Prelab Briefing and Worksheet

**Build A Simple Chemical Probe**

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**Objective**

In this exercise, you’ll build a chemical probe that can be used to estimate ion concentrations and classify substances as strong or weak electrolytes, acids, and bases. (In next week’s lab, you’ll use the probe to determine the stoichiometry of a chemical reaction.)

**Goals**

- Explain what electrical conductivity is.
- Prepare solutions by serial dilution.
- Build a simple conductivity probe using a breadboard, a voltmeter, a resistor, and an LED.
- Calibrate the probe using a range of known ion concentrations (0.1-0.00001 M NaCl).
- Determine the relative conductivity of aqueous solutions of various compounds using the probe. Classify the solutes as strong, weak, or nonelectrolytes on the basis of their conductivities.
- Estimate the salinity of tap water, estuarine water, and seawater using your conductivity probe.

**Required Reading**

Read sections in your text on electrical properties of aqueous solutions and reactions of acids and bases (Hill & Petrucci pp. 132-148).

**Background**

What is electrical conductivity? Electricity is a flow of charged particles. The charged particles can be electrons (as when electricity flows through a wire) or ions (when
electricity flows through soil or water). Conductivity is a measure of how easily electrons or ions can flow through a material.

Some materials conduct better than others. Metals are generally good conductors of electricity because they contain extremely mobile electrons that quickly carry charge from one end of a wire to the other.

Solutions that contain ions can conduct electricity. Ions in solution are less mobile than electrons in metals, so solutions don’t conduct electricity as well as metal wires do. The more ions that are present in a solution, the more readily it will conduct electricity. Conductivity measurements are used to estimate the total concentration of ions in the solution. Environmental scientists, engineers, and geologists use conductivity measurements to monitor salinity or total mineral content in water.

What are electrolytes?

Electrolytes are compounds that ionize (break up into ions) when dissolved or melted.

Strong electrolytes ionize almost completely. Ionic compounds tend to completely dissociate into positive and negative ions. For example, a solution of the strong electrolyte KBr contains potassium ions (K+) and bromide ions (Br-) but no KBr molecules. Strong electrolyte solutions have high electrical conductivity, unless they are very dilute. Strong electrolytes are usually ionic compounds, including the strong bases (alkali metal hydroxides and alkaline earth metal hydroxides). The strong acids HCl, HBr, HI, HNO₃, H₂SO₄, and HClO₄ are also strong electrolytes.

Weak electrolytes only partially ionize. For example, a solution of the weak electrolyte HNO₂ contains some hydrogen ions (H⁺) and nitrite ions (NO₂⁻), but also many undissociated HNO₂ molecules. At moderate or high concentrations, weak electrolyte solutions will have lower electrical conductivity than solutions of strong electrolytes. The lower the concentration, the more completely weak electrolytes ionize. Weak electrolytes are usually organic acids, nitrogen-containing bases, or weak inorganic acids.

Nonelectrolytes do not break up into ions. For example, sugar exists entirely as electrically neutral sugar molecules in solution. Because sugar does not ionize, its solutions do not conduct electricity. Nonelectrolytes are usually molecular (covalent) compounds.

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The sensor. To measure conductivity, we’ll need to
device with properties that change in an easily measurable way when conductivity changes. A pair of wires dipped into the sample solution will serve as a conductivity sensor, since solutions of different conductivity will allow different amounts of current to flow between the wires.

We'll use a piece of ribbon wire which has exposed wires on the tip. A bit of insulation left between the wires keeps them from touching (and keeps them a constant distance apart). One wire will be connected to a +5 V terminal; the other wire will be grounded. Ions in the solution will carry charge from one wire to the other. When the probe is placed in a solution that contains ions, the ions can carry charge between the wires. The more ions there are, the more electricity will flow. We can then measure the electric current directly or indirectly, as a voltage.

If apply five volts of electric potential across the wires, we can symbolize the apparatus as shown in Figure 3.

Measuring sensor response. We need some way to actually indicate the current flowing between the sensor wires. We can place a device called a light-emitting diode (LED) on the positive terminal of our sensor wire. The LED emits light when sufficient current flows across it. When the solution contains enough ions to conduct electricity, the LED will light. The more ions there are, the brighter the light will be.

Diodes act as one-way valves for electricity: current can pass in one direction only. The longer wire on the LED must be attached to the more positive terminal, or the LED is backwards and current will not flow through it. The symbol for the LED is shown in the schematic below. The symbol shows that the diode should “point” from the
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The circuit shown in Figure 7 protects the LED with a current-limiting resistor. The symbol for the resistor is a zig-zag line. We've also clipped a voltmeter across the poles of the resistor. The voltage across the resistor should change when the conductivity of the solution between the probe wires changes. Voltage readings can be calibrated by taking measurements on solutions with known ion concentrations.

In lab, you'll plot readings taken from the voltmeter against ion concentrations in a salt solution. You will then read this plot to estimate the salt concentration in tap water, estuarine water, and sea water. You will also test the conductivity of five compounds and classify the compounds as strong electrolytes, weak electrolytes, or nonelectrolytes.

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4. Which solution would you expect to have the highest conductivity reading: 0.1 M Ba(OH)₂ or 0.1 M NaOH? Explain.
5. An unknown substance is dissolved in water and tested with the conductivity apparatus. The LED lights dimly and the meter reads 0.22 V. Can you classify this substance as a strong, weak, or non-electrolyte? Explain.
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Weak electrolytes only partially ionize. For example, a solution of the weak electrolyte HNO₂ contains some hydrogen ions (H⁺) and nitrite ions (NO₂⁻), but also many undisassociated HNO₂ molecules. At moderate or high concentrations, weak electrolyte solutions will have lower electrical conductivity than solutions of strong electrolytes. The lower the concentration, the more completely weak electrolytes ionize. Weak electrolytes are usually organic acids, nitrogen-containing bases, or weak inorganic acids.

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