Equilibrium and LeChatelier's Principle

This lab illustrates the effect of stresses on a system at equilibrium, reinforcing LeChatelier's Principle [Henry Louis LeChatelier (1850-1936)]. LeChatelier postulated that if a stress, such as a change in concentration, pressure or temperature is applied to a system at equilibrium; the equilibrium is shifted in a way that tends to relieve the effects of that stress.

Le Chatelier's Principle describes the effect that applying various types of stress will have on the position of equilibrium-that is whether it will shift to increase or decrease the concentration(s) of products in the equilibrium system. As you know, stresses include things like variations in concentrations of reactants or products, temperature of the system and (for reactions involving gasses) the pressure.

Most of our investigations are done with systems in water solution. Here, unless gasses are involved in the reaction, the volume of the system is generally defined by the volume of the solution, and the pressure is of little or no consequence. This sort of system permits us to simplify Le Chatelier's Principle to ready: For any system at equilibrium, in solution:

If you add anything to the system, it will try to consume whatever was added.

If you remove anything from the system, it will try to replace whatever was removed

Note that the word "anything" refers to energy (heat) as well as to any of the reactants or products shown in the reaction equation.

Pressure has an effect on gases. Recall that the ideal gas equation states that the product of the gas pressure and Volume of a gas is equal to the product of a gas constant , moles of gas and absolute temp. If you manipulate the equation you can prove that pressure is related to the concentration of the gas.
When an equilibrium exists in a system, that system tries to stay at equilibrium. The equilibrium will shift to relieve or reduce the stress. Here are some ways an equilibrium system could shift:
In summary

1. If a substances is added, the equilibrium will shift away from the added substance.
2. If a substances is removed the equilibrium will shift towards that substance.
3. If it is a gaseous system, and the pressure is increase the reaction will shift toward the side with the smaller volume. If possible.
4. If it is a gaseous system, and the pressure is decreased the reaction will shift toward the side with the larger volume. If possible.
5. If the temperature of a reaction is increased the reaction will shift to the endothermic reaction to remove heat.
6. If the temperature of a reaction is decreased the reaction will shift to the exothermic reaction to add heat.

7. In an aqueous system if a common ion is added to the system, the equilibrium will shift away from the common ion that is added.

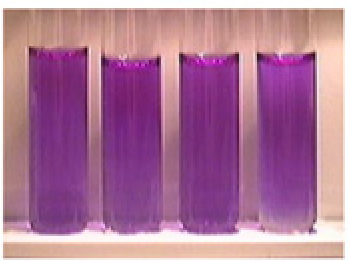
1 to 4

8. In an aqueous system if a common ion is removed from the system, the equilibrium will shift towards the common ion that is removed.

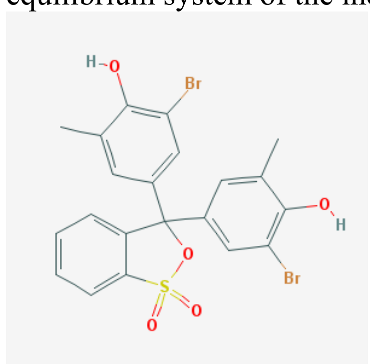
9. A catalyst has no effect on the equilibrium. Because it speeds up both the forward and reverse reactions.

5 to 9

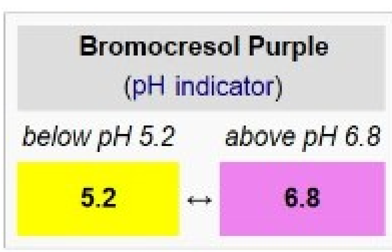
10 to 13



In this experiment you will be working with a solution which contains hydrogen ions and hydrogen carbonate ions produced by adding carbon dioxide gas to water. The solution will reach an equilibrium state. You will be monitoring the Hydrogen ion concentration by recording the color change of the equilibrium system of the indicator.



Molecular form is Yellow



Yellow Purple

Recall that H+ concentration will create a stress on the equilibrium dissociation reaction which will create color changes. When the pH is between 5.2 and 6.8 the indicator will have a amber color.

The purpose of this experiment is to let you observe for yourself what Le Chatelier's Principle means.

Part One of your investigation will deal with two complexes; both contain cobalt (II).

Part Two of your investigation you will determine the effects of pressure on a equilibrium system which involves gases.

