**Exercise 11: Acid-Base Equilibrium**

The exercise is conducted using the Virtual Lab program and a spreadsheet. The online version of the application is available on the website:

<http://chemcollective.org/vlab/vlab.php>

The data obtained in the Virtual Lab program and the calculated values should be recorded in the appropriate tables under the 'ex11' tab in the spreadsheet "Physical Chemistry ".

To launch the relevant task, select the following tabs:

***File → Load an Assignment → Acids and Bases → pKa and Weak Acid Problem***

**NOTE: Remember to insulate the reaction vessels!**

**I. Problem 1: pKa and the strength of weak acids**

**Determine the pKa values of the weak acids: a) acetic acid (CH3COOH), b) hypochlorous acid (HOCl), c) hypobromous acid (HOBr), d) hydrocyanic acid (HCN).**

**To do this, take 10 cm³ of a 1M solution of each of the studied acids and record the pH values, the concentration of the acidic form, and the concentration of the conjugate base of the studied acid (enter the values into the table in section “0”). Next, titrate the samples with a 1M NaOH solution. For each solution, perform 5 additional measurements, adding the volumes of the base indicated in the table and recording the previously specified quantities. Determine the pK~~a~~ values at the various measurement points, as well as the average pKa value along with the standard deviation for each acid. Use the following relationship in your calculations:**

Sample dissociation equation illustrating the formation of the conjugate base from a weak acid:

**CH3COOH + H2O ↔ CH3COO- + H3O+**

**Report**  
  
**Collect the collected data and calculated values in Tables 1, 2, 3, and 4, corresponding to acetic acid, hypochlorous acid, hypobromous acid, and hydrocyanic acid. Present example calculations and provide conclusions.**

**II. Problem 2: Assessment of the acidic properties of the protein:**

**Perform the titration of the available protein solution with hydrochloric acid using a 0.001 M NaOH solution. Reaction equation:**

**ProteinH + Na+ + OH- = Protein- + Na+ + H2O**

**Add 0.25 ml of hydroxide to 10 ml of the protein solution in a total of 8 ml at each point (in this "0" point without the addition of NaOH), noting the pH and concentrations of the acid and base forms. Determine the pKa values of the protein for each measurement point using the formula as above and calculate the average value along with the standard deviation.**

**Determine the derivative value illustrating the change in pH as a function of the volume of added titrant (remember that the derivative cannot be determined at the "0" point).**

**In the spreadsheet, create a graph showing the dependence of the protein solution's pH on the volume of the added NaOH solution and a graph showing the dependence of the first derivative (dpH/dV) on the volume, and determine the equivalence points.**

**Based on the location of the equivalence points in the titration, determine the volume of NaOH solution used to titrate the protein. Remember that this is a protein solution in hydrochloric acid. Calculate the concentration of the protein solution [mol/dm³], taking into account the stoichiometry from the equation provided in the exercise instructions.**

**Report:**  
  
**Compile the collected data and calculated values in Table 5 and present sample calculations.  
  
Create graphs showing the dependence of the protein solution's pH and the first derivative (dpH/dV) on the volume. Determine the concentration of the protein solution, compile the data in Table 6, and present the calculations. Provide conclusions.**

**Problem 3: Buffer Capacity**

**Using 1M solutions of CH3COOH and CH3COONa, prepare three acetate buffers of 20 cm³ each with the following acid to salt concentration ratios: 1:1, 1:2, 2:1.**

**Then add 0.25 cm³ of a 3M NaOH solution to each buffer, recording the pH each time (also at point "0" without the addition of titrant). Continue until a clear change in pH (by more than one unit) is observed, completing the table with the added volumes of titrant.**

**Calculate the change in pH for each measurement point as the difference between consecutive pH meter readings.**

**Calculate the number of moles of added titrant for each measurement point using the formula:**

**Δn = (ΔV/1000) ∙ C**

**ΔV = the difference in the volume of added titrant; C = concentration of the added titrant [mol/dm³]**

**Calculate the buffer capacity β for each measurement point using the formula below:**

**Δn = the number of moles of added titrant; |ΔpH| = change in pH (absolute value); v = volume of buffer solution [20 cm³].**

**Prepare the mentioned buffers again and repeat the entire procedure, replacing the sodium hydroxide solution with a 3M HCl solution.**

**Create 2 graphs (separately for NaOH and HCl) showing the relationship between buffer capacity and the volume of added titrant (excluding the point corresponding to VNaOH/HCl=0).**

**On each of them, include data for three types of acetate buffers with different ratios of acid to salt concentrations.**

**Report**

**Compile the collected data and calculated values in Tables 7, 8, and 9 for the titration of the buffer with the NaOH solution (for the ratios 1:1, 1:2, 2:1, respectively) and in Tables 10, 11, and 12 for the titration of the buffer with the HCl solution.**

**Present example calculations. Create graphs showing the relationship between buffer capacity and the volume of added titrant for NaOH and HCl. Provide conclusions.**