Chemical Equilibrium and LeChatelier's Principle

Two important questions are asked about every chemical reaction: (1) How much product is produced and (2) How fast is it produced? The first question involves chemical equilibrium and the second question belongs to the domain of chemical kinetics. Some reactions are reversible and they go to completion. When you ignite methane gas in your Bunsen burner in the presence of air, methane burns completely and forms carbon dioxide and water.

$$CH_4(g) + 2O_2 \rightarrow CO_2 + 2H_2O(g)$$

Other reactions do not go to completion. They are reversible. In such cases, the reaction can go in either direction: forward or backward. When the reactants are initially mixed, the forward reaction proceeds at maximum rate. As time goes on, the rate of reaction decreases as the amount of reactant s decrease. On the other hand, the rate of the reverse reaction gradually increases. Eventually, the rates become equal. When this point is reached, the system is said to be in a state of (dynamic) equilibrium.

Once at equilibrium, the system will remain stable until it is disturbed. This can be done by adding or removing some reactant or product, changing the temperature, or in the case of gases, changing the volume of the container. When this occurs, the system is not at equilibrium and the rates of the forward and reverse reactions will change until a new equilibrium is established. This series of events is summarized by LeChatelier's Principle: If an external stress is applied to a system in equilibrium, the system reacts in such a way as to partially counteract the stress. In this experiment, LeChatelier's Principle will be demonstrated by changing the concentration of reactants or products and by changing the temperature. These demonstrations are described below.

Part 1: In this part, ammonia will be added to a solution of copper sulfate:

$$Cu(H_2O)_4^{2+}(aq) + 4NH_3(aq) \leftrightarrow Cu(NH_3)_4^{2+}(aq) + 4H_2O(l)$$

A change in color indicates the copper-ammonia complex formation. Adding a strong acid, HCl, to the equilibrium causes the ammonia to react with the acid:

$$NH_3(aq) + H^+(aq) \leftrightarrow NH_4^+(aq)$$

Part 2: In the iron (III) – thiocyanate reaction

$$\underset{\text{orange}}{Fe^{3+}(aq)} + 3Cl^-(aq) + K^+(aq) + SCN^-(aq) \leftrightarrow \underset{\text{red}}{Fe(SCN)^{2+}} + 3Cl^-(aq) + K^+(aq0$$

the chloride and potassium ions are spectator ions. Nevertheless, their concentration may also influence the equilibrium. For example, when the chloride ions are in excess, the yellow color of the Fe^{3+} will disappear with the formation of the colorless $FeCl_4^-$ complex:

$$Fe^{3+}(aq) + 4Cl^-(aq) \leftrightarrow FeCl_4^-(aq)$$

Part 3: Most reactions are accompanied by some energy changes. Frequently, the energy is in the form of heat. If heat is absorbed during the reaction it is referred to as endothermic and if heat is released, it is exothermic. In an endothermic reaction, heat can be considered a reactant and in an exothermic reaction heat is considered a product. Therefore, the addition or removal heat will affect an equilibrium system. The direction of the shift depends on whether the reaction is endothermic or exothermic. The effects of temperature will be demonstrated on the following reaction:

$$\underset{\textbf{red}}{Co(H_2O)_6^{2+}(aq)} + 4Cl^-(aq) \leftrightarrow \underset{\textbf{blue}}{CoCl_4^{2-}(aq)} + 6H_2O(l)$$

PROCEDURE

Part 1

1. Place 20 drops of $CuSO_4$ solution into a test tube.
2. Add 1.0 M NH_3 drop wise until a definite color change occurs, being sure to swirl the test tube after each drop. Record the number of drops required.
3. Add 1.0 M HCl drop wise until the original color returns. Record the number of drops required.

Part 2

1. Prepare a stock solution by adding 1 mL of $FeCl_3$ and 1 mL of KSCN to 50 mL of distilled water in a beaker.
2. Place four test tubes in a rack and label them. To each test tube add 2 mL of the stock solution.
3. Record the color of the first test tube. Use this tube as your standard to compare the others to.
4. Add 10 drops of $FeCl_3$ to the second test tube, 10 drops of KSCN to the third test tube, and 5 drops of NaCl to the fourth test tube. Mix and observe the color of each test tube. Record your observations.

Part 3

1. Place 5 drops of $CoCl_2$ in a test tube. Add concentrated HCl drop wise until a color change occurs (do not stop at a purple color). Record your observations.
2. Place 1 mL of $CoCl_2$ in the test tube from step 1 and record the color. Immerse the test tube in a boiling water bath and record your observations.

DATA TABLES

	Prediction	**Observation**
Data Table 1		
Color of copper sulfate soln		
# of drops of NH_3 added	XXXXXXXXXXXXXXXXXX	
Color of soln after NH_3 added		
# of drops of HCl added	XXXXXXXXXXXXXXXXXX	
Color of soln after HCl added		

Data Table 2

Color of test tube #1		
Color of test tube #2		
Color of test tube #3		
Color of test tube #4		

Data Table 3

Color of $CoCl_2$ before adding HCl		
Color of $CoCl_2$ after adding HCl		
Color of $CoCl_2$ at room temperature		
Color of $CoCl_2$ in water bath		