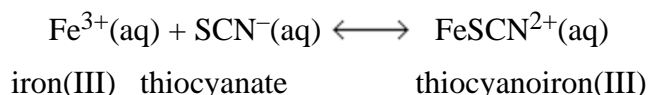


Chemical Equilibrium: Finding a Constant, K_c

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:

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

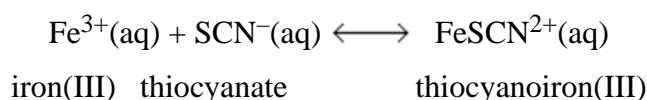
Because one mole of SCN^- is used up for each mole of FeSCN^{2+} ions produced, $[\text{SCN}^-]_{\text{eq}}$ can be determined by:

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

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.

OBJECTIVE

In this experiment, you will determine the equilibrium constant, K_c , for the following chemical reaction:



MATERIALS

computer	0.0020 M KSCN
Vernier computer interface	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 × 150 mm test tubes	three 100 mL beakers
thermometer	tissues (preferably lint-free)

PROCEDURE

1. Obtain and wear goggles.
2. Label four 20 × 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	Fe(NO ₃) ₃ (mL)	KSCN (mL)	H ₂ O (mL)
1	5	2	3
2	5	3	2
3	5	4	1
4	5	5	0

3. Prepare a standard solution of FeSCN^{2+} by pipetting 18 mL of 0.200 M $\text{Fe}(\text{NO}_3)_3$ into a 20 × 150 mm test tube labeled “5”. Pipet 2 mL of 0.0020 M KSCN into the same test tube. Stir thoroughly.
4. Connect the Colorimeter to the computer interface. Prepare the computer for data collection by opening the file “20 Equilibrium Constant” from the *Chemistry with Computers* folder of *LoggerPro*
5. Prepare a blank by filling a cuvette 3/4 full with distilled water. To correctly use a Colorimeter cuvette, remember:
 - All cuvettes should be wiped clean and dry on the outside with a tissue.
 - Handle cuvettes only by the top edge of the ribbed sides.
 - All solutions should be free of bubbles.
 - Always position the cuvette with its reference mark facing toward the white reference mark at the top of the cuvette slot on the Colorimeter.
6. Calibrate the Colorimeter.
 - a. Open the Colorimeter lid.
 - b. Holding the cuvette by the upper edges, place it in the cuvette slot of the Colorimeter. Close the lid.
 - c. If your Colorimeter has a CAL button, Press the < or > button on the Colorimeter to select a wavelength of 470 nm (Blue) for this experiment. Press the CAL button until the red LED begins to flash. Then release the CAL button. When the LED stops flashing, the calibration is complete. Proceed directly to Step 7. If your Colorimeter does not have a CAL button, continue with this step to calibrate your Colorimeter.

First Calibration Point

- d. Choose Calibrate } CH1: Colorimeter (%T) from the Experiment menu and then click .
- e. Turn the wavelength knob on the Colorimeter to the “0% T” position.
- f. Type “0” in the edit box.
- g. When the displayed voltage reading for Reading 1 stabilizes, click .

Second Calibration Point

- h. Turn the knob of the Colorimeter to the Blue LED position (470 nm).
- i. Type “100” in the edit box.
- j. When the displayed voltage reading for Reading 2 stabilizes, click , then click .
7. You are now ready to collect absorbance data for the four equilibrium systems and the standard solution.
 - a. Click to begin data collection.
 - b. Empty the water from the cuvette. Rinse it twice with ~1 mL portions of the Test Tube 1 solution.
 - c. Wipe the outside of the cuvette with a tissue and then place the cuvette in the Colorimeter. After closing the lid, wait for the absorbance value displayed in the meter to stabilize. Then click , type “1” (the trial number) in edit box, and press the ENTER key.
 - d. Discard the cuvette contents as directed by your teacher. Rinse the cuvette twice with the Test Tube 2 solution and fill the cuvette 3/4 full. Follow the Step-c procedure to find the absorbance of this

solution. Type "2" in the edit box and press ENTER.

- e. Repeat the Step-d procedure to find the absorbance of the solutions in Test Tubes 3, 4, and 5 (the standard solution).
- f. From the table, record the absorbance values for each of the five trials in your data table.
- g. Dispose of all solutions as directed by your instructor.

PROCESSING THE DATA

1. Write the K_c expression for the reaction in the Data and Calculation table.
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:

$$[\text{Fe}^{3+}]_i = i (0.0020 \text{ M})$$

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:

$$[\text{SCN}^-]_i = i (0.0020 \text{ M})$$

In Test Tube 1, $[\text{SCN}^-]_i = (2 \text{ mL} / 10 \text{ mL})(0.0020 \text{ M}) = 0.00040 \text{ M}$. Calculate this for the other three test tubes.

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

$$[\text{FeSCN}^{2+}]_{\text{eq}} = i [\text{FeSCN}^{2+}]_{\text{std}}$$

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 $K_C =$				
$[\text{Fe}^{3+}]_i$				
$[\text{SCN}^-]_i$				
$[\text{FeSCN}^{2+}]_{\text{eq}}$				
$[\text{Fe}^{3+}]_{\text{eq}}$				
$[\text{SCN}^-]_{\text{eq}}$				
K_C value				
Average of K_C values $K_C =$ _____ at _____ °C				