Ye Olde Chem 112 Experiment on Acid/Base Titrations, Buffer Systems, and K_A/K_B Measurements

I. Introduction

As is well known, much of chemistry--inorganic, organic, bio, and analytical--hinges on multiple reaction equilibria and acid/base machinery. This Chem 112 experiment will focus on these ideas put together. The measurements will entail titration and enable construction of titration plots or "curves": pH versus the amount of strong acid or strong base added. The plots will contain (among other things) information on the K_A and K_B values associated with a weak acid/weak base system. We will also perform experiments to ascertain the sensitivity of pH to changes in solute concentration and temperature. Experiment Four of Chem 112 involved acid/base titrations. The overall purpose of Experiment Five is to provide additional first-hand experience with titrations, buffer systems, and K_A/K_B measurements.

II. Experimental

A. Equipment

100 ml volumetric flask
100 - 250 ml Erlenmeyer flask
burets
1 - 5 ml transfer pipette
pH probes
pH paper
thermometer
hot plates
ice trays

B. Chemicals

Sodium Bicarbonate ($NaHCO_3$)
Deionized Water
0.100 Molar HCl
0.100 Molar NaOH

C. Procedure

The procedure entails use of several acid and base materials. As will all lab experiments, it is mandatory to wear safety goggles and gloves at all times. Under no circumstances should contact lenses be worn during this Chem 112 lab. If there are no alternatives to contact lenses, please confine all work with acid materials to the hood.

1. Using the volumetric flask, laboratory balance, DI water, etc., please prepare 100 ml of 0.100 molar aqueous solution of $NaHCO_3$. Note that the precise concentration (e.g. 0.103 or 0.113 molar) is not as important as knowing the concentration as precisely as possible.

2. Allow the solution to equilibrate chemically and thermally. Please make sure that all of the $NaHCO_3$ is dissolved in solution and that the solution is free of gas bubbles.

Chem 101 and 102 ideas tell us that the prepared solution will contain a variety of constituents: H_2O(liq), Na^+(aq), HCO_3^-(aq), H_2CO_3(aq), CO_3^{2-}(aq), H^+(aq), OH^-(aq). Are there others to consider?

3. Please note the temperature of the solution prior to titration, and at frequent, intermittent points of the titration process. It is important that the solution be at constant temperature during the entire procedure.

4. Transfer 40 ml of the $NaHCO_3$ aqueous solution to the Erlenmeyer flask. Allow the sample to equilibrate. Record the temperature and the pH of the solution. One will then titrate the solution carefully using the ready-made HCl solution (stored in the hoods) in 1 ml increments. Please allow the solution to equilibrate thermally and chemically after each increment before recording the pH in the lab notebook.

For this portion of the lab, one will be viewing HCO_3^-(aq) as a weak base. One will titrate the 40 ml sample with strong acid to a few percent beyond the equivalence point. Along the way, the solution pH will be measured precisely using an electronic probe. pH paper will also be employed as a monitor of the hydrogen ion concentration. Careful observation of the paper indicator color(s) will discern the proper function--or lack of it--of the electronic probe.

5. After reaching a few percent beyond the equivalence point, one is almost ready to discard the titrated solution. But first a simple experiment must be performed. Please measure the solution pH once more at the titration temperature--and then at temperatures ten degrees above and below. Please record your observations, in addition to any physical changes in the solution appearance.

6. Now one begins another experiment. Transfer 40 ml of the $NaHCO_3$ aqueous solution to a carefully cleaned Erlenmeyer flask. As in (4), allow the sample to equilibrate before recording the temperature and pH of the solution. One will then titrate the solution using the available NaOH aqueous solution in 1 ml increments. As always, please allow the solution to equilibrate thermally and chemically after each increment before recording the pH.

Here one will be viewing HCO_3^-(aq) as a weak acid. One will titrate the initial 40 ml sample with strong base to a few percent beyond the equivalence point. At each step, the pH will be measured using the electronic probe; pH paper will be used as an internal check of the probe-workings.

