Chemical Equilibrium and Application of Le Chatelier's Principle

A system at equilibrium may be disturbed by subjecting the system to a stress, such as changing the concentration of one of the participants or the temperature. LeChatelier's principle indicates that the system readjusts so as to minimize the stress and again restore equilibrium conditions.

In this experiment you will investigate a number of equilibrium systems. You will subject these systems to stresses and explain your observations in terms of Le Chatelier's principle. In Part I you investigate a reaction whose equation may be written:

$$Fe^{3+} + SCN^{-} \rightleftharpoons Fe(SCN)^{2+}$$

You may vary the concentrations of the participants in this reaction and observe, by means of color changes, the effect on the equilibrium. Similarly, you observe and explain the changes which occur when you vary the [H+] in the reaction system whose equation is

$$Cr_2O_7^{2-} + H_2O \rightleftharpoons 2CrO_4^{2-} + 2H^{+}$$

Table I: *Colors of Ions*

Ion	Color
K^+	
Cl^-	
SCN^-	
Fe^{3+}	
$Fe(SCN)^{2+}$	
Na^+	
$FeHPO_4^+$	colorless
$FeCl_4^-$	colorless

In Part II you observe the effect of changing the temperature of a system represented by the equation:

$$CoCl_4^{2-} + 6H_2O \rightleftharpoons Co(H_2O)6^{2+} + 4Cl^{-}$$

Your observations enable you to add a heat term to the equation.

Purpose:

1. To observe and explain the effect of changing concentration on a system at equilibrium.
2. To observe and explain the effect of changing temperature on a system at equilibrium.

Materials:

0.1 mol/L solutions of KCl, KSCN, $BaCl_2$, $FeCl_3$, $K_2Cr_2O_7$, K_2CrO_2, $Na_2Cr_2O_7$, Na_2CrO_4, Na_2HPO_4, test tubes and rack, graduated cylinder, crystals of KCl and $CoCl_2.\ 6H_2O_{(s)}$, 1.0 mol/L HNO_3; ethanol

Procedure:

Part I: Concentration Changes and Equilibrium

1. Examine solutions of KCl, KSCN, $FeCl_3$, and Na_2HPO_4. Write the colors of each ion listed in Table I. You will have to perform Procedure 2 before writing the color of the $Fe(SCN)^{2+}$ ion.
2. Place a few drops of 0.1 mol/L $FeCl_3$ in a test tube and add the same amount of 0.1mol/L KSCN. Swirl the mixture and add water until a transparent, orange-red solution is obtained. Provide 4 more test tubes and divide the solution into 5 approximately equal portions.
3. Use the first tube as a color standard. To tube number 2, add 1 mL of $FeCl_3$ solution; to tube number 5, add 1 mL of Na_2HPO_4 solution. Shake each tube and compare the colors with the standard. Record your observations in Table II. Use the species listed in Table I to help you explain why the equilibrium shifted. Remember that decreasing the concentration of an iron may be decreased by removing it in the form of molecular species, a polyatomic (complex) ion, or a precipitate.

Table II: Effect of Concentration Changes on the Equilibrium System

$$Fe^{3+} + SCN^- \rightleftharpoons Fe(SCN)^{2+}$$

Species added to Equilibrium	Color Change	Direction of Equilibrium Shift	Reasons for Shift
Fe^{3+} from $FeCl_3$			
Cl^- from KCl			
SCN^- from KSCN			
HPO_4^{2-} from Na_2HPO_4			

4. Examine solutions of $K_2Cr_2O_7$, $Na_2Cr_2O_7$, Na_2CrO_4, and K_2CrO_4. Describe the color of the CrO_4^{2-} ion in Table III.

5. Place 5 mL of 0.1mol/L $K_2Cr_2O_7$ in a test tube and add 1.0 mol/L NaOH until a color change is observed. Record your observations in table IV.

Table III: Colors of Ions

Ion	Color
$Cr_2O_7^{2-}$	
CrO_4^{2-}	

6. Put 5 mL of 0.1mol/L K_2CrO_4 in a test tube and add 1.0mol/L HNO_3 until a color change s observed. Record observation in table IV.
7. Add 2 mL of $BaCl_2$ solution to 5 mL of $K_2Cr_2O_7$ solution. Decant and note color of precipitate.
8. Add 2 mL of $BaCl_2$ solution to 5 mL of $K_2Cr_2O_7$ solution. Decant and note color of precipitate. Record your observations in Table IV. Use the results of procedure 7 and 9 to help in the identification of the precipitate and in the identification of the components in aqueous $K_2Cr_2O_7$.

Table IV: **Effect of Changing [H_3O^+] on the Equilibrium System**

$$Cr_2O_7^{2-} + 3H_2O \rightleftharpoons 2CrO_4^{2-} + 2H_3O$$

original solution	species added to original solution	observation	color of precipitate (if any)	explanation for change
$Cr_2O_7^{2-}$	OH^- from NaOH			
CrO_4^{2-}	H^+ from HNO_3			
CrO_4^{2-}	Ba^{2+} from $BaCl_2$			
$Cr_2O_7^{2-}$	Ba^{2+} from $BaCl_2$			
acidified $Cr_2O_7^{2-}$	Ba^{2+} from $BaCl_2$			

9. Repeat procedure 8 but add the $BaCl_2$ solution to 4 mL of $K_2 Cr_2O_7$ solution to which had been added 1 mL of 1.0 mol/L HNO_3.

Table V: Colors of Ions

Ion	Color
$CoCl_4^{2-}$	Blue
$Co(H_2O)_6^{2+}$	Pink

Part II: Temperature and Equilibrium

10. Place about 0.3g (a few crystals) of crushed $CoCl_2.6H_2O$ in a test tube and add 5 mL of ethyl alcohol. Shake vigorously or stir until most of the solid has dissolved. If the solution is not pink in colour, add water dropwise until the solution just turns pink

11. Heat the solution gently in beaker of hot water until it changes color (use a hot plate). Record observations in Table IV.

12. Immerse the test tube in a beaker of cold water until the color changes again. Repeat moving the test tube from hot to cold water several times.

Table VI: Effect of Temperature on the Equilibrium System

$$CoCl_4^{2-} + 6H_2O \rightleftharpoons Co(H_2O)_6^{2+} + 4Cl^-$$

Procedure	Color Change	Equilibrium Shifts (left or right)
In hot water		
In cold water		

Discussion Questions:

1. Complete Table II. Use the data in Table I and you knowledge of LeChatelier's Principle to help you explain in which direction and why a shift in equilibrium occurred.
2. Refer to Table IV and explain what evidence indicates that hydrogen ions are a constituent of the equilibrium mixture.
3. What evidence do you have that a water solution of $K_2Cr_2O_7$ is actually an equilibrium mixture that contains CrO_4^{2-} ions?
4. Use the data in Table V and VI to help you convert the equilibrium equation into a thermochemical equation. Write the heat term (ΔH) on the correct side of the equation with the proper sign. As written, is the reaction exothermic or endothermic?