Name: KEY Per____

Unit 12 Review

Equilibrium

Prep

1. A chemical system tends towards minimum enthalpy and maximum entropy.

2. For each of the following reactions, give the direction of the enthalpy drive and the entropy drive. Predict if the reaction will favor the products (spontaneous reaction), the reactants (non-spontaneous reaction), or result in equilibrium (reversible reaction)

   a. $2N_2\,(g) + O_2\,(g) + 4H_2O\,(g) + 237\ kJ/mol \Leftrightarrow 2NH_4NO_3\,(s)$

   H ← S ← favors reactants, non-spontaneous

   b. $4CH_3NH_2\,(g) + 9O_2\,(g) \Leftrightarrow 4CO_2\,(g) + 10H_2O\,(g) + 2N_2\,(g) + 2934\ kJ/mol$

   H → S → favors products, spontaneous

   c. $Cl_2\,(g) + 3F_2\,(g) \Leftrightarrow 2ClF_3\,(g) + 326.4\ kJ/mol$

   H → S ← reversible, equilibrium

3. Le Châtelier's principle states. If a system in equilibrium is subjected to a change, then processes occur that then to counteract that change, and the system reaches a new state of equilibrium.

4. Explain what would happen to concentration of each substance after each of the following stresses.

   $2NOBr\,(g) + 48.4\ kJ/mol \Leftrightarrow 2NO\,(g) + Br_2\,(g)$

   a. Increase [NOBr]
      EQ → [NO] ↑ [Br_2] ↑

   b. Increase volume
      EQ → [NO] ↑ [Br_2] ↑ [NOBr] ↓

   c. Decrease temperature
      EQ ← [NO] ↓ [Br_2] ↓ [NOBr] ↑

   d. Increase pressure
      EQ ← [NO] ↓ [Br_2] ↓ [NOBr] ↑

5. Explain what would happen to concentration of each substance, state the color observed, and draw a graph that sketches the concentrations after each of the following stresses.

   $3O_2\,(g) + 285.4\ kJ/mol \Leftrightarrow 2O_3\,(g)$

   a. Decrease temperature
      EQ ← [O_2] ↑ [O_3] ↓

   b. Increase [O_2]
      EQ → [O_3] ↑

Name: _____ Per____

c. Increase volume
EQ ← $[O_2]$ ↑ $[O_3]$ ↓

d. Increase pressure
EQ → $[O_2]$ ↓ $[O_3]$ ↑

6. Write a Keq expression for each of the following equilibria.
   a. $CH_3OH\ (l) + NH_3\ (g) \Leftrightarrow CH_3NH_2\ (g) + H_2O\ (l)$ $K_{eq} = \dfrac{[CH_3NH_2]}{[NH_3]}$

   b. $2F_2\ (g) + 2H_2O\ (l) \Leftrightarrow O_2\ (g) + 4HF\ (aq)$ $K_{eq} = \dfrac{[O_2][HF]^4}{[F_2]^2}$

7. Write a Keq expression for each of the following equilibria. Determine the value of Keq. Does the reaction favor the reactants or the products?
   a. $PH_3BCl_3\ (g) \Leftrightarrow PH_3\ (g) + BCl_3\ (g)$
   At equilibrium, $[PH_3BCl_3]$=0.080 M, $[PH_3]$=0.010 M, and $[BCl_3]$=0.015 M

$$K_{eq} = \frac{[PH_3][BCl_3]}{[PH_3BCl_3]} = \frac{(0.010)(0.015)}{(0.080)} = 0.0019,$$ favors reactants

   b. $3H_2\ (g) + N_2\ (g) + 2CO\ (g) \Leftrightarrow 2HCONH_2\ (g)$
   At equilibrium there are 2.00 mol of H_2, 1.40 mol of N_2, 1.50 mol of CO, and 3.20 mol of $HCONH_2$ in a 2.00 L container.

$$K_{eq} = \frac{[HCONH_2]^2}{[H_2]^3[N_2]} = \frac{(1.60)^2}{(1.00)^3(0.75)} = 3.41,$$ favors products

8. Consider the following equilibrium
   $I_2\ (g) + Br_2\ (g) \Leftrightarrow 2IBr\ (g)$ Keq= 120
   Write a Keq expression for the equilibrium. At equilibrium $[I_2]$= 0.0250 M and $[Br_2]$=0.0250 M. Determine the equilibrium concentration of IBr

$$K_{eq} = \frac{[IBr]^2}{[I_2][Br_2]} \qquad 120 = \frac{[IBr]^2}{(0.0250)(0.0250)}$$

$$\boxed{[IBr] = 0.274\ M}$$