5.5 *Factors Affecting Chemical Equilibrium (Qualitative factors)*

Many things can change a reaction rate (think about unit 4), but only three things have the potential to change the forward and reverse reaction rates ***unequally***. These three things are:

1. Change in Concentration
2. Change in Temperature
3. Change in Pressure (or Volume)

Changes that affect reaction rate but ***do not*** affect equilibrium are:

1. Adding a catalyst (or inhibitor): because it affects the forward and reverse reactions equally. It just helps a reaction reach equilibrium sooner.
2. Change in surface area: also because it affects the forward and reverse reactions equally.

Le Chatelier's Principle

- The French chemist Henri-Louis Le Chatelier is credited with first discovering ways to change the equilibrium of a chemical system.
- A system at equilibrium represents a delicate balance between the forward and reverse reactions.
- Small changes in external conditions can cause a shift in the equilibrium.
    - A shift to the right means more products.
    - A shift to the left means more reactants.
- The system readjusts itself to accommodate the changes forced upon it and the readjustments may alter concentrations.
- *Le Chatelier stated that an equilibrium system subjected to an external stress will shift so as to minimize the stress (or remain in equilibrium).*
    - *A stress is anything changed in a system to upset the equilibrium (concentration, temperature or pressure/volume).*

Stresses:

1) Changes in Concentration
    - Adding a reactant or product will cause the equilibrium to shift in the opposite direction to use up the extra material.
    - Taking away a reactant or product will cause the equilibrium to shift in the same direction as the removal of material
    - Does not change K_c or K_{eq} (which is a quantitative change)

2) Changes in Volume or Pressure
    - Gaseous systems are affected by volume and pressure changes but not solid or liquid systems.
    - Volume and pressure changes will only affect equilibrium if the # of moles on the product and reactant sides are different.
    - Does not change K_c or K_{eq}

3) Changes in Temperature
    - The shift will be to minimize the stress
    - Shifts due to changes in temperature are dependent upon whether the system is endothermic or exothermic.
    - Does change K_c or K_{eq}

Factors that Affect Equilibrium		
Stress	***Shift and Affect***	***Reason***
Concentration		
↑ [reactant]		
↑ [product]		
↓ [reactant]		
↓ [product]		
Temperature		
↑ T° on endothermic reaction		
↑ T° on exothermic reaction		
↓ T° on endothermic reaction		
↓ T° on exothermic reaction		
*Pressure/Volume *ignore for solids and liquids ** only has affect if unequal # moles on reactant and product sides*		
↑ P(↓ V) more #moles on reactant side		
↑ P(↓ V) more #moles on product side		
↓ P(↑ V) more #moles on reactant side		
↓ P(↑ V) more #moles on product side		

5.5 La Chatelier's Principle Assignment

1. For the following system at equilibrium:

$$H_{2\,(g)} + Br_{2\,(g)} \leftrightarrow 2\,HBr_{\,(g)} + 36.4\ kJ$$

   a. Predict the shift in equilibrium when more $HBr_{(g)}$ is added to the system.

   b. How will a temperature increase shift equilibrium?

2. For the reaction below, predict the direction the equilibrium will shift given the following changes. Temperature and volume are held constant.

$$2\,NO_{2\,(g)} + 7\,H_{2\,(g)} + \text{energy} \leftrightarrow 2\,NH_{3\,(g)} + 4\,H_2O_{(g)}$$

   a. addition of ammonia
   b. removal of nitrogen dioxide
   c. decrease the temperature
   d. removal of water vapour
   e. addition of hydrogen

3. At a particular temperature, the following reaction has an equilibrium constant, K_{eq} of 0.18

$$PCl_{3\,(g)} + Cl_{2\,(g)} + 87.9\ kJ \leftrightarrow PCl_{5\,(g)}$$

   a) If more PCl_3 is added to the system. Will the value of K_{eq} increase, decrease, or remain the same?

   b) How would the equilibrium shift if a catalyst is introduced?

   c) Explain how you can shift the equilibrium to the products by separately altering the concentration of one of the substances, the temperature, or the pressure.