7. Before discarding the titrated solution, please measure the pH as in (5) at two or three different temperatures over a twenty degree range.

8. Transfer the remaining $NaHCO_3$ solution to a clean Erlenmeyer. Then titrate the sample so that it contains equivalent amounts of HCO_3^-(aq) and CO_3^{2-}(aq). Should one add strong acid or strong base to arrive at this solution?

9. After allowing the titrated sample of (8) to equilibrate, proceed to add DI water in 2 ml increments. Please record the pH after each addition. This experiment will end after the initial solution volume has been doubled.

10. The final experiment involves measuring the pH of the sample of (9) at three different temperatures over a twenty degree range. Please carry out these measurements and then discard the aqueous solution.

III. Data Tabulation

1. Use the results of **II, (4)** to construct a weak base/strong acid titration plot. Please construct a high-quality plot of the solution pH versus ml of strong acid added. Do not connect the points by lines; rather the "curve" should remain in the mind's eye. Clearly label the titration midpoint and equivalence point on the plot.

2. Use the data of **II, (4)** to calculate multiple values of K_A for H_2CO_3(aq). Compute as many values as the data allow; calculate an average value and a standard deviation. Do the K_A-values appear consistent across the titration plot? Given the data of **II, (5)**, do the K_A values depend significantly on the temperature of the solution?

3. Use the results of **II, (6)** to construct a weak acid/strong base titration plot: construct a high-quality plot of the solution pH versus ml of strong base added. As before, please do not connect the points by lines. As above, identify the midpoint and equivalence point on the plot.

4. Use the data of **II, (6)** to calculate multiple values of K_A for HCO_3^-(aq). Compute as many values as the data allow; calculate an average value and a standard deviation. Do the K_A-values appear consistent across the titration plot? Given the data of **II, (7)**, do the K_A values depend significantly on the solution temperature?

5. Use the results of **II, (8)** to construct a plot of the solution pH versus ml of DI water added. Do not connect the points by lines. What does one learn from this plot? And does the solution pH depend significantly on temperature?

IV. Preliminary Report

Using the form on the last page, please report average values and standard deviations for K_A of H_2CO_3(aq) and HCO_3^-(aq). Are the K_A values significantly different for H_2CO_3(aq) and HCO_3^- (aq)?

V. Final Report

A. Introduction

State the purpose of the experiment. Briefly summarize the acid/base reaction chemistry relevant to the experiment.

B. Experimental

Please describe the procedure briefly. State any deviations from the procedure presented here.

C. Data Analysis

Include all data and calculations in a clearly-labeled format. Include all graphs which have been constructed and labeled very carefully.

D. Questions in Addition to Ones Stated in **III**:

What reaction equations are relevant to the titration procedures?
What role does K_W assume in the chemistry and calculations?
Is the pH of a buffer solution sensitive to dilution with water and changes in temperature?
In general, how can one identify the equivalence point on an acid/base titration plot?

Ye Olde Pre-Lab Assignment

A chemist titrates 40 ml of 0.105 molar $NaH_2PO_4(aq)$ with 0.110 molar HCl at temperature 298 K. Please construct a high quality plot of pH versus ml of HCl added, after referring to K_A data in Brown, LeMay, and Bursten. The plot should include data a few percent beyond the equivalence point. Please label the mid- and equivalence points on the plot.

Appendix

Values of K_W at several different temperatures

Temperature (K)	**K_W (moles^2/liters^2)**
273	0.114×10^{-14}
283	0.295×10^{-14}
293	1.00×10^{-14}
303	1.47×10^{-14}
313	2.71×10^{-14}
323	5.30×10^{-14}

Preliminary Report

Average value and standard deviation for K_A of $H_2CO_3(aq)$:

Average value and standard deviation for K_A of $H_2CO_3(aq)$:

Are the K_A values significantly different for $H_2CO_3(aq)$ and $HCO_3^-(aq)$? Please comment.