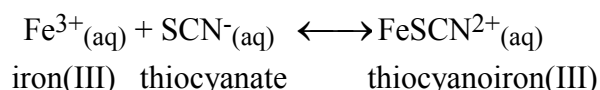


Chemical Equilibrium: Determination of K_c

The purpose of this lab is to experimentally determine the equilibrium constant, K_c , for the following chemical reaction:



When Fe^{3+} and SCN^{-} are combined, equilibrium is established between these two ions and the FeSCN^{2+} ion. In order to calculate K_c for the reaction, it is necessary to know the concentrations of all ions at equilibrium: $[\text{FeSCN}^{2+}]_{\text{eq}}$, $[\text{SCN}^{-}]_{\text{eq}}$, and $[\text{Fe}^{3+}]_{\text{eq}}$. You will prepare four equilibrium systems containing different concentrations of these three ions. The equilibrium concentrations of the three ions will then be experimentally determined. These values will be substituted into the equilibrium constant expression to see if K_c is indeed constant.

In order to determine $[\text{FeSCN}^{2+}]_{\text{eq}}$, you will use the colorimeter shown in Figure 1. The FeSCN^{2+} ion produces solutions with a red color. Because the red solutions absorb blue light very well, the blue LED setting on the colorimeter is used. The computer-interfaced colorimeter measures the amount of blue light absorbed by the colored solutions (absorbance, A). By comparing the absorbance of each equilibrium system, A_{eq} , to the absorbance of a *standard* solution, A_{std} , you can determine $[\text{FeSCN}^{2+}]_{\text{eq}}$. The standard solution has a known FeSCN^{2+} concentration.

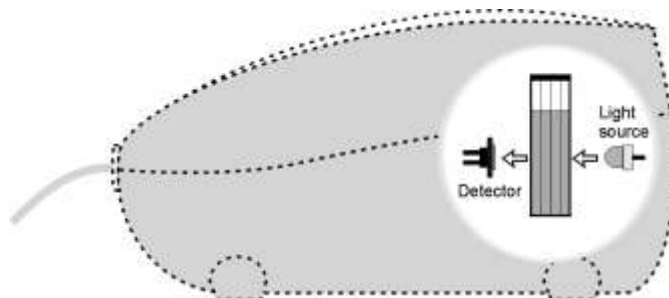


Figure 1

To prepare the standard solution, a very large concentration of Fe^{3+} will be added to a small initial concentration of SCN^{-} (hereafter referred to as $[\text{SCN}^{-}]_i$). The $[\text{Fe}^{3+}]$ in the standard solution is 100 times larger than $[\text{Fe}^{3+}]$ in the equilibrium mixtures. According to LeChatelier's principle, this high concentration forces the reaction far to the right, using up nearly 100% of the SCN^{-} ions. According to the balanced equation, for every one mole of SCN^{-} reacted, one mole of FeSCN^{2+} is produced. Thus $[\text{FeSCN}^{2+}]_{\text{std}}$ is assumed to be equal to $[\text{SCN}^{-}]_i$.

Assuming $[\text{FeSCN}^{2+}]$ and absorbance are related directly (Beer's Law), the concentration of FeSCN^{2+} for any of the equilibrium systems can be found by:

$$[\text{FeSCN}^{2+}]_{\text{eq}} = \frac{A_{\text{eq}}}{A_{\text{std}}} \times [\text{FeSCN}^{2+}]_{\text{std}}$$

Knowing the $[\text{FeSCN}^{2+}]_{\text{eq}}$ allows you to determine the concentrations of the other two ions at equilibrium. For each mole of FeSCN^{2+} ions produced, one less mole of Fe^{3+} ions will be found

in the solution (see the 1:1 ratio of coefficients in the equation on the previous page). The $[\text{Fe}^{3+}]$ can be determined by:

$$[\text{Fe}^{3+}]_{\text{eq}} = [\text{Fe}^{3+}]_i - [\text{FeSCN}^{2+}]_{\text{eq}}$$

Because one mole of SCN^- is used up for each mole of FeSCN^{2+} ions produced, $[\text{SCN}^-]_{\text{eq}}$ can be determined by:

$$[\text{SCN}^-]_{\text{eq}} = [\text{SCN}^-]_i - [\text{FeSCN}^{2+}]_{\text{eq}}$$

Knowing the values of $[\text{Fe}^{3+}]_{\text{eq}}$, $[\text{SCN}^-]_{\text{eq}}$, and $[\text{FeSCN}^{2+}]_{\text{eq}}$, you can now calculate the value of K_c , the equilibrium constant.