When you have finished and cleaned your work area, return to your desk and answer the attached post-lab questions based on your observations.

Materials:

Cobalt (II) chloride hexahydrate
Ethanol
Three Micro vials with Teflon caps
Two 100l beakers
.1M Silver Nitrate
Ice
20 ml syringe with hole in plunger shaft with cap for tip of syringe
Bromocresol puple indicator
Can of plain seltzer water
Push pin
Hot plate
Thermometer
Water
Calcium Chloride
Beral Micro Droppers
Micro Stirrer

Part 1 Procedure:

1. Let us begin by taking some Cobalt (II) Chloride hexahydrate and add it to the small micro vial provided. Add enough to cover the bottom of the small vial. Add approximately 1.5 ml of ethanol to the vial.

The magenta crystal dissolves in the ethanol and the ethanol replaces two of the water molecules forming the blue complex below.

$CoCl_2(H_2O)_2$
Blue Complex

2. Place .5ml of the blue complex solution to two additional micro vials. You should now have three vials with .5mls of blue complex. Add one drop of water to each vial and stir. You should see the formation of a purple solution which contains two complexes.

$CoCl_2(H_2O)_2$ and $CoCl(H_2O)_{5\,(aq)}^{1+}$
Blue Complex and Pink Complex Ion

Now you have the following equilibrium system.

$$CoCl(H_2O)_{5\,(aq)}^{1+} + Cl_{(aq)}^{-} \rightleftarrows CoCl_2(H_2O)_{2(aq)} + 3H_2O_{(l)}$$

3. Add one drop of .1M AgNO3 to one of the vials. Note the color change. The equilibrium is stressed and the reaction rates are changed.

a. Determine which rate forward or reverse is affected by the stress.
b. How are the concentrations affected? Use arrows to indicate change according to the following equation.

c. Place arrows on top to indicate stress applies and arrows below to indicate shift effects.

$$CoCl(H_2O)_5^{1+}{}_{(aq)} + Cl^-_{(aq)} \rightleftarrows CoCl_2(H_2O)_{2(aq)} + 3H_2O_{(l)}$$

4. To the second vial add a few small pellets of Calcium Chloride. Note the color change.

a. Determine which rate forward or reverse is affected by the stress.
b. How are the concentrations affected? Use arrows to indicate change according to the following equation.
c. Place arrows on top to indicate stress applies and arrows below to indicate shift effects.

$$CoCl(H_2O)_5^{1+}{}_{(aq)} + Cl^-_{(aq)} \rightleftarrows CoCl_2(H_2O)_{2(aq)} + 3H_2O_{(l)}$$

5. To the third vial cap and seal. First place it into some ice water and note the color change.
Remove it from the ice water and place it into some hot water. Indicate how the equilibrium and concentration will be stressed using the following equation:

$$CoCl(H_2O)_5^{1+}{}_{(aq)} + Cl^-_{(aq)} \rightleftarrows CoCl_2(H_2O)_{2(aq)} + 3H_2O_{(l)}$$

a. Determine which rate forward or reverse is affected by the stress.
b. How are the concentrations affected? Use arrows to indicate change according to the following equation.
c. Place arrows on top to indicate stress applies and arrows below to indicate shift effects

$$CoCl(H_2O)_5^{1+}{}_{(aq)} + Cl^-_{(aq)} \rightleftarrows CoCl_2(H_2O)_{2(aq)} + 3H_2O_{(l)}$$

Post Lab Questions

1. When water was added to the vial with blue complex which complex was formed?
2. When the water was added which reaction above was forced to move faster (the forward or reverse)?
3. When CaCl2 was added explain which way the equilibrium shifted and what happened to the quantity or concentration of each of the chemicals in the equilibrium reaction above?
4. When silver nitrate was added explain shift of equilibrium and what happened to the quantity or concentration of each of the chemicals in the equilibrium reaction above?
5. What color was AgCl (s)?
6. What is the new equilibrium reaction formed in this vial containing AgCl?
7. Rewrite the original equilibrium equation including heat in the equation.
8. Is the forward reaction endothermic or exothermic?
9. Explain the shift in equilibrium when heat was added to the beaker and wat happened to the quantity or concentration of each of the chemicals in the equilibrium reaction above?

