Conductivity Measurements

Calibration Notes

Measuring Conductivity

Conductivity is a measure of the number of mobile ions per unit volume in a solution. At first glance, one might consider this a simple measurement: Place two conducting plates in a solution, connect a battery and current meter, and read the current. The resistance of the solution could be calculated by Ohm’s law: \( R \) (Ohms) = Voltage (Volts) / Current (Amps). Conductance is simply the reciprocal of resistance. Conductance = 1/R. The units of conductance used to be Ohm spelled backwards (Mho), but conductance is now expressed in Siemens (S), or micro Siemens, \( \mu \)S.

Figure 1: An ionic solution has equal numbers of positive ions (red) and negative ions (blue). This model attempts to measure solution resistance by giving electrons to positive ions and picking them up from negative ions.

The problem with this model is that ions in a solution are free to move, and will quickly migrate – positive ions to the negative plate and negative ions to the positive plate, as shown in Figure 2. Once the ions are all pulled to one side or the other, and once their charges are neutralized, the current in the circuit will fall to zero. This can happen very fast.

Figure 2: Because ions are mobile, they will quickly gather at the oppositely charged plate. Once the ions are separated and neutralized, current stops in the external circuit. You can’t make a measurement.

This problem is solved by rapidly alternating the polarity of the “battery” voltage. In the MicroLab FS-522, the voltage is changed from + 100 millivolts to – 100 millivolts about 1000 times per second. This keeps the ions mixed up.
Once, right at the end of each voltage cycle, the MicroLab very quickly measures the current caused by ions against the plates accepting or giving up electrons. This measurement, made on a randomly mixed group of ions, is a good measure of the number of ions per unit volume of the solution, or the ionic concentration of the solution.

**The Conductance Electrode**

Conductance electrodes are quite simple. They consist of two parallel conducting plates made of a material that will not chemically react with the ions or solvent in the solution. This limits the materials that can be used for conductivity electrodes basically to platinum or gold and carbon (graphite).

The MicroLab Model 160 conductance electrode uses two parallel graphite electrodes. They are imbedded in a ½” epoxy rod, with a slot milled near the end to allow the solution to contact the bare graphite.

![Figure 3: MicroLab provides a small alternating voltage to the electrodes. Because this voltage spends exactly as much time positive as negative, at the end of each "cycle" of applied voltage, the ions are completely mixed up. The current measurement is made exactly at this point of maximum randomness.](image)

Here’s where care of the electrode is important. The manufacturing process produces graphite electrode surfaces that are clean and within about ± 10% in area from electrode to electrode. This means that, if one wants to compare measurements, you have to calibrate the electrode by immersing it in several standard solutions and making a calibration graph.

**Cleanliness:** The electrode surface has to be very clean. This means that it has to be well rinsed with distilled water before it is used and before it is stored. If ionic compounds (salts) are allowed to dry on the electrode, it can be cleaned by soaking for several hours in dilute HCl, at room temperature. Then rinse very well with distilled water. It won’t work if it is not clean.

**Hydration:** The surface of the electrode has to be covered with water molecules prior to placing it in the test solution. You can do this by soaking the electrode in distilled water for several minutes before use.

**Bubbles:** Air bubbles can form on the surface of the graphite electrode as you transfer it from one solution to another. You can stir with the electrode or even tap it gently against the side of the beaker to get rid of the bubbles.
Calibration

Turn on your MicroLab FS-522 and start the software. Select the “MicroLab Experiment” icon.

Now click the “Add Sensor” button, and choose “Conductivity Probe”.

Click on the conductance input, and then select either the “High Range” (0-20,000 uS) or the “Low Range” (0-2000 uS). Plug your conductance probe into the MicroLab FS-522.

Then click “Next” to get ready to calibrate the sensor.
Now Click “Perform New Calibration”. You are ready to start your calibration process.

**Mixing Calibration Solutions:**

Use the calibration solution menu below to mix up several (at least three) standard solutions in a range specified by your instructor. You can distribute this work around the lab, each group mixing up one calibration standard. You can make “half-batches” with 500 mL of water and half the amount of salt.

<table>
<thead>
<tr>
<th>Table 1</th>
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<tbody>
<tr>
<td><strong>Preparation of Conductance Standards</strong></td>
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<tr>
<td><strong>Grams of NaCl per liter (1000.0 mL) of deionized or distilled water:</strong></td>
</tr>
<tr>
<td>2.000 g</td>
</tr>
<tr>
<td>1.500 g</td>
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<td>1.000 g</td>
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<tr>
<td>0.500 g</td>
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<td>0.200 g</td>
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<td>0.150 g</td>
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<tr>
<td>0.100 g</td>
</tr>
<tr>
<td>0.050 g</td>
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Conductance values are at 25 °C

Click “Add a Calibration Point” to prepare to calibrate your conductance electrode.

This screen will come up. The display with a green bar is a rate-of-change meter. It centers when the probe is in equilibrium and stable. The Sensor History graph shows a history of the calibration process.
If the red rate of change needle moves too fast, you can reduce the sensitivity by clicking the “Show Advanced Calibration Controls” box, and then adjusting the slider to an appropriate sensor sensitivity.

Enter the actual value of the standard in the “Actual Value” box. Place the conductance electrode in your conductivity standard, and wait for it to equilibrate. You can watch the history graph go up and stabilize. Stir with the electrode until this graph stabilizes and the needle settles in the green “equilibrium” bar on the rate of change meter. Then click “OK”.

The calibration graph will come up, with one calibration point added:

Repeat this process with at least two additional standards. You need at least one more standard than the order of the line fit you choose to use. If you do a linear fit, two points define the line and the third point proves that you are right if it is on the line. If you do a second-order polynomial fit, you need four points. Three will define the line, and the fourth will prove that you are right.

When you are done, click “Accept and Save this Calibration”. You will have to save the file – it should default into the calibration folder in your MicroLab software folder. Make sure you know where it was saved.
Here is a sample calibration graph. This graph used a linear line fit, and produced a correlation coefficient of 0.999935 – Four 9’s is very good. A perfect fit would produce a correlation coefficient of 1.0000.

Once the calibration graph is saved, you are ready to do your experiment. You can use this calibration with the same probe in a future experiment.