Punnett, Campbell and Vacala, Trevor - Integrating Microlab into General Chemistry I & II Experiments

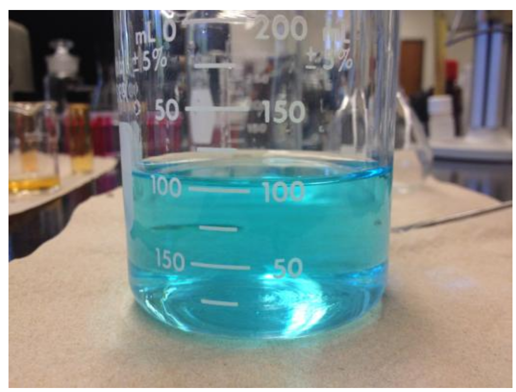
Introduction

Our project was centered around a new piece of equipment, Microlab, which has the capability to replace or add to equipment currently in use in the Chemistry department. Microlab is, on whole, smaller, cheaper, and more efficient than the equipment used in many of the experiments in the General Chemistry laboratory sections. Though it is not necessarily more accurate than existing instruments, its other qualities stand to serve the Chemistry Department and future chemistry students greatly. The goal of our summer project was to redo General Chemistry experiments with the use of Microlab and to check if data obtained from Microlab was worse, comparable, or better than data obtained using existing instruments. Microlab could only be integrated in some laboratory experiments based on the sensors Microlab has to offer. Thus, out of the 26 experiments performed in the General Chemistry laboratory sections, only 11 of these experiments could be redone.

Experiment 1: Absorbency Plots of Vitamin B12

One of the first experiments done in chemistry lab is to make a absorbency plot, or Beer's Law plot, of standard solutions of vitamin B12. Beer's Law states that the amount of light absorbed by a solution is directly proportional to the concentration of the solution. Measurements of absorbed light are made by an instrument call a spectrophotometer, which is just one of the instruments offered in Microlabs' arsenal. Standard solutions of varying and known concentration are made for an accurate Beer's law plot, which can then be used to identify the concentration of an unknown solution based on its absorption. A set of standard solutions were made at the same concentrations used in the laboratory sections. Microlab actually had a smaller correlation coefficient (a statistically calculated number used to judge the accuracy of data) then the instruments used in laboratory, but it performed comparably well at one-half and one-fourth concentrations. Thus, Microlab could serve as reasonable substitute for current instruments and be more cost efficient since it performs better at lower concentrations. Ocean Optics, a smaller spectrophotometer, was also tested with all of the same samples used in Microlab. It obtained quality data at all concentrations and could also replace machines currently in use.

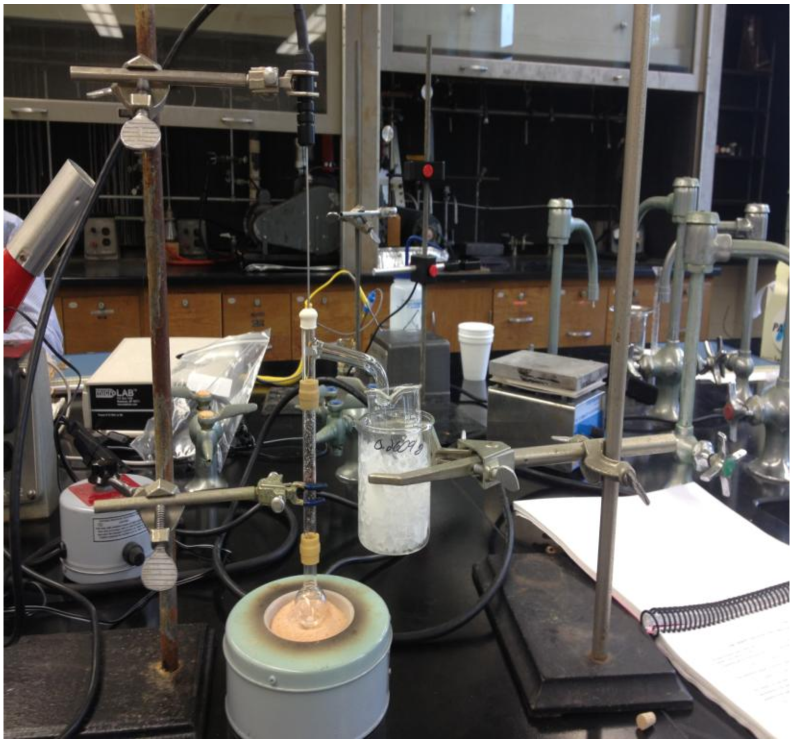
Experiment 2: Copper (II) Ions in $[Cu(NH_3)_4]SO_4$-H_2O



The same procedure was used in this experiment as in Experiment 1. A set of standard solutions were made of copper tetraamine ($Cu(NH)_4$) in 6 molar nitric acid according to the same concentrations used in laboratory sections. Both Microlab and Ocean Optics data were as accurate as data obtained used by current machines. Both Microlab and Ocean Optics could be easily integrated into this experiment.

