plug the red probe into the port labeled "VΩmA".

Figure 2. Picture of how to connect the multimeter probes.

2. Assemble your circuit as shown in Figures 3 and 4. There are several important notes before you begin.
   a. **Important:** Never let exposed metal from the different alligator clips or probes, or the conductance sensor wires, touch each other directly. This will create a short circuit, which could damage your multimeter by blowing out the fuse. Always keep the various wires a safe distance away from each other, as shown in Figure 4.
   b. Always make sure you connect the alligator clips to the exposed metal parts of probes or wires, not to the colored insulation. This is easy to do with the multimeter probes since the metal tips are rather large, but can be difficult with the battery snap connector since the exposed metal parts at the ends of the wires are fairly small. If you connect to insulation instead of the metal, your circuit will not work.
   c. Your work area can get messy with all the wires. You can use twist ties to bundle them up and keep your work area neater, as shown in Figure 4. This also helps you avoid short circuits by making sure the metal parts do not bump into each other.
   d. Connect the snap connector to the 9 V battery.
   e. Use an alligator clip to connect the red multimeter probe to the red wire from the battery snap connector. The colors of the alligator clips do not matter; they do not need to match the colors shown in Figures 3 and 4.
   f. Use an alligator clip to connect the black multimeter probe to one wire of the conductance sensor.
   g. Use an alligator clip to connect the black wire from the battery snap connector to the other wire of the conductance sensor.

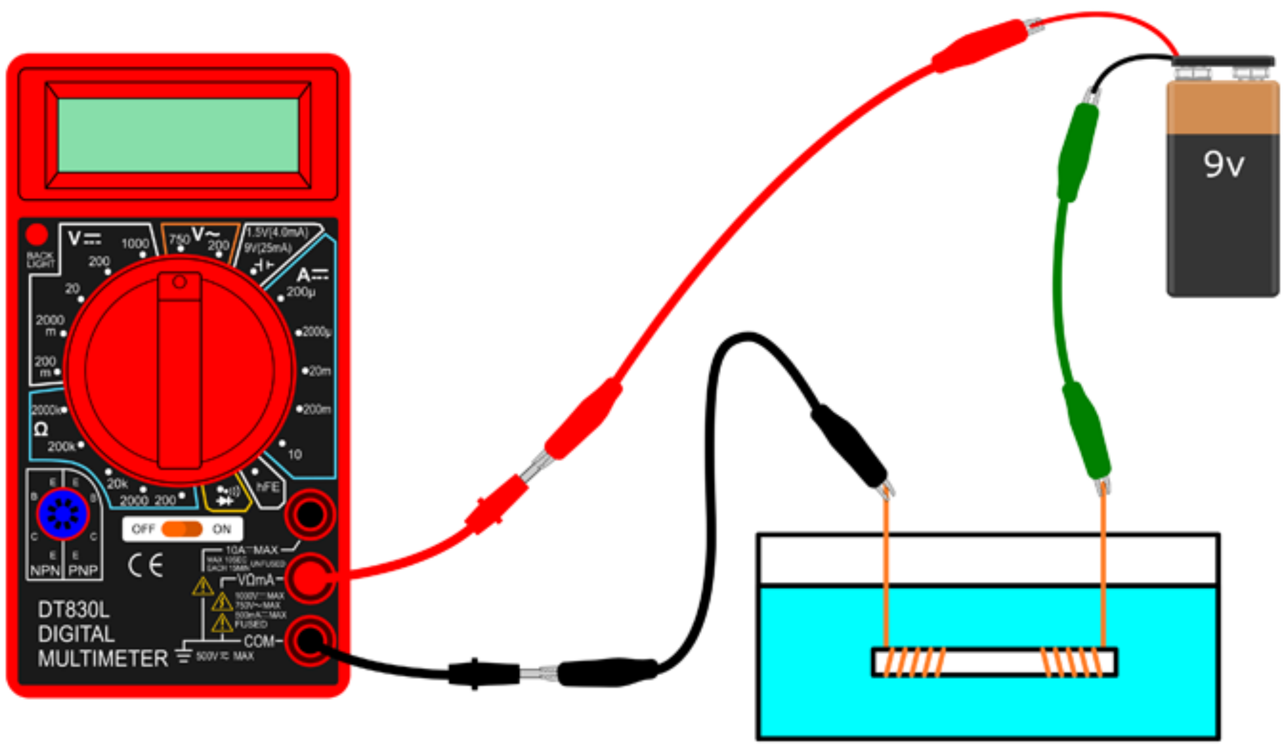

Figure 3. A schematic of how you should build the circuit. The colors of the alligator clips do not matter.

Figure 4. A picture of the completed conductance measuring circuit. The colors of the alligator clips do not matter.

8. Double-check your connections to make sure they match those shown in Figures 3 and 4 before you proceed.
9. Note that this is an **open circuit** because of the gap between the wires wrapped around the (non-conducting) straw. You will use the electrolytes in the solutions to close the circuit. The amount of current that flows is proportional to the electrolyte concentration.

