DATE: NAME: CLASS:

CHAPTER 16
HANDOUT

BLM 16.2.2

Investigation 16.B: Disturbing Equilibrium

In this investigation, you will use Le Châtelier's principle to predict the effect of changing one factor that affects a system at equilibrium. Then you will design a test to check your prediction by assessing a change of colour or the appearance (or disappearance) of a precipitate.

Question

How can Le Châtelier's principle qualitatively predict the effect of a change in a chemical equilibrium?

Part 1 Changes to a Base Equilibrium System

Safety Precautions

- Hydrochloric acid and aqueous ammonia are corrosive to eyes and skin and harmful if swallowed or inhaled. Wash any spills on your skin or clothing with plenty of cool water. Inform your teacher immediately. Also inform your teacher immediately if you spill hydrochloric acid or aqueous ammonia on the lab bench or floor.
- Ammonium chloride is harmful if inhaled or swallowed and causes skin and eye irritation. Avoid contact with eyes and treat spills with copious amounts of cool water. Inform your teacher immediately.
- Phenolphthalein solution may irritate skin, eyes, and mucous membranes. This solution is flammable. Keep away from open flames.
- Wash your hands when you have completed the investigation.

Materials

- 0.01 mol/L $NH_3(aq)$
- phenolphthalein solution
- $NH_4Cl(s)$
- 6.0 mol/L $HCl(aq)$
- 25 mL beaker
- white paper
- 2 test tubes
- test-tube rack
- scoopula

Equilibrium System

$NH_3(aq) + H_2O(\ell) \leftrightarrow NH_4^+(aq) + OH^-(aq)$

You can detect a shift in this equilibrium by using phenolphthalein indicator.

Procedure

1. Pour about 10 mL of $NH_3(aq)$ into a small beaker. Place the beaker on a sheet of white paper. Add two drops of phenolphthalein indicator.

2. Divide the solution equally into two small test tubes. Given the list of materials, design a procedure to test Le Châtelier's principle. Describe how you will shift the equilibrium and predict the colour of the phenolphthalein indicator as a result of the shift. Include guidelines for the safe disposal of all materials.

Investigation 16.B: Disturbing Equilibrium (continued)

3. Construct a data table to record your observations.

4. Check your procedure with your teacher. Carry out your procedure and record your observations.

Investigation 16.B: Disturbing Equilibrium (continued)

Part 2 Concentration and Temperature Changes

Safety Precautions

- Concentrated hydrochloric acid is corrosive to your eyes, skin, and clothing. Avoid contact with eyes and treat spills with copious amounts of cool water. Inform your teacher immediately. Also inform your teacher if you spill hydrochloric acid on the lab bench or floor.
- Cobalt chloride and silver nitrate solutions are toxic and corrosive. Keep away from eyes and skin. Wash spills on your skin with plenty of cool water. Inform your teacher immediately. Silver nitrate is flammable. Keep away from open flames.
- Ethanol is flammable. Keep ethanol and solutions containing ethanol away from open flames.

Materials

- $CoCl_2$ dissolved in a solution of water and ethanol
- concentrated HCl(aq) in a dropper bottle
- $AgNO_3$(aq) 0.1 mol/L in a dropper bottle
- distilled water in a dropper bottle
- hot water bath
- cold water bath
- 25 mL or 50 mL beaker
- 4 small test tubes
- test-tube rack
- test-tube holder

Equilibrium System

When $CoCl_2$(s) dissolves in a solution of water and ethanol(aq/et), the salt dissociates and the Co^{2+} ion combines with water to form $Co(H_2O)_6^{2+}$(aq/et). The state (aq/et) indicates a solution of water and ethanol:

Heat + $Co(H_2O)_6^{2+}$(aq/et) + $4Cl^-$(aq/et) $\leftrightarrow$ $CoCl_4^{2-}$(aq/et) + $6H_2O$(ℓ/et)
pink **blue or purple**

Procedure

1. Pour 25 to 30 mL of $CoCl_2$(aq/et) into a small beaker. The solution should be blue or purple. If it is pink, add drops of concentrated HCl(aq) until the solution is blue-purple.

2. Pour about 5 mL of the solution into one of the tubes and put it aside as a control.

3. Given the list of materials, design as many procedures as possible to test Le Châtelier's principle. Describe how you will shift the equilibrium and predict the colour of the solution as a result of the shift. Include guidelines for the safe disposal of all materials.

Investigation 16.B: Disturbing Equilibrium (continued)

4. Construct a data table to record your observations.

5. Carry out your procedures and record your observations.

Investigation 16.B: Disturbing Equilibrium (continued)

Part 3 Investigating Gaseous Equilibriums

Caution These are not student tests. Your teacher may demonstrate this equilibrium if a suitable fume hood is available for the first test and if sealed tubes containing a mixture of nitrogen dioxide, $NO_2(g)$, and dinitrogen tetroxide, $N_2O_4(g)$, are available for the second test. If either or both experiments are not demonstrated, refer to the photographs that show the changes.

Safety Precautions

- Concentrated nitric acid is highly corrosive and a strong oxidizing agent.
- Nitrogen dioxide and dinitrogen tetroxide are poisonous gases.

