

A P CHEMISTRY

Lab 13-2 Stresses Applied to Equilibrium Systems

Pre-Lab Questions - (Must be completed before lab work begins.)

Given the gas phase reaction, $N_2 + 3H_2 = 2NH_3$. Suppose the reaction has already taken place, and the system has come to equilibrium. If the following changes are made to the system at equilibrium, tell what effect these changes will have on the system (whether the equilibrium is shifted to the left, the right, or is not shifted).

1. Additional N_2 is added to the system
2. Ammonia is removed from the system as soon as it forms
3. the pressure of the system is increased (all components are gases)
4. a very efficient catalyst is used for the reaction

INTRODUCTION - Many reactions come to equilibrium. The reaction in Experiment 13-1 seemed to have stopped before the full amount of product expected had been formed. When equilibrium had been reached in this system, there were significant amounts of both products as well as original reactants still present. In this choice, you will study changes made in a system *already in equilibrium*.

LeChatelier's principle states that, if we *disturb* a system that is already in equilibrium, then the system will *react* so as to minimize the effect of the disturbance. This is most easily demonstrated in cases where additional reagent is added to a system in equilibrium, or when one of the reagents is removed from the system in equilibrium.

Solubility Equilibria

Suppose we have a solution that has been saturated with a solute: This means that the solution has already dissolved as much solute as possible. If we try to dissolve additional solute, no more will dissolve, because the saturated solution is in equilibrium with the solute: $\text{Solute} + \text{Solvent} = \text{Solution}$

LeChatelier's principle is most easily seen when an ionic solute is used: Suppose we have a saturated solution of sodium chloride, NaCl. Then, $\text{NaCl}(s) = \text{Na}^{+1}(aq) + \text{Cl}^{-1}(aq)$ will describe the equilibrium that exists. Suppose we then try adding an *additional amount* of one of the ions involved in the equilibrium: For example, suppose we added several drops of HCl solution (which contains the chloride ion). According to LeChatelier's principle, the equilibrium would shift so as to consume some of the added chloride ion. This would result in a net decrease in the amount of NaCl that could dissolve. If we watched the saturated NaCl solution as the HCl was added, we should see some of the NaCl precipitate as a solid.

Complex Ion Equilibria

Oftentimes, dissolved metal ions will react with certain substances to produce brightly colored species called complex ions. For example, iron(III) reacts with the thiocyanate ion (SCN^-) to produce a bright red complex ion:

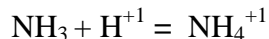


This is an equilibrium process that is easy to study, because we can monitor the bright red color of $[\text{FeNCS}^{+2}]$ as an indication of the position of the equilibrium: If the solution is very red, there is a lot of $[\text{FeNCS}^{+2}]$ present; if the solution is not very red, then there must be very little $[\text{FeNCS}^{+2}]$ present.

Using this equilibrium, we can try adding additional Fe^{+3} or additional SCN^{-1} to see what effect this has on the red color according to LeChatelier's principle. We will also add a reagent (silver ion) that removes SCN^{-1} from the system to see what effect this has on the red color.

Acid/Base Equilibria

Many acids and bases exist in solution in equilibrium sorts of conditions: This is particularly true for the weak acids and bases. For example, the weak base ammonia is involved in an equilibrium in aqueous solution



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Once again, we can use LeChatelier's principle to play around with this equilibrium: We will try adding more ammonium ion or hydrogen ion to see what happens. Since none of the components of this system is itself colored, we will be adding an acid/base indicator that changes color with pH, to have an index of the position of the ammonia equilibrium. The indicator we will use is the same used in Experiment 13-1, phenolphthalein, which is pink in basic solution and colorless in acidic solution.

SAFETY

- ⇒ Wear safety glasses at all times while in the laboratory.
- ⇒ Concentrated ammonia is a strong respiratory and cardiac stimulant; use concentrated ammonia *only in the exhaust hood*.
- ⇒ Concentrated hydrochloric acid is *severely damaging to skin* and its *vapor is highly toxic*; use concentrated HCl in the *exhaust hood*; wear gloves while handling the acid to protect your hands; if HCl is spilled on the skin, wash immediately and inform the instructor.
- ⇒ Iron(III) chloride and potassium thiocyanate are toxic; wash hands after use.