Experiment 3: Conductors and Non-conductors

This experiment is slightly tweaked from its laboratory counterpart. In regular lab, the conductance of several ionic solutions of varying concentration and strength are tested using the lightbulb test. This test consists of dipping two electrodes into the desired solution; the solution completes the circuit to the lightbulb and the intensity from the resulting light can be used to estimate the conductance of tested solution. This approximation of intensity consists of four possibilities: non-existent, weak, strong, and very strong. Microlab enables students to obtain quantifiable data with the use of its conductivity probe. Only conductive solutions were chosen to test the conductivity probe, which amounted to five in total. All five solutions acted as predicted, with lower concentration and less conductive solutions having a smaller conductance values than high concentration and highly conductive solutions. If Microlab were integrated into this experiment, it would give data which may better convey the ideas of conductance.



Experiments 4: Fractional Distillation

The main idea of fractional distillation is that two or more substances in a solution together can be separated by their different boiling points, which is dependent on the strength of their intermolecular forces. The apparatus for this experiment requires a solution of cyclopentane and cyclohexane to be heated until they boil. A thermometer is set up at the top of the apparatus to measure the temperature of passing gasses. After the gasses pass the thermometer, they condense and drip out of the apparatus. The drips are counted and the temperature at which they fell is recorded. This information can be graphed and can clearly illustrate a separation of boiling point, since good graphs results in a two clusters of points at separate temperatures. For the Microlab experiment, a thermistor was used instead of a thermometer and a drop counter was used to automatically count the drops as they fell. This setup resulted in unreliable data. A second trial was conducted without the drop counter. The results were more reliable, but not comparable or better than data obtained from standard lab protocol. A third trial was conducted with a insulation around exposed parts of the thermistor, which could have previously effected results. Again, however, the results obtained were not good enough to replace the standard lab protocol. An improper calibration of the thermistor used may be at the heart of the problem. This problem should be fixed before Microlab gets integrated in General laboratory use.

Experiment 5: The Nerst Equation and Formation Constants

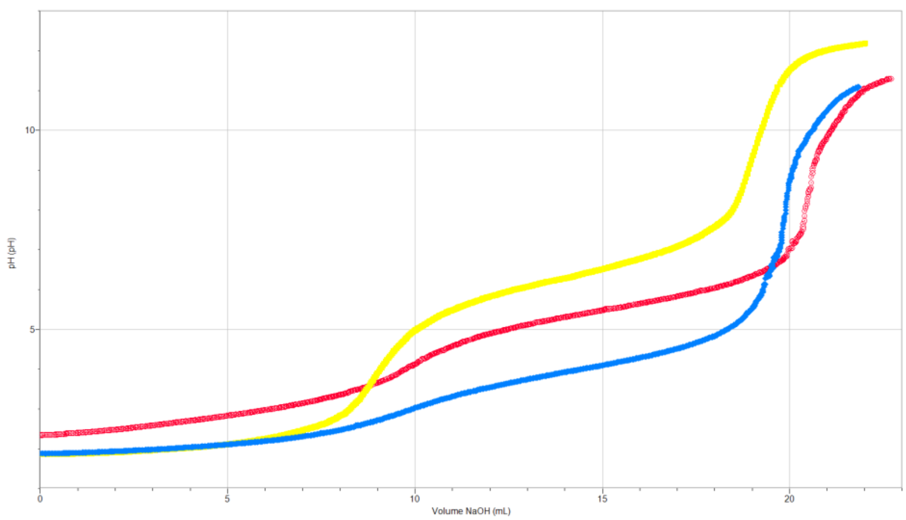
This experiment relies on experimentally obtained data from electric half-cells to calculate formation constants of silver, a numerical value which describes the bonding behavior of silver with ions at equilibrium. This experiment was done using the Microlab voltmeter and multiple half-cell module. This experiment relies heavily on precise measurements of voltages between cells, which the Microlab voltmeter does not do as well as current instruments. The Microlab voltmeter only gives data to two significant figures, while current instruments give three. Formation constant values obtained from Microlab data were significantly lower then the real values. There is nothing wrong with the voltmeter, but it may not be sensitive enough to give accurate data in present laboratory conditions. The one upside to using Microlab half-cell module is that is uses fewer supplies then the current lab conditions. Thus, if the experiment used materials that gave higher half-cell voltages, then Microlab could integrated as a more cost-effective alternative.

