Chemistry 12 Lab 19A: Investigating Equilibrium

Name:____________________________________ **Block:** __________
Group Members:______________________________ **Due Date:**_____________

Lab: **This experiment is based on Experiment 19A in Heath Laboratory Experiments*.

Objectives

1. To recognize the macroscopic properties of four chemical systems at equilibrium.
2. To observe shifts in equilibrium concentrations as stresses are applied to the systems.
3. To explain observations by applying *LeChatelier's Principle*.

Criteria	Excellent 5	Good 4	Satisfactory 3	Needs Improvement 2	Poor/Not shown 1	Student Self Evaluation	Teacher Assessment
Objective: Clearly states the aim of the experiment and briefly outlines the related theory **Procedure:** refers to handout/textbook page by correct citation and *note any changes to the method (as noted by your teacher)*						/2	/2
Pre-Lab: flow chart is completed individually by each group member ***before the lab!*** **Pre-Lab Questions:** *displays a critical understanding of the background theory. To be completed on a separate page*						/7	/7
Data, Results & Calculations: *(hand written neatly)* Provides results/observations (and diagrams where appropriate) that are presented in **correctly labelled** tables and/or graphs with **accurate titles**.						/4	/4
Follow-up Questions: *(word processed)* Correctly identifies and explains the theory relating to the experiment and supports this with accurate observations & data.						/8	/8
Conclusion: *(word processed)* Identifies and defines important concepts and principles relevant to the experiment by relating back to the objective and hypothesis. ***Be sure to address the points*** listed in the lab handout when answering the conclusion.						/2	/2
Presentation: Practical report is presented in the **correct format**, is written fluently and provides **appropriate section headings** and accurate referencing. ***Tables & graphs*** have numbered headings. Data & calculations may be hand written, however the remainder of the report is to be **word-processed.**						/2	/2
Safety: Demonstrates an organized and safe approach to experimental work during the lab						/5	/5
Results Summary						/30	/30

Materials

12 test tubes	test tube rack	2 x100mL beakers	beaker tongs	2 x125	Erlenmeyer flask
safety glasses	2 x250mL beakers	10mL graduated cylinder			gloves

Part I: 1.0M HCl	1.0M NaOH	Thymol Blue		
Part II: 0.2M $FeCl_3$	0.2M KSCN	0.2M KCl	0.2M $Fe(NO_3)_3$	6.0M NaOH
Part IV: 0.1M K_2CrO_4	0.1M $K_2Cr_2O_7$	1M NaOH	1M HCl	0.1M $Ba(NO_3)_2$
Part V: 0.1M $CuSO_4$	1.0M NH_3	1.0M HCl		

Pre-lab Questions:

Carefully read the pre-lab discussion. Heath Chemistry page 208. See attatched pages for reference & supplementary information you will find helpful..

1. **Draw a flow chart** for this experiment. Separate it into parts 1, 2, 4 and 5 *(part 3 is omitted due to the use of highly toxic chemicals).*

Part 1: Thymol Blue

2. Write the equilibrium equation for the reaction involving the formation of the iron (III) thiocyanate complex. *(see data table)*
3. What is the purpose of adding thymol blue to two Erlenmeyer flasks if additional reagents are only to be added to the first flask?

Part 2: Thiocyanatoiron (III) Ion

4. Write the equation for the equilibrium reaction resulting from the combination of iron(III), Fe^{3+}, ions and thiocyanate, SCN^-, ions. *(see data table)*
5. What was the purpose of adding distilled water to the beaker in step 2?
6. What happens when OH^- ions are added to Fe^{3+} ions?
7. You will be adding KCl, $Fe(NO_3)_3$, KSCN and NaOH to the equilibrium. Which ions contained in these substances are likely to have a pronounced effect on equilibrium?

Part 4: Chromate & Dichromate

8. Write the equation for the equilibrium reaction between the chromate and dichromate ions. *(see data table)*
9. How do you expect this equilibrium to respond when HCl id added? When NaOH is added?
10. Write the equilibrium involving barium and chromate ions. Under what conditions would this equilibrium shift to the right, causing a precipitate of $BaCrO_4$?

Part 5: Copper (II) Complexes

11. Write the equilibrium equation involving hydrated copper II ions, $Cu(H_2O)_4^{2+}$, and ammonia molecules.
12. What happens to molecules of NH_3 when H^+ is added?
13. How would you expect the equilibrium in step #11 to respond when HCl is added in step 4?
14. What is a spectator ion?