Setting Up Your Test Solutions

1. Clean the eight small bowls with warm soapy water, rinse thoroughly, and dry them right away with a clean dry cloth or paper towel. This will remove ions in the tap water. If you want to be extra careful, rinse the bowls with distilled water before drying.
2. Put masking tape on all eight bowls.
    a. Label four bowls with the following labels: *Distilled Water, Tap Water, Sports Drink,* and *Orange Juice.*
    b. Label one bowl *Tap Water Rinse.*
    c. Label the final three bowls as follows: *dH_2O Rinse 1, dH_2O Rinse 2,* and *dH_2O Rinse 3.* Use these bowls to rinse the conductance sensor between uses.
3. Pour each liquid into the appropriately labeled bowl. All of the solutions should be at room temperature. The liquids should be deep enough to completely submerge the coiled part of the conductance sensor. Make sure you fill each bowl to the same level, so the sensor can be submerged to the same depth. This is important because the extra surface area of the

"tail" part of the wires in contact with the liquid will affect the conductance.

Measuring the Conductance

1. Turn your multimeter on and set it to measure direct current in the 200 µA range. This is the "200µ" on the upper-right part of your multimeter dial, as shown in Figure 5. This is a high-sensitivity setting that you will *only* use to measure distilled water, which is less conductive than the other liquids.

Figure 5. Multimeter dial set to the 200 microamp (µA) range, represented by the "200µ."

2. Place the conductance sensor in the distilled water. Make sure the straw is completely immersed. You will need to submerge the straw to the same depth each time. This is probably easiest if you let it rest on the bottom of the bowl.
3. Read the current on the multimeter.
    a. Always make your readings quickly and remove the conductance sensor from the solutions immediately. Over time, the copper wires will start to dissolve in the solutions, skewing your results. In addition, **electrolysis** may take place, forming tiny bubbles on your conductance sensor that can interfere with your data.
    b. Your readings may fluctuate slightly, and this is normal. Try to record an "average" reading, or a number in the middle of the range that you observe.
4. Record the current (the readings from your multimeter) in your lab notebook in a data table. Make sure to record that this reading is in *microamps* (µA). Remember that a microamp is one millionth of an amp.
5. You do not need to rinse your conductance sensor this time because you used distilled water.
6. Now set your multimeter to measure direct current in the 200 mA range. This is the "200m" on the right side of the multimeter dial, as shown in Figure 6. This setting can measure higher current values, which you need to do for the more conductive liquids.

Figure 6. Multimeter dial set to the 200 milliamp (mA) range, represented by the "200m". Be careful not to get this mixed up with the "200m" on the other side of the dial. That setting is for measuring voltage, not current.

7. Now place the conductance sensor in the tap water. Make sure you submerge it to the same depth that you did when you measured the distilled water.
8. Record the current. Again, make sure you record the correct units. Since your multimeter dial is set to 200m, this reading is in milliamps (mA), not microamps (µA).
9. Tap the sensor on a paper towel to remove drops of tap water. Then rinse the sensor in distilled water, dipping it briefly in each of the three distilled water rinse bowls.
10. Place the sensor in the sports drink and measure the current (you do not need to change the multimeter dial). Record the current in your lab notebook, and remember to record units of milliamps.
11. Tap the sensor dry, and then dip the sensor in tap water, then in the three bowls of distilled water.
12. Place the sensor in the orange juice and measure the current. Record the current in your lab notebook.
13. Rinse the sensor in the tap water and then in all three distilled water bowls.
14. Repeat steps 1–13 in the "Measuring the Conductance" section two more times to obtain a total of three measurements for each liquid.
    a. Remember that you will need to switch back to the "200µ" setting to measure the distilled water, and then use the "200m" setting to measure tap water, sports drinks, and orange juice.
    b. Always remember to submerge the conductance sensor to the same depth for each trial. This is important since the conductance depends on the amount of surface area of the wire that is in contact with the liquid.
    c. Record all data and measurements, including the proper units, in the data table in your lab notebook.
15. Average your current measurements across the three trials for each liquid.
16. Before you proceed, convert all of your current measurements to amps (A).
    a. Convert microamps (µA) to amps (A) by dividing by 1,000,000. For example, 20 microamps is 0.00002 amps (20/1,000,000 = 0.00002).
    b. Convert milliamps (mA) to amps (A) by dividing by 1,000. For example, 20 milliamps is 0.02 amps (20/1,000 = 0.02).
17. Calculate the conductance for each liquid by using Equation 1 (#equation1) from the Introduction.
    a. The current (I) for each liquid is the average current that you calculated. Make sure you convert the current to amps. Do not use milliamps or microamps in Equation 1.
    b. Since the voltage was always from your 9 V battery, you can use 9 V as the voltage (V) in your calculations. In reality, the voltage is likely to be slightly less than 9 V due to *internal resistance* of the battery. But this change is quite small and nearly constant across the experiment. Because it is so small, you do not need to take it into account. If you have a second multimeter, you can adapt the circuit to monitor both current and voltage across the battery at the

same time.

18. Which liquid has the highest conductance, meaning the most electrolytes?

Frequently Asked Questions (FAQ)

FAQ for this Project Idea available online at https://www.sciencebuddies.org/science-fair-projects/project-ideas/Chem_p053/chemistry/electrolyte-challenge-orange-juice-vs-sports-drink#help.