Experiment 6: Enthalpy Changes in a Copper and Zinc Reaction

This lab exercise is typically not conducted in General lab, but was tested anyway. Enthalpy describes the amount of heat that is given off or taken in by a reaction. A negative enthalpy describes a reaction which gives off heat (exothermic) while a positive enthalpy corresponds to one which takes heat to proceed (endothermic). The goal of this experiment is to measure the heat given of by the exothermic reaction between zinc metal and copper ions in an aqueous solution. The amount of heat given off (given in Joules per mol of reactants) can be calculated from the change in temperature- the highest recorded temperature minus the lowest. The experimental apparatus was relatively simple. Two styrofoam cups were used to insulate the reacting copper and zinc solution and a thermistor was placed into the solution to record temoerature. Three trials of this experiment were done. All three experimentally obtained values for the enthalpy change were lower than real values, but were fairly consistent between each other. This leads to the conclusion that there may again be some calibration issues with the thermistor or that there was some other consistent error between them all. More work needs to be done with the thermistor before it can be reliably used in General lab.

Experiment 7: Titration of a Diprotic acid with a standardized base

This experiment is usually a two-week project, standardizing the base the first week and then titrating the unknown acid the second. However, Microlab makes it possible to combine both into a one lab experiment. The base used in this experiment was roughly 1 molar sodium hydroxide (NaOH). Using Microlab's constant volume drop dispenser, we were able to easily titrate three unknown masses of potassium hydrogen phthalate (KHP) and calculate the exact molarity of the base. After the base was standardized, we then used it to titrate three unknown diprotic acids. A diprotic acid differs from a monoprotic acid, in that its structure contains two hydrogen atoms per molecule of base consumed. Microlab's drop counter and pH meter were used in this experiment in order to graph pH vs. time. As a result, a beautiful graph of the titration was created. The graph highlights the two endpoints of the titration, only possible with a diprotic acid. The results from this experiment, as well as its ease compared to the traditional method, make Microlab a great substitution for our current equipment.

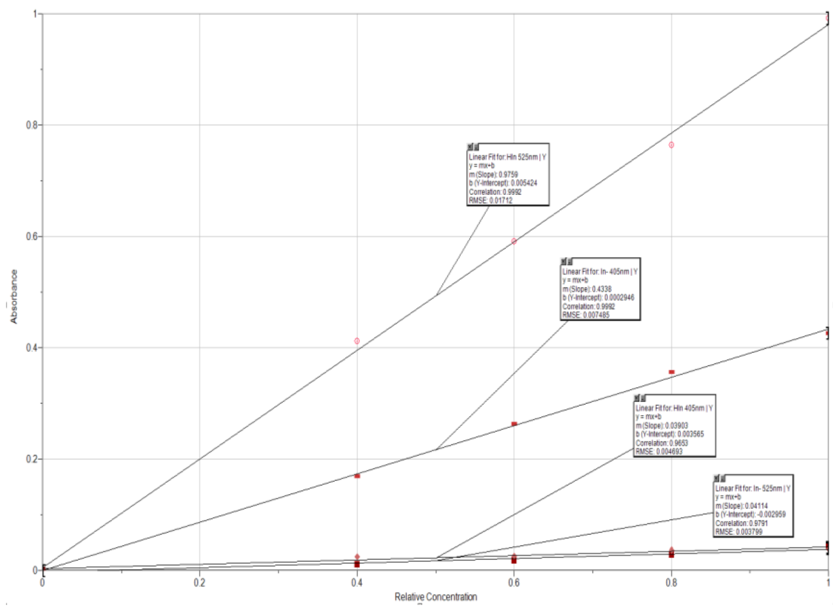


Experiment 8: Neutralization

This lab experiment consisted of neutralizing an acid with a base, and measuring the change in temperature of the reaction. The change in temperature corresponds to the change in enthalpy of the net ionic reaction. In this experiment, 2 molar hydrochloric acid (HCl) and 2 molar sodium hydroxide (NaOH) were used as the acid and base, respectively. Traditionally, we were to use alcohol-based thermometers and constantly estimate their value as the reaction progressed. With Microlab, a thermocouple was used which gave us far more accurate data than the thermometers. Before, students had to constantly be looking at the temperature readings, but with Microlab, the values are kept in a data table and can easily be exported to excel for comparison. Satisfactory temperature results were achieved with Microlab, indicating that it may be used as a replacement for the traditional, alcohol-based thermometers we currently use.