Materials

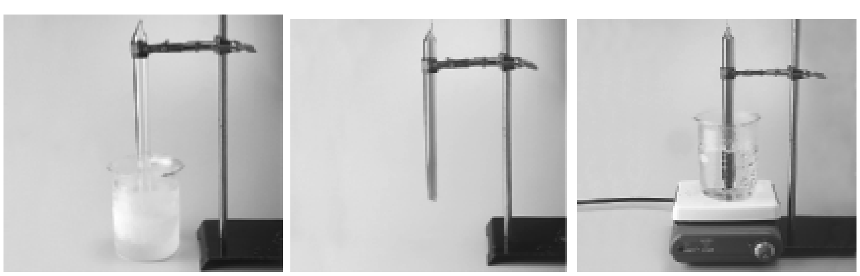
- small piece of copper
- concentrated nitric acid
- boiling water
- ice water
- test tube
- test-tube rack
- one-hole stopper
- glass delivery tube
- short length of rubber tubing
- syringe with a cap or rubber stopper to seal the tip
- $NO_2(g)/N_2O_4(g)$ tubes

Equilibrium System

$$\text{Heat} + \underset{\textbf{colourless}}{N_2O_4(g)} \leftrightarrow \underset{\textbf{brown}}{2NO_2(g)}$$

Procedure

1. Your teacher will use sealed tubes containing a mixture of $N_2O_4(g)$ and $NO_2(g)$. One tube will be placed in boiling water, and a second tube will be placed in ice water. A third tube (if available) will remain at room temperature as a control. Compare and record the colour of the gas mixture at each temperature.



These three tubes contain a mixture of $NO_2(g)$ and $N_2O_4(g)$. The tube on the left is in an ice-water bath. The centre tube is at room temperature. The tube on the right is in boiling water. Given that $NO_2(g)$ is brown, can you explain the shift in equilibrium? Think about Le Châtelier's principle and the enthalpy of the reaction between the two gases.

Investigation 16.B: Disturbing Equilibrium (continued)

2. $NO_2(g)$ can be prepared by reacting copper with concentrated nitric acid. The gas is poisonous. The reaction, if your teacher performs it, must take place in a fume hood.

3. By using a one-hole stopper, glass delivery tube, and a short length of rubber tubing, some $NO_2(g)$ can be collected in a syringe. The syringe is then sealed by attaching a cap or by pushing the needle into a rubber stopper.

4. Observe what happens when the syringe plunger is pressed down sharply, changing the volume of the equilibrium mixture. You will observe an immediate change in colour. Then, if the plunger is held in a fixed position, the colour will change over a few seconds as the system re-establishes equilibrium. Carefully record these colour changes.

The sealed syringe contains a mixture of $NO_2(g)$ and $N_2O_4(g)$. The photograph on the left shows an equilibrium mixture at atmospheric pressure. The middle photograph shows that the plunger has been pushed down, increasing the pressure. The darker appearance of the gas mixture is caused by two changes. First, the concentration of gases is greater. Second, decreasing the volume heats the gas. Why does heating the mixture of gases result in the colour becoming darker? The photograph on the right shows the result a few seconds after the plunger was forced down. The gas has cooled back to room temperature. The colour of the mixture is less brown. Explain this observation.

Investigation 16.B: Disturbing Equilibrium (continued)

Analysis

1. Compare the predictions you made using Le Châtelier’s principle with the observations you made in your tests. Account for any differences.

2. In which tests did you increase the concentration of a reactant or product? Did your observations indicate a shift in equilibrium to form more or less of the reactant or product?

3. In which tests did you decrease the concentration of a reactant or product? Did your observations indicate a shift in equilibrium to form more or less of the reactant or product?

Investigation 16.B: Disturbing Equilibrium (continued)

4. In two of the systems you studied, energy changes were indicated:

Heat + $Co(H_2O)_6^{2+}(aq/et) + 4Cl^-(aq/et) \leftrightarrow CoCl_4^{2-}(aq/et) + 6H_2O(\ell/et)$

Heat + $N_2O_4(g) \leftrightarrow 2NO_2(g)$

(a) Are these systems endothermic or exothermic when read from left to right?

(b) When heated, did these systems shift to the left or to the right? In terms of the energy change, was the observed shift in equilibrium toward the endothermic or exothermic side of the reaction?

(c) Do you think the value of K_c changed or remained the same when the equilibrium mixture was heated? Explain your answer.

5. Think about the $N_2O_4(g)/NO_2(g)$ equilibrium.

(a) How was the total pressure of the mixture affected when the plunger was pushed down?

(b) How was the pressure of the mixture affected by the total number of gas molecules in the syringe?

Investigation 16.B: Disturbing Equilibrium (continued)

(c) Explain the observed shift in the reaction when the plunger was pushed down. In your explanation, refer to Le Châtelier's principle and the total amount of gas in the syringe.

6. Did any groups perform experiments on an equilibrium system that differed from the investigations of the same system performed by your group? If so, briefly describe the experiment and the observations.

Conclusion

7. How did your results compare with your predictions? Discuss with your class and resolve any discrepancies.

Investigation 16.B: Disturbing Equilibrium (continued)

Application

8. What would be the effect, if any, on the following equilibrium system if the volume were reduced at constant temperature? Explain.

$$2IBr(g) \leftrightarrow I_2(g) + Br_2(g)$$