19A: Investigating Chemical Equilibrium

Introduction

Most chemical reactions appear to proceed to completion. However, under certain conditions 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 visible properties of the system.

The reactions in this activity show observable reversibility. Under changing conditions, the system will respond to oppose any stress placed upon the equilibrium. A colour change or the formation or disappearance of a precipitate provides the observable evidence that a shift has occurred.

Objectives

1. To recognize visible properties of five equilibrium systems.
2. To observe shifts in equilibrium concentrations as stresses are applied to the systems.
3. To observe a shift in equilibrium concentrations associated with changes in temperature.
4. To explain the observations by applying Le Chatelier’s principle.

Materials

5 test tubes 0.1 M HCl 0.1 M K2CrO4 0.1 M CuSO4

Test tube rack 0.1 M NaOH 1.0 M HCl 1.0 M NaOH

250 mL beaker 0.2 M FeCl3 6.0 M NaOH 1.0 M NH3

250 mL Erlenmeyer flask 0.2 M KSCN 0.2 M Fe(NO3)3 thymol blue solution

10 mL graduated cylinder 0.2 M KCl 0.1 M Ba(NO3)2

Safety glasses 0.1 M K2Cr2O7 Procedure/Data and Observations

Part I: Equilibrium Involving Thymol Blue

Thymol blue + H+  thymol blue+

(blue) (yellow)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Reagent Added | Number of Drops | Stress Ion | Spectator Ion | Colour Observation | Direction of Equilibrium Shift |
| HCl  (step 2) |  |  |  |  |  |
| NaOH  (step 3) |  |  |  |  |  |

**Caution: Hydrochloric acid is corrosive to skin, eyes, and clothing. When handling this acid be careful not to spill it on yourself. Wash any spills or splashes immediately with water.**

1. Obtain a clean 250 mL Erlenmeyer flask. Add approximately 100 mL of water and 1 mL of thymol blue solution to the flask. If the solution is yellow, add a few drops of 1.0 M NaOH until the solution turns blue.
2. Slowly add 0.1 M HCl to the flask until you see a colour change. Swirl the flask as you add the HCl. Record the new colour and the number of drops required.
3. Now add 0.1 M NaOH to the flask until you see a colour change. Swirl the flask as you add the NaOH. Record the new colour and the number of drops.
4. Determine which of the ions added in each step caused the equilibrium to shift. Record the stress ion in your data table.

Part II: Equilibrium Involving Cobalt(II) Complexes

Co(H2O)6+2 + 2Cl-  Co(H2O)4Cl2 + 2H2O

(light red) (dark purple)

|  |  |  |
| --- | --- | --- |
| Stress | Colour Observation | Direction of Equilibrium Shift |
| Heat | Turns purple | 🡪 |
| Cold | Turns light red | 🡨 |

**This part has been done for you. Go on to Part III.**

Part III: Equilibrium Involving Thiocyanatoiron(III) Ion

Fe+3 + SCN-  FeSCN+2

Colour of FeCl3: \_\_\_\_\_\_\_\_\_\_\_\_ (reactant)

Colour of KSCN: \_\_\_\_\_\_\_\_\_\_\_\_ (reactant)

Colour of FeSCN+2: \_\_\_\_\_\_\_\_\_\_\_\_ (product)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Reagent Added | Stress Ion | Spectator Ion | Colour Observation | Direction of the Equilibrium Shift |
| KCl  (Step 5) |  |  |  |  |
| Fe(NO3)3  (Step 6) |  |  |  |  |
| KSCN  (Step 7) |  |  |  |  |
| NaOH  (Step 8) |  |  |  |  |

**Caution: sodium hydroxide is corrosive to skin, eyes, and clothing. When handling this base be careful not to spill it on yourself. Wash any spills or splashes immediately with water.**

1. Place 1 mL of 0.2 M FeCl3 into a 250 mL beaker. Using a graduated cylinder, measure 1 mL of 0.2 M KSCN. Record the colour of each solution.
2. Add the KSCN in the graduated cylinder to the beaker containing FeCl3. Swirl the mixture and record the colour. Add approximately 80 mL of water to dilute the solution.
3. Pour 5 mL of this solution into each of 5 separate test tubes labelled A to E. Test tube A is a control.
4. For each of the following reactions (steps 5 to 8) record the results in the table. To record the “stress ion” state which of the two ions in the compound caused the equilibrium to shift.
5. To test tube B, add 10 drops of 0.2 M KCl.
6. To test tube C, add 10 drops of 0.2 M Fe(NO3)3.
7. To test tube D, add 10 drops of 0.2 M KSCN.
8. To test tube E, add 10 drops of 6 M NaOH.

