Week 11
Ion-selective Electrodes

“Is it right to probe so deeply into Nature’s secrets? The question must here be raised whether it will benefit mankind, or whether the knowledge will be harmful.”

—Pierre Curie
Physicist

The determination of the concentration of both cations and anions in solutions can take several forms. So far in this course you have seen spectroscopy and titrations. For several potential analytes (like H$_3$O$^+$, Na$^+$, K$^+$, Ca$^{2+}$, Cl$^-$, NO$_3^-$, F$^-$) the ion selective electrode (ISE) represents one of the most attractive and straightforward means of determining solution concentrations.

An ideal quantitative technique would involve placing a “probe” in the sample to be measured and then “reading out” the concentrations of all chemical species present. Potentiometric techniques approach this ideal situation. The probe (the ISE) is placed into a sample solution and is connected to a potentiometer, a device for measuring voltage differences between the ISE and a reference electrode. If the conditions of the measurement are well understood and controlled, the potential difference between these two electrodes can be related to the concentration of a specific chemical species present in the sample.

**Educational Objectives:** A student who has successfully completed this experiment will be able to
- prepare a series of standards using a serial dilution,
- make voltage measurements using an ISE,
- generate a calibration plot using voltage measurements, and
- determine the molarity of an ion in solution from ISE measurements.

**Experimental Objectives:** A student who performs this experiment is asked to
- prepare a series of standards using a 1:10 serial dilution,
- measure the potential of the standards and samples using a millivolt meter and an ISE,
- generate calibration plots, and
- calculate the [Ca$^{2+}$], [Na$^+$] and [H$_3$O$^+$] for all samples using the ISE measurements.

**Background**
The concept of a “probe” as a device that can read out information without altering the substance being analyzed is as old as science. The first such probe was a thermometer. Probes to provide chemical information have been more elusive and have only become practical with the advent of electrochemical measurements. The first ion selective electrode was a pH electrode developed in the first decade of the 20th century. But it wasn’t until the 60’s that the field developed to the point where practical probes for other things became available. Today there are electrodes specific for many different ions and molecules that are extensively used in medicine and industry.
Ion selective electrodes are discussed in great detail in chapter 9 of your technique book. You will need to review this material before continuing.

**Overview**
The problem put to your group is to determine the $[\text{Na}^+]$, $[\text{Ca}^{2+}]$ and $[\text{H}_3\text{O}^+]$ of your water samples. You will do this by using a sodium ion selective electrode to determine the $[\text{Na}^+]$, a calcium ion selective electrode to determine the $[\text{Ca}^{2+}]$ and a pH electrode to determine the $[\text{H}_3\text{O}^+]$. Each electrode is unique and will have to be handled separately. The activities required to determine the ion concentrations in your samples can be summarized as follows:

- Set up the electrode and prepare it to make measurements
- Make the appropriate standard solutions.
- Measure the potentials of all standards and check for proper electrode function and construct a calibration plot.
- Measure the potential of all samples.
- Finally, you will measure the pH of all your samples.

**Procedure**
Details on using ion selective electrodes are given in chapter 9 of the technique book. Detailed instructions on how to use Logger Pro to collect ISE data can be found here.

[http://slb.faculty.arizona.edu/sites/slb.faculty.arizona.edu/files/152/CHEM%20152%20NaCa%20ISE%20Inst%20Logger%20Pro.pdf](http://slb.faculty.arizona.edu/sites/slb.faculty.arizona.edu/files/152/CHEM%20152%20NaCa%20ISE%20Inst%20Logger%20Pro.pdf)

Your group will need to make measurements of $[\text{Na}^+]$, $[\text{Ca}^{2+}]$ and $[\text{H}_3\text{O}^+]$ for all of your water samples. The sodium and calcium electrodes will need to be calibrated which will require you to have a series of solutions of known concentration for each ion. Your group will need to prepare these solutions.

These solids will be available for making standard solutions.

- Anhydrous sodium chloride, NaCl
- Anhydrous calcium chloride, CaCl$_2$

**Data Analysis**
There are relatively few calculations involved for this analysis. You will need to do the following:

- Calculate the concentrations of your standard solutions based on the dilutions performed.
- Construct a calibration plot suitable for interpolating values.
- Interpolate ion concentrations from the calibration plot.

The relationship between the ion concentration and the measured potential is logarithmic. To create a linear calibration plot you will need to plot potential against log[ion] as shown in figure 9-4 of the technique book. This means that the interpolated values will be log[ion] values. These will need to be converted to concentration values.

**The Water Project Report**
Unlike all other reports in this course, this is a GROUP REPORT - one report for the entire group to contain the names of all who contributed to its construction. It is due next week.

The report is to cover all three weeks of the project and incorporate the results, but not the raw data and calculations. The following is a summary of the four required sections.

- **Introduction.** This is to include the hypothesis, all background information necessary to understand the hypothesis and a discussion of why the particular samples were selected. It is
also to include a description of how each of the three techniques contributed useful data to the resolution of the hypothesis.

- **Calculation.** For the combination of the results from the three techniques
- **Results.** This section should collate the results from the three techniques into one complete results presentation.
- **Discussion.** Conclusions regarding your initial hypothesis, how those conclusions are supported by your data and what additional experiments could be performed to improve your conclusions.