Part I. The $\text{Cu(H}_2\text{O)}_5^{2+}$ system.

In Part I of the lab, the following equilibrium was studied.

$$\text{Cu(H}_2\text{O)}_5^{2+} (aq) + 4 \text{NH}_3 (aq) \rightleftharpoons \text{Cu(NH}_3)_4^{2+} (aq) + 4 \text{H}_2\text{O (l)}$$

Aqueous $\text{NH}_3$ (ammonia) was added to the $\text{Cu(H}_2\text{O)}_5^{2+}$ system in step 2.

1. What physical change did you observe when the $\text{NH}_3 (aq)$ was added? [3]

2. In 1-2 sentences explain how the addition of $\text{NH}_3 (aq)$ shifted the equilibrium shown above. [5]

3. Aqueous HCl was added next. What did you observe upon addition of the acid. [3]

4. a. With which species did the HCl react? [2]

   b. Write a balanced chemical equation for the reaction. [2]

5. In 1-2 sentences explain how the addition of HCl shifted the equilibrium shown above. [5]
Part II. The Ag$_2$CO$_3$ system.

In Part II of the lab, the following reaction occurred when silver nitrate and sodium carbonate were mixed.

\[
2 \text{AgNO}_3 (aq) + \text{Na}_2\text{CO}_3 (aq) \rightleftharpoons \text{Ag}_2\text{CO}_3 (s) + 2 \text{NaCO}_3 (aq)
\]

1. What did you observe when the two reagents were mixed? [3]

2. Ag$_2$CO$_3$ (s) is only slightly water soluble and the equilibrium equation maybe written as:

\[
\text{Ag}_2\text{CO}_3 (s) \rightleftharpoons 2 \text{Ag}^+ (aq) + \text{CO}_3^{2-} (aq)
\]

   What did you observe when in step 2 aqueous HNO$_3$ was added. [3]

3. a. With what species did the HNO$_3$ react? [2]

   b. Write a balanced chemical equation for the reaction. [2]

4. Briefly explain how the equilibrium above was shifted upon the addition of HNO$_3$. [5]
5. In step 3, HCl was added to the test tube establishing the following equilibrium.

\[
\text{Ag}^+ (aq) + \text{Cl}^- (aq) \rightleftharpoons \text{AgCl} (s)
\]

Based upon your observations, does this equilibrium favor the reactants or the products? Briefly justify your answer. [5]

6. In the next step of the lab, ammonia was added to the reaction mixture. What did you observe upon addition of NH\(_3\) in this step? [3]

7. a. With which species did the NH\(_3\) react? [2]

b. Write a balanced chemical equation for the reaction with NH\(_3\). [2]

8. Briefly explain how the addition of NH\(_3\) shifted the equilibrium shown above. [5]
Part III. The Co(H₂O)₆²⁺ system.

In part III, the equilibrium shown below was studied:

$$4 \text{Cl}^- (\text{aq}) + \text{Co(H₂O)}₆^{2+} (\text{aq}) \rightleftharpoons \text{CoCl}_4^{2-} (\text{aq}) + 6 \text{H₂O (l)}$$

1. What color is the reactant Co(H₂O)₆²⁺ (aq)? [2]

2. What color is the reactant CoCl₄²⁻ (aq)? [2]

3. After the HCl was added did the equilibrium favor the reactants or the products? Briefly explain how the addition of 12 M hydrochloric acid shifted the equilibrium above. [4]

4. After the addition of water did the above equilibrium favor the reactants or products? Briefly explain how the addition of water shifted the equilibrium shown above. [4]
5. When the solution was placed in warm water, what did you observe? [3]

6. Based on the observation in question 5, briefly explain how you know whether the reaction is endothermic or exothermic? [5]

7. When the solution was placed in ice, what did you observe? [3]

8. Based upon the observation in question 7, briefly explain how you know whether the reaction is endothermic or exothermic? [5]

9. Briefly, in one page or so,

   a. Discuss Two major items you learned from this lab regarding Le Châtelier’s Principle and how you may use this knowledge in your scientific career. [10]

   b. Discuss in detail one Chemical “real world” application of Le Châtelier’s Principle not mentioned in the lab. Be sure to include appropriate references. [10]