CHM 115 Lab 15

Kinetics: Temperature Effects

In this experiment, you will measure the average rate of a redox reaction at several different temperatures, and then analyze the data to find the Arrhenius activation energy, E_a. The reaction is that between permanganate ion (MnO_4^-) and oxalate ion ($C_2O_4^{2-}$), where manganese is reduced from its purple +7 oxidation state to the pale pink +2 state. Progress of the reaction is monitored by watching the color change.

$$2\ MnO_4^-(aq) + 5\ C_2O_4^{2-}(aq) + 16\ H^+(aq) \rightarrow 2\ Mn^{2+}(aq) + 10\ CO_2(g) + 8\ H_2O(l)$$

The average rate will be defined as ($\Delta[MnO_4^-]/\Delta t$). The time taken for all of the permanganate ion to react is Δt and, since all of the permanganate has been used up when that time has elapsed, $\Delta[MnO_4^-]$ is equal to the initial permanganate concentration. A complication is that the reaction proceeds by way of a yellow intermediate, so the end point (the point at which the final time reading is made) will be when the purple color of the permanganate ion has just disappeared and the solution is pale yellow. When the average rate has been found for six different temperatures, a plot of the Arrhenius equation in the form $\ln(k) = -E_a/R*(1/T) + \ln(A)$, where $R = 8.314\ J\ K^{-1}\ mol^{-1}$, will yield the activation energy.

Note: The Arrhenius equation is $k = Ae^{-Ea/RT}$. You do not actually measure k, but we assume that since the concentration of reactants is the same at each temperature, the measured rate is k times a constant. Thus ln(rate) = ln(k) + ln(constant). Similarly, taking the log of the right-hand side, we get ln(A) - Ea/RT. Since ln(A) is also a constant, the overall equation becomes $\ln(k) = -E_a/R(1/T) +$ constant. You don't need to know the value of the constant to find the slope and evaluate E_a.

The temperatures used are **initial** temperatures, since we are not keeping the reaction mixtures in the water bath after mixing the reactants. Obviously the mixtures, other than the room temperature one, will cool some during the course of the reaction. For the purposes of this experiment, this factor is not critical, other than being aware of it.

Procedure:
Work in partners. Obtain a thermometer from the stockroom.

1. Obtain 35 mL (and only 35 ml) of each of the reagents required, 0.0050 M $KMnO_4$ and saturated oxalic acid, in *labeled* 50 mL beakers.

2. Determine the room temperature by examining the thermometer.

3. Use the graduated cylinder to measure 5.0 mL of 0.0050 M $KMnO_4$ solution into two of your large test tubes. Similarly measure 5.0 mL of saturated oxalic acid solution into two other large test tubes.

4. Set up a water bath in your 800 mL beaker. The beaker need be only about one-third full of water. Place your thermometer in the water. Place one test tube of each solution in the bath.

5. Begin *slowly* heating the bath to 10 degrees above room temperature.

6. Meanwhile, watching the time, pour the room-temperature tube of oxalic acid into the room-temperature test tube of potassium permanganate solution. Pour the solution back and forth twice to mix the solutions.

7. Note the exact time that the oxalic acid contacts the potassium permanganate solution. Use this as the initial time.

8. When the test tube has become yellow, with no hint of pink remaining, note the time. This value is the final time.

9. Place the test tube of reacted solutions in a 250 mL beaker so that you may observe any additional color change (Remember to record any observations in your notebook!)

10. Rinse out the empty tube from the room temperature trial. Measure 5.0 mL of 0.0050 M $KMnO_4$ solution into the tube. Measure 5.0 mL of oxalic acid solution into your remaining large test tube.

11. When the temperature of the water bath reaches 10°C above room temperature, record the temperature, remove the two tubes from the bath, mix and record the initial time as before. Place the newly-filled test tubes in the water bath and continue *slowly* heating to 20°C above room temperature; the temperature does not need not be exactly 20° C above room temperature, but record the experimental value.

12. Repeat the procedure, measuring times to disappearance of the purple MnO_4^- color at 30, 40, and 50 degrees above room temperature. (You will have to reuse your test tubes.)

13. Note any trend or pattern in your data; record this in your lab notebook. If one run does not fit the pattern, decide whether to repeat it or not.

14. Clean up.