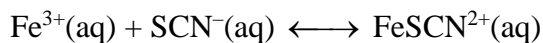


Chemical Equilibrium: Finding a Constant, K_c

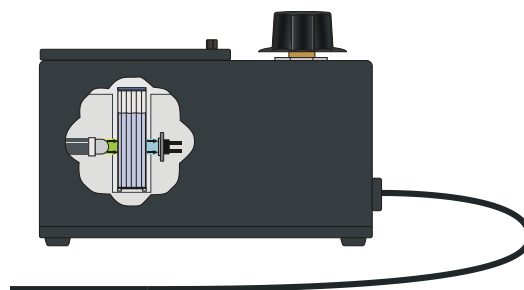
The purpose of this lab is to experimentally determine the equilibrium constant, K_c , for the following chemical reaction:



iron(III) thiocyanate thiocyanoiron(III)

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. 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 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.



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

LabQuest interface
Vernier Colorimeter
four pipets
pipet bulb or pipet pump
one cuvette
five 20 x 150 mm test tubes

0.0020 M KSCN
0.0020 M $\text{Fe}(\text{NO}_3)_3$ (in 1.0 M HNO_3)
0.200 M $\text{Fe}(\text{NO}_3)_3$ (in 1.0 M HNO_3)
three 100-mL beakers
tissues (preferably lint-free)
thermometer

PROCEDURE

1. Obtain and wear goggles.
2. 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

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 x 150 mm test tube labeled "5". Pipet 2 mL of 0.0020 M KSCN into the same test tube. Stir thoroughly.
4. Plug the Colorimeter into Channel 1 of the LabQuest interface.
5. Prepare a *blank* by filling an empty cuvette $\frac{3}{4}$ full with distilled water. Seal the cuvette with a lid. 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 right of the cuvette slot on the Colorimeter.
6. Set up the interface for the Colorimeter.
 - a. Place the blank in the cuvette slot of the Colorimeter and close the lid.
 - b. When the LabQuest recognizes the Colorimeter (CH 1:Absorbance), set the wavelength on the Colorimeter to 470 nm. Then calibrate by pressing the CAL button on the Colorimeter.
7. Set up the data-collection mode.
 - a. Select MODE to establish the data collection parameters.
 - b. Select SELECTED EVENTS from the menu.
 - c. Select OK to return to the main screen.

8. You are now ready to collect absorbance data for the four equilibrium systems and the standard solution.
 - a. Empty the water from the cuvette. Using the solution in Test Tube 1, rinse the cuvette twice with ~1-mL amounts and then fill it 3/4 full. Wipe the outside with a tissue, place it in the Colorimeter, and close the lid.
 - b. Press the green “START” arrow in the lower left corner of the screen. When the value displayed on the calculator screen has stabilized, press the “KEEP” but to save the absorbance value for the first trial.
 - c. Discard the cuvette contents as directed by your instructor. Using the solution in Test Tube 2, rinse the cuvette twice with ~1-mL amounts, and then fill it 3/4 full. After closing the lid, wait for the value displayed on the calculator screen to stabilize and press “KEEP” to save the reading for the second trial.
 - d. Repeat the Step-c procedure to find the absorbance of the solutions in Test Tubes 3, 4, and 5 (the standard solution).
 - e. Press the red “STOP” button in the lower left hand corner to stop data collection. The absorbance have now been saved for each of the 5 test tubes.
 - f. Examine the data points along the curve on the displayed graph. As you move the cursor right or left, the test tube (X) and absorbance (Y) values of each data point are displayed below the graph. Record the absorbance values in your data table (round to the nearest 0.001).
 - g. Return to the HOME screen and then select the SYSTEM folder and “Shut Down”..

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:

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

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, $[\text{SCN}^-]_i = (2 \text{ mL} / 10 \text{ mL})(.0020 \text{ M}) = .00040 \text{ M}$. 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		