MATERIALS

Macintosh or IBM-compatible computer	0.0020 M KSCN
Serial Box Interface or ULI	0.0020 M $\text{Fe}(\text{NO}_3)_3$ (in 1.0 M HNO_3)
LoggerPro	0.200 M $\text{Fe}(\text{NO}_3)_3$ (in 1.0 M HNO_3)
Vernier Colorimeter	four pipets
1 plastic cuvette	pipet bulb or pipet pump
five 20 x 150 mm test tubes	three 100-mL beakers
thermometer	tissues (preferably lint-free)

PROCEDURE

- Obtain and wear goggles.
- Label four 20 x 150 mm test tubes 1-4. Pour about 30 mL of 0.0020 M $\text{Fe}(\text{NO}_3)_3$ into a clean, dry 100-mL beaker. Pipet 5.0 mL of this solution into each of the four labeled test tubes. Use a pipet pump or bulb to pipet all solutions. **CAUTION:** *$\text{Fe}(\text{NO}_3)_3$ solutions in this experiment are prepared in 1.0 M HNO_3 and should be handled with care.* Pour about 25 mL of the 0.0020 M KSCN into another clean, dry 100-mL beaker. Pipet 2, 3, 4 and 5 mL of this solution into Test Tubes 1-4, respectively. Obtain about 25 mL of distilled water in a 100-mL beaker. Then pipet 3, 2, 1 and 0 mL of distilled water into Test Tubes 1-4, respectively, to bring the total volume of each test tube to 10 mL. Mix each solution *thoroughly* with a stirring rod. Be sure to clean and dry the stirring rod after each mixing. Measure and record the temperature of one of the above solutions to use as the temperature for the equilibrium constant, K_c . Volumes added to each test tube are summarized below:

Test Tube Number	$\text{Fe}(\text{NO}_3)_3$ (mL)	KSCN (mL)	H_2O (mL)
1	5	2	3
2	5	3	2
3	5	4	1
4	5	5	0

- Prepare a standard solution of FeSCN^{2+} by pipetting 18 mL of 0.200 M $\text{Fe}(\text{NO}_3)_3$ into a 20 x 150 mm test tube labeled "5". Pipet 2 mL of 0.0020 M KSCN into the same test tube. Stir thoroughly. [
- Connect a Colorimeter to Channel 1 of the Vernier computer interface. Connect the interface to the computer with the proper cable.

5. Start the Logger *Pro* program on your computer. Open the file “10 Equilibrium” from the *Advanced Chemistry with Vernier* folder.
6. Calibrate the Colorimeter.
 - a. Prepare a *blank* by filling an empty cuvette $\frac{3}{4}$ full with distilled water. Place the blank in the cuvette slot of the Colorimeter and close the lid.
 - b. If your Colorimeter has a CAL button, set the wavelength on the Colorimeter to 470 nm, press the CAL button, and proceed directly to Step 6. If your Colorimeter does not have a CAL button, continue with this step to calibrate your Colorimeter.
 - c. Choose Calibrate ► CH1: Colorimeter (%T) from the Experiment menu, then click .
 - d. Turn the wavelength knob on the Colorimeter to the “0% T” position.
 - e. Type “0” in the edit box.
 - f. When the displayed voltage reading for Input 1 stabilizes, click .
 - g. Turn the knob of the Colorimeter to the Blue LED position (470 nm).
 - h. Type “100” in the edit box.
 - i. When the voltage reading for Input 1 stabilizes, click , then click .
7. You are now ready to collect absorbance data for the standard solutions. Click to begin data collection. **Note:** Take readings within 4 minutes of preparing the mixtures.
 - a. Empty the water from the cuvette. Using the solution in Beaker 1, rinse the cuvette twice with ~1 mL amounts and then fill it $\frac{3}{4}$ full. Wipe the outside with a tissue, place it in the Colorimeter, and close the lid. Wait for the absorbance value displayed in the Meter window to stabilize. Click , type the concentration of FeSCN^{2+} (from your pre-lab calculations) in the edit box, and press the ENTER key.
 - b. Discard the cuvette contents as directed. Rinse and fill the cuvette with the solution in Beaker 2. Follow the procedure in Part a of this step to measure the absorbance, and enter the concentration of this solution.
 - c. Repeat Part b of this step to measure the absorbance of the solutions in Beakers 3, 4, and 5.
 - d. Click when you have finished collecting data to view a graph of absorbance vs. concentration. Click the examine button, , and record the absorbance values for each data pair.
8. Click the Linear Fit button, . A best-fit linear regression line will be shown for your five data points. This line should pass near or through the data points *and* the origin of the graph. (Note: Another option is to choose Curve Fit from the Analyze menu, and then select Proportional. The Proportional fit has a y-intercept value equal to 0; therefore, this regression line will always pass through the origin of the graph.)]
9. Repeat the Step 7 procedure to find the absorbance of the solutions in Test Tubes 3, 4, and 5 (the standard solution).
10. From the Table window, record the absorbance values for each of the five trials in your Data and Calculations table. Dispose of all solutions as directed by your teacher.