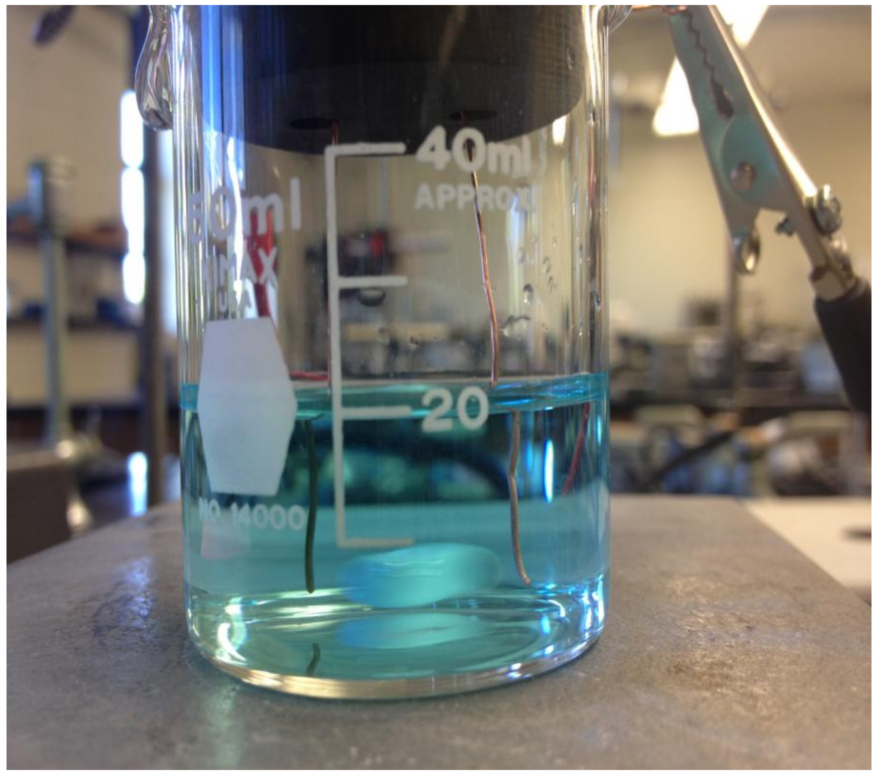
<u>Experiment 9: The acid equilibrium constant for Methyl red</u>

In this experiment, Microlab's spectrophotometer was used to measure absorbance values for various mixtures of both methyl red's acidic and basic form with hydrochloric acid and acetic acid. Combining these substances resulted in variant shades of orange and yellow, creating a visually appealing lab environment. After the fifteen samples were made, absorbance values at two different wavelengths (525nm and 405nm) were measured. The plots of the absorbance values agreed greatly with the plots from the UV/Vis spectrophotometer used in lab. From the slopes of these lines and the pH values of the buffer solutions created, we are able to determine the acid equilibrium constant for Methyl red. Our results agreed with the accepted value with a percent error less than two. Microlab is perfect for this lab; instead of using multiple different pieces of equipment, Microlab is an all-in-one solution to the problem.



<u>Experiment 10: Electroplating copper in copper sulfate</u>

This lab is not a part of General Chemistry I or II, however, Microlab included this lab and equipment to perform it, so we decided to test it out anyway. This experiment involved running current through two electrodes (copper wire) in a copper sulfate solution. With Microlab, we are able to measure the amount of current that has passed, and with an analytical balance we can determine the mass of the copper wire before and after the experiment. With these two pieces of data, we can calculate Avogadro's number, the amount of molecules in 1 mol. It's difficult to measure the mass of the wires, as some of the electroplated copper easily falls off when extracting it from the copper sulfate solution. In the photo to the right, the anode is on the left and the cathode on the right. Oxidation occurs at the anode, which causes it to lose mass. The copper that the anode loses transfers through the solution of copper sulfate and then collects on the cathode, which gains mass. The results of our experiment were fair, but not perfect. With a little tweaking, this could possibly be a viable experiment in the General Chemistry lab.



Experiment 11: A Clock Reaction

In this experiment, the concentrations of the reactants determined the time it took for the reaction to complete. A starch indicator was used to determine when the reaction finished, and in the presence of triiodide. Traditionally, timers were used and students needed to react quickly to stop the timer as soon as the reaction was finished. With Microlab's light sensor, thermocouple, and timer, it measures all of the data far more accurately than a student with a timer. The thermocouple is used to make sure all reactions occurred at similar temperatures. The light sensor was placed into the reaction beaker, and used to determine the end of the reaction. The solution is initially clear, and the light sensor reads a relatively high reading. As the reaction progresses, the solution turns darker and darker and the light sensor reads a constantly lowering value. It would have been a better option to use Microlab's spectrophotometer in this lab, however, it is still a work in progress in being implemented into lab experiments. The results from the light sensor were satisfactory and agreed with the measured results from actual lab.

Acknowledgements

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