Safety glasses are to be worn at <u>all times</u>, for <u>all experiments!</u>
Gloves are required for select portions (see individual method notes).

Reagent Disposal: all waste is to be collected in the **WASTE DISPOSAL**. All test tubes must be rinsed *<u>thoroughly</u>* in order to be used in the following reactions.

Clean Up: clean up all materials, wipe lab bench with disinfectant and wash hands *well* with soap and water before you leave the lab each day.

Procedure

PART I – Equilibrium involving Thymol Blue

1. Add 100mL of water to a 125mL Erlenmeyer flask. Add ~10 drops of Thymol Blue to get colour change. Swirl to mix. Then add ~3 drops NaOH until a strong blue colour appears.

2. Remove 50mL and place in a second Erlenmeyer flask and label: *control*.

3. Add ~2-3 drops of 1.0M HCl. Swirl to mix. Continue adding HCl drop by drop until a *definite color change* is observed. Be sure to use your control flask to compare. Record the new colour in Table 1.

4. Continue drop by drop addition of 1.0M HCl into the first flask until a second colour shift occurs. Compare with the control and record the new colour in Table 1.

5. Repeat steps 3 & 4 BUT this time add 1.0M NaOH drop by drop until you see a colour change. Record results in Table 1.

PART II – Equilibrium involving Thiochyanatoiron (III) Ion

1. Use a 10mL graduated cylinder to measure 1mL of 0.2M $FeCl_3$ and pour it into a 250mL beaker. Using *another* 10mL graduated cylinder, measure 1mL of 0.2M KSCN. Record the colour of each solution under the equilibrium reaction in Table 2.

2. Add the 1mL portion of 0.2M KSCN to the beaker containing 0.2M $FeCl_3$. *Carefully* swirl the mixture and record the colour of $FeSCN^{2+}$ under the equilibrium reaction in Data and Observations. Add enough water to the solution (80-120mL) to dilute the intense colour to a light amber colour.

3. Pour approximately 5mL of this solution each into 5 *small* test tubes labeled A to E. Test tube A serves as a control.

4. For each of the following reactions (steps 5-8), record the results in Data Table 2. To record “stress”, *state which ion* in the original equilibrium *changed concentration*, and if it was an *increase or decrease*.

    a. To test tube B, add 10 drops of 0.2M KCl.

    b. To test tube C, add 10 drops of 0.2M $Fe(NO_3)_3$.

    c. To test tube D, add 10 drops of 0.2M KSCN.

    d. To test tube E, add 10 drops of 6.0M NaOH.

5. All solutions can go down the sink with *plenty* of water.

PART IV – Equilibrium involving Chromate and Dichromate Ions

**The dust from chromates and dichromates is dangerously poisonous and a skin irritant. WEAR GLOVES. Do not get any in or around your mouth. Inform teacher of any spills, and clean up carefully*

1. Place 10 drops of 0.1M K_2CrO_4 and 10 drops of 0.1M $K_2Cr_2O_7$ in different test tubes.
2. Add 1.0M NaOH drop by drop *(alternating between the 2 test tubes)* until a **colour change occurs in one** of the test tubes. Record results in Table 3.
3. To the same test tubes add 1.0M HCl in the same manner until a colour change is observed. Record results in Table 3. *(a colour change should be observed in one of the test tubes)*
4. **Repeat** steps 1-3, but **add the 1.0M HCl first** until a **colour change is observed in one** of the test tubes, then add 1.0M NaOH until a colour change is observed in one of the test tubes. Record results in Table 3.
5. Place 10 drops of 0.1M K_2CrO_4 in a test tube. Add two drops of 1.0M NaOH. Then add 0.1M $Ba(NO_3)_2$ drop by drop until a change is noted. Record *colour change* & if the solution is *clear or cloudy* in Table 3.
6. Add 1M HCl drop by drop to the test tube from Step 5 until a change occurs. Record results in Table 3.
7. Place 10 drops of 0.1M $K_2Cr_2O_7$ in a test tube. Add two drops of 1.0M HCl. Then add 0.1M $Ba(NO_3)_2$ drop by drop until a change is noted. Record *colour* & if the solution is *clear or cloudy* in Table 3.
8. Add 1.0 M NaOH drop by drop to the test tube from Step 7 until a change occurs. Record detailed results in Table 3.
9. Place 10 drops of 0.1M K_2CrO_4 and 10 drops of 0.1M $K_2Cr_2O_7$ in different test tubes. Add 10 drops of 0.1M $Ba(NO_3)_2$ into each. Record results in Table 3.
10. All solutions should be put into the **designated waste container.**