PROCESSING THE DATA

1. In the Data and Calculations table, write the K_c expression for the reaction .
2. Calculate the initial concentration of Fe^{3+} , based on the dilution that results from adding KSCN solution and water to the original 0.0020 M $\text{Fe}(\text{NO}_3)_3$ solution. See Step 2 of the procedure for the volume of each substance used in Trials 1-4. Calculate $[\text{Fe}^{3+}]_i$ using the equation:

$$[\text{Fe}^{3+}]_i = \frac{\text{Fe}(\text{NO}_3)_3 \text{ mL}}{\text{total mL}} \times (0.0020 \text{ M})$$

This should be the same for all four test tubes.

3. Calculate the initial concentration of SCN^- , based on its dilution by $\text{Fe}(\text{NO}_3)_3$ and water:

$$[\text{SCN}^-]_i = \frac{\text{KSCN mL}}{\text{total mL}} \times (0.0020 \text{ M})$$

In Test Tube 1, $[\text{SCN}^-]_i = (2 \text{ mL} / 10 \text{ mL})(0.0020 \text{ M}) = .00040 \text{ M}$. Calculate this for the other three test tubes.

4. $[\text{FeSCN}^{2+}]_{\text{eq}}$ is calculated using the formula:

$$[\text{FeSCN}^{2+}]_{\text{eq}} = \frac{A_{\text{eq}}}{A_{\text{std}}} \times [\text{FeSCN}^{2+}]_{\text{std}}$$

where A_{eq} and A_{std} are the absorbance values for the equilibrium and standard test tubes, respectively, and $[\text{FeSCN}^{2+}]_{\text{std}} = (1/10)(0.0020) = 0.00020 \text{ M}$. Calculate $[\text{FeSCN}^{2+}]_{\text{eq}}$ for each of the four trials.

5. $[\text{Fe}^{3+}]_{\text{eq}}$: Calculate the concentration of Fe^{3+} at equilibrium for Trials 1-4 using the equation:

$$[\text{Fe}^{3+}]_{\text{eq}} = [\text{Fe}^{3+}]_i - [\text{FeSCN}^{2+}]_{\text{eq}}$$

6. $[\text{SCN}^-]_{\text{eq}}$: Calculate the concentration of SCN^- at equilibrium for Trials 1-4 using the equation:

$$[\text{SCN}^-]_{\text{eq}} = [\text{SCN}^-]_i - [\text{FeSCN}^{2+}]_{\text{eq}}$$

7. Calculate K_c for Trials 1-4. Be sure to show the K_c expression and the values substituted in for each of these calculations.
8. Using your four calculated K_c values, determine an average value for K_c . How constant were your K_c values?

DATA AND CALCULATIONS

Absorbance	Trial 1 _____	Trial 2 _____	Trial 3 _____	Trial 4 _____
Absorbance of standard (Trial 5) _____			Temperature _____ °C	

K _c expression	K _c = _____			
[Fe ³⁺] _i				
[SCN ⁻] _i				
[FeSCN ²⁺] _{eq}				
[Fe ³⁺] _{eq}				
[SCN ⁻] _{eq}				
K _c value				
Average of K _c values				
K _c = _____ at _____ °C				