THE KINETICS OF THE FADING OF PHENOLPHTHALEIN

Objective:
There are three objectives to this experiment:
(1) To verify that under the conditions used the reaction is pseudo first order.
(2) To determine the order in $[OH^-]$ of the rate law.
(3) To determine the energy of activation (E_a) for this reaction.

Introduction:
Phenolphthalein is commonly used as an indicator in acid-base titrations. In the presence of a slight excess of hydroxide ion, phenolphthalein is pink. This colour fades with time, and this observation can be used to study the rate of reaction between phenolphthalein and hydroxide ion.

The colourless form of phenolphthalein has structure H_2Ph. The addition of hydroxide ion removes the two protons from the phenol groups, producing the pink Ph^{2-}. If still more OH^- is added, an ion with the strucure $PhOH^{3-}$ is produced, which is colourless.

The reactions can be written as follows:

$$H_2Ph + 2OH^- \leftrightarrows Ph^{2-} + 2H_2O \quad \textit{(fast)} \quad (1)$$

$$Ph^{2-} + OH^- \leftrightarrows PhOH^{3-} \quad \textit{(slow)} \quad (2)$$

In the presence of a great excess of OH^- ($\approx 10^4$ times the concentration of phenolphthalein), the rate of reaction (2) can be easily determined by measuring the absorbance of a solution of phenolphthalein and OH^- over time. The rate law for reaction (2) can be written,

$$\text{rate} = k[Ph^{2-}]^m[OH^-]^n$$

Since the experiment is set up such that $[OH^-] >> [Ph^{2-}]$, the $[OH^-]$ can be considered constant (i.e. the amount of OH^- used through the reaction with the Ph^{2-} is negligible), and the rate law can be rewritten as a pseudo-*m*th order reaction:

$$\text{rate} = k'[Ph^{2-}]^m, \text{ where } k' = k[OH^-]^n$$

If this reaction is first order in $[Ph^{2-}]$ then the integrated rate law has the form $Ln[Ph^{2-}] = -k't$. To verify whether or not this rate law is valid, a series of trials must be carried out where the $[Ph^{2-}]$ is measured as a function of time. This is easily done by using spectrophotometric means. Since Beer's law states that absorbance is directly proportional to concentation, by measuring the absorbance of the pink Ph^{2-} solution over time, and plotting *Ln*(absorbance) vs. time should prove or disprove that the reaction (2) is or is not pseudo-first order in Ph^{2-}. Data is collected by reacting Ph^{2-} with OH^- over a range of hydroxide concentrations. The stronger the $[OH^-]$, the faster the Ph^{2-} reacts with OH^- and the faster the colour fades. The ionic strengths of the solutions are kept constant by the use of NaCl solution as a diluent.

Materials provided:
0.3000 *M* NaOH
0.3000 *M* NaCl
5.00, 10.00, 15.00, and 20.00 mL pipet
phenolphthalein solution (approx. 0.5% by volume)

25.00 mL Volumetric flasks

Procedure:

Pipet 5.00 mL, 10.00 mL, 15.00 mL, and 20.00 mL of the NaOH solution provided into each of four 25.00 mL flasks. Make up to the mark with the NaCl solution. Starting with the least concentrated NaOH solution, pour 10.0 mL (use a graduated cylinder) of the solution into a clean dry 20 mL beaker. Add two drops of phenolphthalein and swirl the beaker to mix. The solution should be uniformly pink throughout.

Use the NaCl solution to zero the Spectronic 20 set at 550 nm, and then measure the absorbance (or %T) of the pink solution at two minute intervals. Remove the cuvette from the Spectronic 20 in between measurements since the Spectronic 20 causes a 1.5°C increase in temperature for every 5 minutes. Continue until **eight** absorbance (or %T)readings have been obtained.

Repeat the experiment with the other solutions, taking readings at one minute intervals for the 0.1200 *M* and 0.1800 *M* NaOH solutions, and taking readings at 30 second intervals for the 0.2400 *M* and the undiluted 0.3000 *M* NaOH solutions. You should have four sets of data, each with **eight** absorbance (or %T)/time readings. Record the room temperature and assume that this is the same as the temperature of the solutions.

Repeat the experiment with the 0.1200 *M* NaOH solution at two different temperatures, one at a temperature higher than room temperature (25°C, 30°C, or 35°C) and one at a temperature lower than room temperature (ice bath or cold tap water).

NOTE: For the 0.0600 *M* NaOH take readings every 2 minutes.
For the 0.1200 and 0.1800 *M* NaOH take readings every 1 minute.
For the 0.2400 and 0.3000 *M* NaOH take readings every 0.5 minute.
For the low temperature take readings every 2 minutes
For the 30°C or 35°C take readings every 0.5 minute.
For the 25°C take readings every minute.

Treatment of data:

With these sets of data you should be able to make the appropriate plots to meet the three objectives stated at the start of this experiment.