10. Is the change in enthalpy for the forward reaction positive or negative?
11. Draw a potential energy diagram for the forward reaction. Indicate the following on the graph.

- Reactant PE
- Activated Complex PE
- Activation Energy for forward Reaction
- Activation Energy for reverse Reaction
- Product PE
- Enthalpy Change in reaction

12. Which reaction has the greater activation energy?

Part 2 Procedure:

1. Drill a hole through the shaft of the plunger if not predrilled.. This hole should be above the level of the cylinder when the piston is pulled back to the 20 mL range. The hole should be large enough to accommodate a nail or push pin. When the nail is poked through the hole in the piston, the nail should rest against the top of the cylinder wall when the plunger is pushed into the cylinder a short way.

2. Pour approximately 20 mL of seltzer water or soda into the 100-mL beaker. Add enough of the bromocresol indicator to give the soda a distinct and definite coloring. Note the color of this indicator in your solution.

   $CO_2(g) \rightleftharpoons CO_2(aq)$ how much of gas will can dissolve is based on Henry's Law

   Then

   $$CO_2(aq) + H_2O \rightleftharpoons H_2CO_3(aq)$$

   Then

   $H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ the H^+ will then effect the equilibrium of Indicator

   $HIn_{(aq)} \rightleftharpoons H^+(aq) + In^-_{(aq)}$

3. Withdraw approximately 1 mL of this solution into the syringe. Hold the syringe upright (tip upward) and squeeze the piston to expel the air from the system. Fit the cap onto the tip of the syringe to seal the system. Draw back the plunger and lock it in position with the nail or the harness lock. This will reduce pressure inside the cylinder. Hold the syringe by the body and shake it . Slowly remove the cap and have air slowly enter the syringe. Remove the pin from the shaft and expel air from the surface of the liquid again. Replace the cap, Draw back the plunger and lock it

in position with the nail or the harness lock again. This will reduce the pressure above the liquid even more and effect the equilibrium of the system further. Observe any color changes.

4. If a change in color is observed, release the lock and allow the piston to return to its original position. Shake again and note color.

Post Lab Questions:

1. What did the reduction of pressure on the surface of the soda do to the solubility of the gas in the soda?
2. Write the law and mathematical equation that is being applied?
3. Based on the equation given for this equilibrium system what will an increase pressure due to the equilibrium system of all the equilibrium systems in the soda? Justify your answer with experimental observations?
4. Based on the indicator used what was the pH of the solution in the beginning of the experiment and at the point when the pressure on the surface of the liquid was at its lowest?

<u>Problems:</u>

1) Describe what will happen to the equilibrium in the following equation:

$$PCl_5\,(g) + \text{Heat} \leftrightarrow PCl_3\,(g) + Cl_2\,(g)$$

A) If you add PCl_3 to the system?

B) If you remove Cl_2 from the system?

C) If pressure is increased?

D) If temperature is increased?

2) Describe what will happen to the equilibrium in the following equation:

$$C\,(s) + H_2O\,(g) \leftrightarrow CO\,(g) + H_2\,(g)$$

A) If you added H_2O to the system?

B) If you remove CO from the system?

C) If you decrease pressure?

D) If you add C (s) to the system?

3) Describe what will happen to the equilibrium in the following equation:

$$Mg(OH)_2\ (s) \leftrightarrow Mg^{+2}\ (aq) + 2\ OH^{-1}\ (aq) + \text{Heat}$$

A) If $MgCl_2$ was added to the system?

B) If the pressure was increased?

C) KOH was added to the system?

D) KCl was added to the system?

E) Is this reaction exothermic or endothermic?

4) Describe what will happen to the equilibrium in the following equation:

$$CaCO_3\ (s) + \text{Heat} \leftrightarrow CaO\ (s) + CO_2\ (g)$$

A) If CO_2 (g) was removed from the system?

B) A catalysts was added to the system?

C) The reaction was done in an open test tube?

D) If CaO (s) was added to the system?

E) You decreased the temperature?

5) Describe what will happen to the equilibrium in the following equation:

$$H_2 (g) \quad + \quad Br_2 (g) \quad \leftrightarrow \quad 2\,HBr (g)$$

A) Pressure is increased?

B) Br_2 is removed?

C) N_2 is added?

D) If HBr is added?

E) If NaBr is added?