4. For the following reactions, how will equilibrium shift for an increase in pressure?
   a) $H_{2(g)} + Cl_{2(g)} \leftrightarrow 2HCl_{(g)}$

   b) $PCl_{3\,(g)} + Cl_{2\,(g)} \leftrightarrow PCl_{5\,(g)}$

5. For the following reactions, how will equilibrium shift if the pressure is decreased?
   a) $CH_{4\,(g)} + H_2O_{(g)} \leftrightarrow CO_{(g)} + 3H_2$

   b) $N_{2(g)} + 3H_{2(g)} \leftrightarrow 2NH_{3(g)}$

6. Methyl alcohol is produced according to the equation:
   $CO_{(g)} + 2H_{2(g)} \leftrightarrow CH_3OH_{(g)} + heat$
   Predict the effect on the equilibrium species distribution if there was an increase in:
   a) Temperature

   b) Pressure

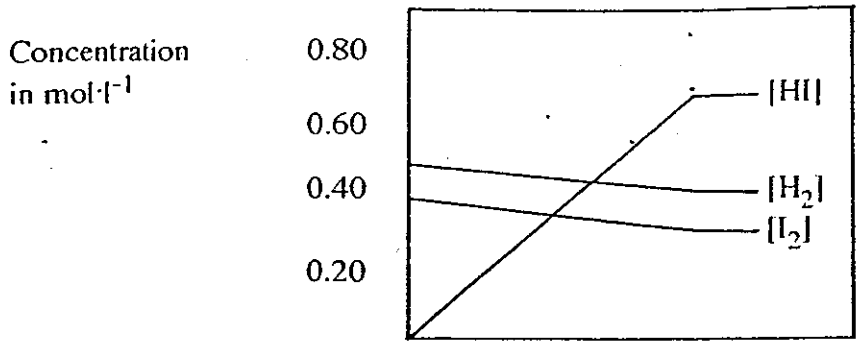
7. List three ways that the following equilibrium reaction could be forced to shift to the right:
   $2NO_{2(g)} \leftrightarrow 2NO_{(g)} + O_{2(g)}$

9. In each of the following equilibria, would you increase or decrease the temperature to force the reaction in the forward direction?
   c) $H_{2(g)} + CO_{2(g)} \leftrightarrow H_2O_{(g)} + CO_{(g)} \qquad \Delta H = +41kJ$

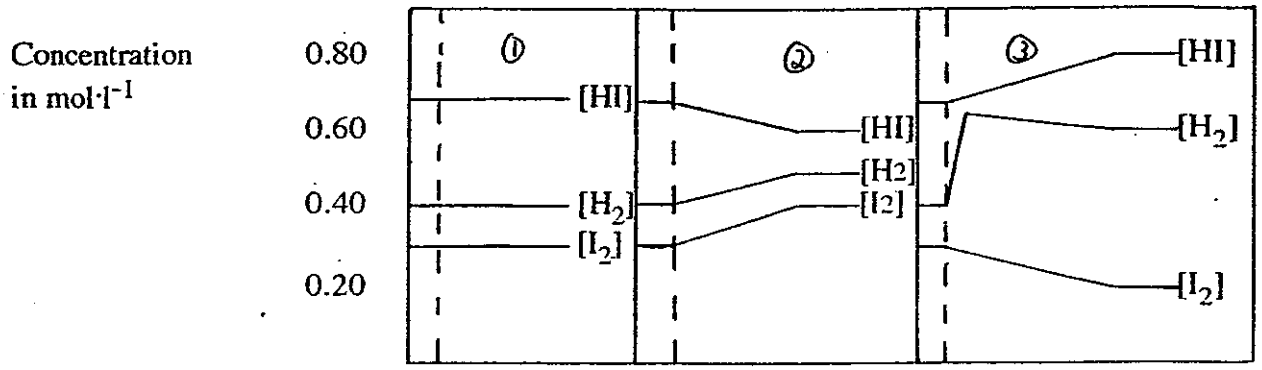
   d) $2SO_{2(g)} + O_{2(g)} \leftrightarrow 2SO_{3(g)} \qquad \Delta H = -198kJ$

10.

The following graph show how the concentration of the reactants and product changes until equilibrium is established for the reactions: $H_2\ (g) + I_2\ (g) \longleftrightarrow 2\ HI\ (g) + 12.6\ J$



The following graphs begin with the system at equilibrium and then have a stress applied. Select whether graph 1, 2 or 3 best represents the change that would be caused by the stress.



Stresses:

a) The temperature is increased while the pressure is constant.

b) The temperature and pressure are increased.

c) Some hydrogen gas is added.

d) The pressure is increased while the temperature is constant.

e) A catalyst is added.

Additional Practice Problems: Matter and Change Textbook pp. 574 # 11, 12, 13