Part IV: Equilibrium Involving Chromate and Dichromate Ions

2CrO4-2 + 2H+  Cr2O7-2 + H2O

Colour of K2CrO4: \_\_\_\_\_\_\_\_\_\_\_\_\_ (reactant)

Colour of K2Cr2O7: \_\_\_\_\_\_\_\_\_\_\_\_\_ (product)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Steps 2 and 3 |  | 0.1 M K2CrO4 | | 0.1 M K2Cr2O7 | |
| Initial colour |  | |  | |
| 1 M NaOH added |  | |  | |
| 1 M HCl added |  | |  | |
| Step 4 |  | Initial Colour | + 1 M NaOH | + 0.1 M Ba(NO3)2 | + 1 M HCl |
| 0.1 M K2CrO4 |  |  |  |  |
| Step 5 |  | Initial Colour | + 1 M HCl | + 0.1 M Ba(NO3)2 | + 1 M NaOH |
| 0.1 M K2Cr2O7 |  |  |  |  |

**Caution: Chromates are poisonous and are skin irritants. Do not get any in your mouth; do not swallow any. Wash any spills and splashes off your skin with plenty of water.**

**ALL SOLUTIONS MUST BE PUT IN THE DESIGNATED WASTE CONTAINER**.

1. Place 10 drops of 0.1 M K2CrO4 and 10 drops of 0.1 M K2Cr2O7 into different test tubes. Record the colour of each solution.
2. Add 1 M NaOH drop by drop to each test tube, alternating, until a colour change occurs in **one** of the test tubes. Record the colour of each solution.
3. To the same test tubes used in step 2, add 1 M HCl, alternating, until a colour change occurs in **both** of the test tubes. Record the colour of each solution.
4. Place 10 drops of 0.1 M K2CrO4 in a test tube. Record the colour.
   1. Add 2 drops of 1 M NaOH.
   2. Then add 0.1 M Ba(NO3)2 drop by drop until a change is observed.
   3. Add 1 M HCl drop by drop to the test tube until a change occurs.
   4. Record the changes after each addition.
5. Place 10 drops of 0.1 M K2Cr2O7 in a test tube. Record the colour.
   1. Add 2 drops of 1 M HCl.
   2. Then add 20 drops of 0.1 M Ba(NO3)2.
   3. Add 1 M NaOH drop by drop to the test tube until a change is observed.
   4. Record the changes after each addition.

Part V: Equilibrium Involving Copper(II) Complexes

NH3 + H2O  NH4+ + OH-

(colourless)

Cu(H2O)4+2 + 2OH-  Cu(OH)2(s) + 4H2O

(light blue) (precipitate)

Cu(H2O)4+2 + 4NH3  Cu(NH3)4+2 + 4H2O

(light blue) (dark blue)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 0.1 M CuSO4 | + 3 drops NH3 | + more NH3 | + 1M HCl |
| Observations |  |  |  |  |

1. Place 2 mL of 0.1 M CuSO4 in a test tube.
2. Add 3 drops of 1 M NH3 and observe the result.
3. Predict what will happen if you continue adding 1 M NH3: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. Continue adding 1 M NH3 until another change occurs and record the change.
5. Did the change match your prediction? \_\_\_\_\_\_\_\_
6. Add 1 M HCl drop by drop until a change occurs. Record the result.

Questions:

Show chemical reactions when necessary for explaining your answers.

Part I: Equilibrium Involving Thymol Blue

1. Use Le Chatelier’s principle to explain the colour change observed when HCl was added to the equilibrium.
2. Use Le Chatelier’s principle to explain the colour change observed when NaOH was added to the equilibrium.

Part II: Equilibrium Involving Cobalt(II) Complexes

1. If the Co(H2O)6+2 solution was refrigerated, what would you predict for the colour of the refrigerated solution?
2. From your lab results, which reaction (forward or reverse) is endothermic? Explain.
3. Predict how the addition of NaCl would affect the equilibrium. Explain using Le Chatelier’s principle.

Part III: Equilibrium Involving Thiocyanatoiron(III) Ion

1. What evidence was there that the equilibrium shifted when Fe(NO3)3 was added? In which direction did it shift?
2. What evidence was there that the equilibrium shifted when KSCN was added? In which direction did it shift?
3. Use Le Chatelier’s principle to explain the effect of adding NaOH to the equilibrium.

Part IV: Equilibrium Involving Chromate and Dichromate Ions

1. Compare the solubility of BaCrO4 to the solubility of BaCr2O7 (use your observations after the addition of Ba(NO3)2 in steps 4 and 5).
2. Explain why the precipitate dissolved when HCl was added in step 4?
3. Explain why a precipitate formed when NaOH was added in step 5?