Hydrolysis of Ethyl Acetate

Introduction

This experiment is the first in a series of kinetic studies. Ethyl acetate hydrolyzes in alkaline solution to give ethanol and acetate. The production of acetate, at the expense of hydroxide in the solution, allows the rate to be followed through the conductivity of the solution:

$$\frac{d([A]_0 - x)}{dt} = -k([A]_0 - x)([B]_0 - x)$$

where $[A]_0$ is the initial molarity of ethyl acetate, $[B]_0$ is the initial molarity of sodium hydroxide, x is the amount of reactant lost in time t, and k is the rate constant. The integrated form of the equation above depends on whether $[A]_0$ and $[B]_0$ are equal. If equal:

$$\frac{x}{[A]_0([A]_0 - x)} = kt$$

and, if not equal,

$$\ln\left(\frac{[B]_0([A]_0 - x)}{[A]_0([B]_0 - x)}\right) = k([A]_0 - [B]_0)t$$

We may follow the progress of the reaction by monitoring the conductance of the solution as a function of time, since the conductance is determined by the concentrations and equivalent conductances of the ions in the solution:

$$\frac{x}{([A]_0 - x)} = \frac{(L_0 - L_t)}{(L_t - L_c)} = k[A]_0 t$$

for the equal concentrations case, where L_0 is the initial conductance, L_c the conductance at completion, and L_t the conductance at time t. Thus, a plot of $\frac{(L_0 - L_t)}{(L_t - L_c)}$ versus t should yield a straight line, the slope being $k[A]_0$. For the unequal concentrations, x is given by

$$x = c\frac{(L_0 - L_t)}{(L_t - L_c)}$$

where c is the concentration of the limiting reagent. From this, a plot of $ln\left(\frac{([B]_0([A]_0-x)}{([A]_0([B]_0-x)}\right)$ versus t will yield a line having a slope of $k([A]_0 - [B]_0)$. The rate constants will be determined at two temperatures, so that the activation energy for the reaction may be obtained from a plot of $ln\ k$ versus $1/T$:

$$\ln k = -\frac{E_a}{RT} + lnA$$

the slope being $-E_a/R$, the intercept $ln\ A$.

Procedure

Each group will work at two temperatures. Prepare 250 mL each of 0.04 M ethyl acetate and 0.04 M NaOH. Store 100 mL of each solution immersed in one of the constant temperature baths, the remainder in the other. Rinse the conductivity cell several times with distilled water. The reaction is initiated by mixing the solutions in a conductivity cell. In each bath, there should be one run with equal concentrations and one with unequal concentrations. The cell can comfortably accommodate 60 mL, so the proportions should be 30-30 or 20-40. Once the solutions have been mixed (call this t=0), read the resistance every minute for the first ten minutes, once every two minutes for another ten minutes, then once every five minutes for the last 25 minutes. Once the solution has reacted for 45 minutes, leave it in the water bath until the end of the lab period. Do the same for the other solutions. {HINT: since 4×45 minutes is the length of the lab period, you will need to overlap the series of measurements by starting one run once the preceding run is in the slow phase of reaction.}

R₀, the initial resistance, may be measured for each solution by mixing an aliquot of the NaOH with an aliquot of water having a volume equal to the ethyl acetate solution volume.

Calculations

Use the cell constant from the resistance of the KCl solution (L_s for 0.0100 M KCl is 0.001412 ohm^{-1} cm^{-1}) in Experiment 5. Determine the rate constants for each of the four solutions, using the appropriate plots described above. Compare the values of L_0 obtained by extrapolation of the data and those obtained from the NaOH-water mixture. Share the data. Report the standard errors in the k values, and estimate the error in the values of E_a and A.