PART V – Equilibrium involving Copper (II) Complexes

1. Place ~5mL of 0.1 $CuSO_4$ in a 100mL beaker *(use approximate scale on beaker)* and record the initial colour in Table 4.
2. Add 3 drops of 1.0M NH_3 and Record *colour change* & if the solution is *clear or cloudy* in Table 4.
3. Continue to add NH_3 drop by drop until another change occurs. Record *colour change* & if the solution is *clear or cloudy* in Table 3.
4. Add 1.0M HCl drop by drop until a change occurs. Record *colour change* & if the solution is *clear or cloudy* in Table 3. *(there should be 2 colour changes that occur)*

Data and Observations:

PART I

Equilibrium Equation ________ + ________ ⇔ ________

Colour ________ + ________ ⇔ ________

Table 1 – Stresses on Thymol blue

Reagent Added	Stress (Ions added)	Observation (colour change)	Direction of Equilibrium Shift
HCl (Step 3)			
HCl (Step 4)			
NaOH (Step 5)			
NaOH (Step 6)			

PART II

Equilibrium Equation ________ + ________ ⇔ ________

Colour ________ + ________ ⇔ ________

Table 2 – Stresses on Thiocyanate (III) Iron

Reagent Added	Stress (Ions added)	Observation (colour change)	Direction of Equilibrium Shift
KCl (B)			
$Fe(NO_3)_3$ (C)			
KSCN (D)			
NaOH (E)			

PART IV

Equilibrium Equation ________ + ________ ⇔ ________________

Colour ________ + ________ ⇔ ________________

Table 3 – Stresses on Chromate and Dichromate Ions

		0.1M K_2CrO_4		**0.1M $K_2Cr_2O_7$**	
Step 1	Initial Colour				
Step 2	**1M NaOH added**				
Step 3	**1M HCl added**				
		0.1M K_2CrO_4		**0.1M $K_2Cr_2O_7$**	
Step 4	Initial Colour				
	1M HCl added				
	1M NaOH added				
Step 5 & 6		**Initial Colour**	**+1M NaOH**	**+0.1M $Ba(NO_3)_2$**	**+ 1.0M HCl**
	0.1M K_2CrO_4				
Step 7 & 8		**Initial Colour**	**+1M HCl**	**+0.1M $Ba(NO_3)_2$**	**+ 1.0M NaOH**
	0.1M $K_2Cr_2O_4$				
Step 9		**0.1M K_2CrO_4**		**0.1M $K_2Cr_2O_4$**	
	Add 0.1 M $Ba(NO_3)_2$				

PART IV

Equilibrium Equation ________ + ________ ⇔ ________________

Colour ________ + ________ ⇔ ________________

Table 4 – Stresses on Copper (II) Complexes

	0.1M $CuSO_4$	**+ 3 drops NH_3**	**+ more NH_3**	**1.0M HCl added**
Appearance				

Follow-up Questions:

Carefully read the post-lab discussion. Heath Chemistry page 211. See attatched pages for reference.

PART I

1. How would increasing the molarity of the NaOH solution from 1 M to 2 M affect the number of drops required for the observed colour changes?

PART II

2. Explain, using *LeChatelier's Principle*, the results obtained when 0.2M $Fe(NO_3)_3$ was introduced into the iron (III) thiocyanate ion equilibrium system. Support any and all explanations with your observations.

3. Explain, using *LeChatelier's Principle*, the results obtained when 6.0M NaOH was introduced into the iron (III) thiocyanate ion equilibrium system. Include the formula of any precipitate that may have formed. Support any and all explanations with your observations.

PART IV

4. Explain the reasons for the equilibrium shifts observed in Steps 1 to 4 of Part IV.

5. Explain why no precipitate formed in $K_2Cr_2O_7$ in Step 7 of Part IV, while some precipitate did form later, in step 9. *(2 marks)*

Part V

6. Explain the cause of the color change observed when HCl was added to the complex ion $Cu(NH_3)_4^{2+}$ *(2 marks)*

<u>Conclusion</u>

1. State the effect on the position of an equilibrium due to a change in concentration of a reactant or product.

2. ~~State the effect on the position of an equilibrium due to a change in temperature.~~

**This experiment is based on Experiment 19A in* *Heath Laboratory Experiments*.

Supplementary Information Provided:

Investigating Chemical Equilibrium

Most chemical reactions appear to proceed to completion. Under certain conditions, however, the products may have sufficient energy to reform reactants in a reverse reaction. When forward and reverse reaction rates are equal, a state of equilibrium is established. Although both reactions continue to occur, the net concentration of each substance remains the same.

