The Rate and Order of a Chemical Reaction

A basic kinetic study of a chemical reaction often involves conducting the reaction at varying concentrations of reactants. In this way, you can determine the order of the reaction in each species, and determine a rate law expression. Once you select a reaction to examine, you must decide how to follow the reaction by measuring some parameter that changes regularly as time passes, such as temperature, pH, pressure, conductance, or absorbance of light.

In this experiment you will conduct the reaction between solutions of potassium iodide and iron (III) chloride. The reaction equation is shown below, in ionic form.

$$2\ I^-\ (aq) + 2\ Fe^{3+}\ (aq) \rightarrow I_2\ (aq) + 2\ Fe^{2+}\ (aq)$$

As this reaction proceeds, it undergoes a color change that can be precisely measured by a Colorimeter or Spectrometer. By carefully varying the concentrations of the reactants, you will determine the effect each reactant has on the rate of the reaction, and consequently the order of the reaction. From this information, you will write a rate law expression for the reaction.

OBJECTIVES

- Conduct the reaction of KI and $FeCl_3$ using various concentrations of reactants.
- Determine the order of the reaction in KI and $FeCl_3$.
- Determine the rate law expression for the reaction.

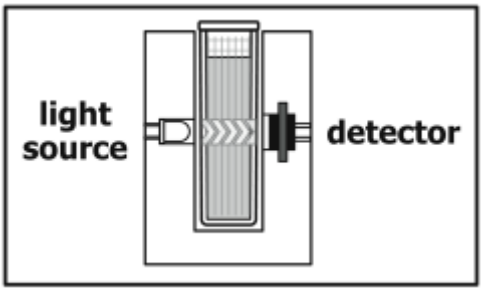

Figure 1

MATERIALS

Vernier computer interface*
Logger *Pro*
computer
Colorimeter **or** Spectrometer
three 250 mL beakers
two 100 mL beakers
three 25 mL graduated cylinders
five plastic Beral pipets
plastic cuvettes
0.020 M potassium iodide, KI, solution
0.020 M iron (III) chloride, $FeCl_3$, solution, in 0.10 M HCl
distilled water
*Interface not required if using a Spectrometer

PROCEDURE

Both Colorimeter and Spectrometer Users

1. Obtain and wear goggles.

2. Obtain the materials you will need to conduct this experiment.

   - Three 25 mL graduated cylinders
   - Three 100 mL beakers
   - Approximately 100 mL of 0.020 M KI solution in a 250 mL beaker. *Potassium iodide, 0.5 M,* KI: *This chemical is considered nonhazardous according to GHS classifications. Treat all laboratory chemicals with caution. Prudent laboratory practices should be observed.*
   - Approximately 100 mL of 0.020 M $FeCl_3$ solution in a separate 250 mL beaker **DANGER**: *Iron(III) chloride hexahydrate*, Fe(III)Cl_3: *Causes severe skin and eye burns and damage. Harmful if swallowed or inhaled. Do not eat or drink when using this product. Do not breathe mist, vapors, or spray*.
   - Approximately 60 mL of distilled water in a third 250 mL beaker

3. Prepare a *blank* by filling a cuvette 3/4 full with distilled water. To correctly use cuvettes, remember:

   - Wipe the outside of each cuvette with a lint-free tissue.
   - Handle cuvettes only by the top edge of the ribbed sides.
   - Dislodge any bubbles by gently tapping the cuvette on a hard surface.
   - Always position the cuvette so the light passes through the clear sides.

Spectrometer Users Only (Colorimeter users proceed to the Colorimeter section)

4. Use a USB cable to connect the Spectrometer to the computer. Choose New from the File menu.

5. To calibrate the Spectrometer, place the blank cuvette into the cuvette slot of the Spectrometer, choose Calibrate ► Spectrometer from the Experiment menu. Wait for the Spectrometer to warm up, and then click OK.

6. Determine the optimal wavelength for the $FeCl_3$ solution and set up the mode of data collection.

   a. Empty the blank cuvette and rinse it twice with small amounts of 0.020 M $FeCl_3$ solution. Fill the cuvette about 3/4 full with the $FeCl_3$ solution and place it in the Spectrometer.

   b. Click Collect. The absorbance *vs*. wavelength spectrum will be displayed. Click Stop.

   c. To save your graph of absorbance *vs*. wavelength, select Store Latest Run from the Experiment menu.

   d. To set up the data collection mode and select a wavelength for analysis, click Configure Spectrometer Data Collection, , on the toolbar.

   e. Click Abs *vs*. Time (under the Set Collection Mode). Under the list of wavelengths, click Clear Selection. Choose the wavelength nearest to 430 nm from the list. Click OK to continue. Click OK. Remove the cuvette of $FeCl_3$ solution from the Spectrometer and dispose of the solution as directed. Save the cuvette for Step 8.

Colorimeter Users Only

4. Connect the Colorimeter to the computer interface. Open the file "25 Rate and Order" from the *Advanced Chemistry with Vernier* folder of Logger *Pro*.

5. Open the Colorimeter lid, insert the blank, and close the lid.

6. To calibrate the Colorimeter, press the < or > button on the Colorimeter to select the wavelength of 430 nm (Blue). Press the CAL button until the red LED begins to flash and then release the CAL button. When the LED stops flashing, the calibration is complete.

Both Colorimeter and Spectrometer Users

7. During this experiment you will conduct 5 trials of the reaction between KI and $FeCl_3$, using the volumes of liquids described in the table below.

Trial	$FeCl_3$ (mL)	KI (mL)	H_2O (mL)
1	20.0	20.0	0.0
2	20.0	10.0	10.0
3	10.0	20.0	10.0
4	15.0	10.0	15.0
5	10.0	15.0	15.0

8. Conduct Trial 1.

a. Measure 20.0 mL of $FeCl_3$ solution into a 100 mL beaker.
b. Measure 20.0 mL of KI solution into a second 100 mL beaker.
c. Add the 20.0 mL of $FeCl_3$ solution to the beaker of KI solution. Swirl the beaker to mix.
d. Rinse the cuvette twice with ~1-mL amounts of the reaction mixture, fill it 3/4 full, and place it in the device (Colorimeter or Spectrometer). Close the lid of the Colorimeter.

9. Click Collect. The default settings are suitable for this experiment. You may click Stop to end the data collection early. Observe the progress of the reaction.

10. When the data collection is complete, carefully remove the cuvette from the device. Dispose of the contents of the beaker and cuvette as directed. Rinse and clean the beakers and the cuvette for the next trial.

11. Examine the graph of the first trial. Select a linear region in the first minute of the data collection to analyze (for example, from 20 seconds to 50 seconds). Click Linear Regression, . Record the slope, as the initial rate of the Trial 1 reaction, in your data table and then close the Linear Regression box. Note the time region that you selected; this same region should be used for all remaining trials.

12. Repeat Steps 8–11 to conduct Trials 2–5 using the information in the table. It works well to add the distilled water to the beaker of KI solution before adding the $FeCl_3$ solution. Use the same region of the graph to calculate the initial rates for Trials 2–5 that you used in Trial 1.

DATA TABLE

Trial	[$FeCl_3$]	[KI]	Initial rate (s^{-1})
1			
2			
3			
4			
5			

DISCUSSION QUESTIONS

1. Calculate the molar concentration of $FeCl_3$ and KI for each reaction and record the values in the table above. Provide one example to show how you completed the calculation.

2. What is the order of the reaction in $FeCl_3$ and KI? Explain.

3. Write the rate law expression for the reaction.

4. Is it possible to calculate the rate constant, *k*, from your data? If so, calculate the rate constant. If not, explain why not.