Procedure

1. Record all data and observations directly in your notebook in ink.

Solubility Equilibria

2. Obtain 5 mL of saturated sodium chloride solution in each of two test tubes. This solution was prepared by adding solid NaCl to water until no more would dissolve. Then the clear solution was filtered from any undissolved solid NaCl.
3. Add 10 drops of 12 M MCl (*Caution!*) to one test tube of saturated NaCl solution. A small amount of solid NaCl should form and precipitate out of the solution. The crystals may form slowly, and may be very small. Examine the test tube carefully.
4. Add 10 drops of 1 M HCl to the other test tube of saturated NaCl solution. Why does no precipitate form in this instance?
5. On the lab report sheet describe what happens in terms of LeChatelier's principle.

Results / Observations

A. Solubility Equilibria

Effect	of	adding	HCl	to	saturated	NaCl	observation
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Explanation _____

Complex Ion Equilibria

6. Prepare a stock sample of the bright red complex ion $[\text{FeNCS}^{+2}]$ by mixing 2 mL of 0.1 M iron(III) chloride and 2 mL of 0.1 M KSCN solutions. The color of this mixture is too intense to use as it is, so dilute this mixture with 100 mL of water.
7. Pour about 5 mL of the diluted red stock solution into each of four test tubes. Label the test tubes as 1, 2, 3, and 4.
8. Test tube 1 will have *no change* made in it, so that you can use it to compare color with what will be happening in the other test tubes.
9. To test tube 2, add about 1 mL of 0.1 M FeCl_3 solution.
10. To test tube 3, add about 1 mL of 0.1 M KSCN solution.
11. To test tube 4, add AgNO_3 solution dropwise until a change becomes evident. Ag^{+1} ion removes SCN^{-1} ion from solution as a solid (silver thiocyanate, AgSCN).
12. Describe the intensification or fading of the red color in each test tube in terms of LeChatelier's

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principle.

Results / Observations

B. Complex Ion Equilibria

Effect of adding Fe^{+3} to $[\text{FeNCS}^{+2}]$ observation _____

Explanation _____

Effect of adding SCN^{-1} to $[\text{FeNCS}^{+2}]$ observation _____

Explanation _____

Effect of adding Ag^{+1} to $[\text{FeNCS}^{+2}]$ observation _____

Explanation _____

Acid/Base Equilibria

13. In the exhaust hood, prepare a dilute ammonia solution by adding 4 drops of concentrated ammonia to 100 mL of water.

14. Add 3 drops of phenolphthalein to the dilute ammonia solution, which will turn pink (ammonia is a base, and phenolphthalein is pink in basic solution).

15. Place about 5 mL of the pink dilute ammonia solution into each of three test tubes.

16. To one of the test tubes, add several small crystals of ammonium chloride (which contains the ammonium ion, NH_4^{+1}).

17. To a second test tube, add a few drops of 12 M HCl (*Caution!*). To the third test tube, add 1 drop of concentrated ammonia.

18. Describe what happens to the pink color in terms of how LeChatelier's principle is affecting the ammonia equilibrium.

Results / Observations

C. Acid-Base Equilibria

Effect _____ of _____ adding _____ NH_4^{+1} _____ observation _____

Explanation _____

Effect of adding HCl observation _____

Explanation _____

Questions

1. Explain how a saturated solution represents an equilibrium between the solution and any undissolved solute present.
2. Addition of 12 M (concentrated) HCl to saturated NaCl results in precipitation of NaCl. Yet when 1 M HCl is added to the same NaCl solution, *no* precipitate forms. Explain.
3. How do you explain that addition of silver nitrate to the Fe/SCN equilibrium had an effect on the equilibrium, even though neither silver ion nor nitrate ion are written as part of the equilibrium reaction?
4. How do you explain that addition of HCl affected the ammonia equilibrium, even though neither hydrogen ions nor chloride ions are written as part of the ammonia equilibrium reaction?