Le Chatelier's principle allows us to predict the effects of a stress placed on an equilibrium system. The stress produces a shift in concentrations that may be recognized by changes in the macroscopic properties of the system.

The reactions presented in this investigation demonstrate observable reversibility. Under changing conditions, the systems will respond to counteract any stress placed upon the equilibrium state. A variation in a precipitate provides the observable evidence that a shift has occurred in the equilibrium concentrations.

You will study five different equilibrium systems involving ions in solution. The first system, studied in Part I, is the conversion of the indicator thymol blue from its blue form to its yellow form. The extent to which the forward reaction is favored depends upon the concentration of hydrogen ions in solution:

$$\text{thymol blue (blue form)} + H^+ \rightleftharpoons \text{thymol blue}^+ \text{ (yellow form)}$$

The second reaction (Part II) involves the light yellow iron(III) ion, Fe^{3+}, and thiocyanate ion, SCN^-, which forms the colored complex $FeSCN^{2+}$:

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

The third system (Part III) involves the hydrated cobalt(II) ion, $Co(H_2O)_6^{2+}$, which can be converted to the chlorinated complex ion, $Co(H_2O)_4Cl_2$.

$$Co(H_2O)_6^{2+}(aq) + 2Cl^-(aq) \rightleftharpoons Co(H_2O)_4Cl_2(aq) + 2H_2O(l)$$

You will study the effects on this system of changing the temperature. Your data should allow you to predict whether the forward or reverse reaction is exothermic.

The fourth system (Part IV) involves the equilibrium between the yellow chromate ion, CrO_4^{2-}, and the orange dichromate ion, $Cr_2O_7^{2-}$. You will study the effect of adding H^+ and OH^- to this equilibrium, and also the effect of adding Ba^{2+} to it.

The last system (Part V) involves an equilibrium between hydrated copper(II) ion, $Cu(H_2O)_4^{2+}$, and the tetramminocopper(II) ion, $Cu(NH_3)_4^{2+}$, in which the water molecules have been replaced with NH_3 molecules. The effect of acid and of NH_3 on this equilibrium will be examined.

POST LAB DISCUSSION

The equilibrium system in Part I can be affected by the addition of any reagent supplying H^+ or OH^-. Recall that the H^+ ions are characteristic of acids and OH^- ions are characteristic of bases. The addition of an acid should favor the conversion into the lighter colored form of the indicator.

Another factor to consider in explaining your observations is the fact that H^+ will react with OH^- to form water molecules. As a result of the formation of water, the concentrations of H^+ and OH^- in the equilibrium reaction are reduced.

In reviewing your data from Part II, it is important to note that the formation of $FeSCN^{2+}$ is heavily favored over the reverse decomposition reaction. Diluting the solution with water allows you to observe small changes in the equilibrium more readily. In explaining your observations of this equilibrium, remember that spectator ions do not participate in the net reaction.

In Step 6 of Part II, you noted the formation of a precipitate. In this case, the precipitate is $Fe(OH)_3$. In explaining your results, remember that the formation of this precipitate reduces the Fe^{3+} concentration of the solution.

For the reaction in Part III, recall that increasing the temperature of an equilibrium reaction favors the endothermic reaction. From your observations, you should be able to predict which of the two reactions is endothermic.

The equilibrium in Part IV can be represented by the equation

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

The presence of $H^+(aq)$ in the equilibrium explains how it is that adding H^+ and OH^- is able to affect the position of this equilibrium. The other equilibrium involved in Part IV is the one in which Ba^{2+} ions react with CrO_4^{2-} ions to give solid $BaCrO_4$:

$$Ba^{2+}(aq) + CrO_4^{2-}(aq) \rightleftharpoons BaCrO_4(s)$$

Whether or not a precipitate could be observed here depends on the position of the first equilibrium involving CrO_4^{2-} and $Cr_2O_7^{2-}$.

The equilibrium in Part V initially involves the formation of OH^- ions in NH_3 solution:

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

The OH^- ions then react with $Cu^{2+}(aq)$ to give a precipitate of $Cu(OH)_2$:

$$Cu^{2+}(aq) + 2OH^-(aq) \rightleftharpoons Cu(OH)_2(s)$$

When more NH_3 was added, NH_3 molecules replaced H_2O molecules in $Cu^{2+}(aq)$:

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

H^+ ions can react with NH_3 to give NH_4^+; therefore, the equilibrium shifts in response to this change.