Equilibrium Worksheet

1. Write the equilibrium expressions (K_{eq}) for each of these reactions. (Hint: make sure that all equations are balanced first).
   a. H_2 (g) + F_2 (g) ⇔ HF (g)
   b. NO (g) + O_2 (g) ⇔ N_2O_5 (g)
   c. $BaCO_3$ (s) ⇔ BaO (s) + CO_2 (g)
   d. $Na_2CO_3 \cdot 10H_2O$ (s) ⇔ $Na_2CO_3 \cdot H_2O$(s)+H_2O(g)
2. How can you increase the concentration of the product(s) in each of these reactions bv varying the temperature and pressure (caused by a volume change)?
   a. $4NH_3$ (g) + $2O_2$ ⇔ 4NO (g) + $6H_2$ (g)
      ΔH = -216 kcal/mol
   b. Br_2 (g) + Cl_2 (g) ⇔ 2BrCl (g)
      ΔH = 3.5 kcal/mol
   c. $BaSO_4$ (s) ⇔ Ba^{2+} (aq) + SO_4^{2-} (aq)
      ΔH = 5800 kcal/mol
3. Under a given set of condition an equilibrium mixture exists:
   SO_2 (g) + NO_2 (g) ⇔ SO_3 (g) + NO (g)
   A one liter container was analyzed and found to contain 0.300 mol of SO_3, 0.200 mol of NO, 0.0500 mol of NO_2, and 0.400 mol of SO_2. Calculate the equilibrium constant for this reaction.
4. What is the molar concentration of O_2 (g) in an equilibrium mixture at 1000 K that has equimolar amount of SO_2 and SO_3?
   $2SO_2$ (g) + O_2 (g) ⇔ $2SO_3$ (g) $K_{eq} = 2.8 \times 10^2$
5. Equilibrium is established in the reversible reaction: N_2O_4 (g) ⇔ $2NO_2$ (g) at 25 ºC. The amounts of reactant and product present in a 3.0 liter flask are found to be 1.56 g of NO_2 and 7.64 g of N_2O_4. What is the value of K_{eq} for this reaction?
6. Continuous removal of one of the products of a chemical reaction has the effect of causing the reaction to go to completion. Explain.

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   d. $Na_2CO_3 \cdot 10H_2O$ (s) ⇔ $Na_2CO_3 \cdot H_2O$(s) + H_2O (g)
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   $2SO_2$ (g) + O_2 (g) ⇔ $2SO_3$ (g) $K_{eq} = 2.8 \times 10^2$
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Answer Key

1. Write the equilibrium expressions (K_{eq}) for each of these reactions. (Hint: make sure that all equations are balanced first).
   a. H_2 (g) + F_2 (g) ⇔ **2** HF (g)
   $K_{eq} = \frac{[HF]^2}{[H_2][F_2]}$
   b. **4**NO (g) + **5**O_2 (g) ⇔ **2**N_2O_5 (g)
   $K_{eq} = \frac{[N_2O_5]^2}{[NO]^4[O_2]^5}$
   c. $BaCO_3$ (s) ⇔ BaO (s) + CO_2 (g)
   $K_{eq} = [CO_2]$
   d. $Na_2CO_3 \cdot 10H_2O$ (s) ⇔ $Na_2CO_3 \cdot H_2O$ (s) + **9**H_2O (g)
   $K_{eq} = [H_2O]^9$
2. How can you increase the concentration of the product(s) in each of these reactions by varying the temperature and pressure (caused by a volume change)?
   a. $4NH_3$ (g) + $2O_2$ ⇔ 4NO (g) + $6H_2$ (g)
   ΔH = -216 kcal/mol
   To shift right, ↓T, ↓P
   b. Br_2 (g) + Cl_2 (g) ⇔ 2BrCl (g)
   ΔH = 3.5 kcal/mol
   To shift right, ↑T, no change in P = #moles
   c. $BaSO_4$ (s) ⇔ Ba^{2+} (aq) + SO_4^{2-} (aq)
   ΔH = 5800 kcal/mol
   To shift right,↑T, no change in P; solid and aq species
3. Under a given set of condition an equilibrium mixture exists:
   SO_2 (g) + NO_2 (g) ⇔ SO_3 (g) + NO (g)
   A one liter container was analyzed and found to contain 0.300 mol of SO_3, 0.200 mol of NO, 0.0500 mol of NO_2, and 0.400 mol of SO_2. Calculate the equilibrium constant for this reaction.
   $K_{eq} = \frac{[SO_3][NO]}{[SO_2][NO_2]} = \frac{(0.3)(0.2)}{(0.4)(0.05)} = 3$
4. What is the molar concentration of O_2 (g) in an equilibrium mixture at 1000 K that has equimolar amount of SO_2 and SO_3?
   $2SO_2$ (g) + O_2 (g) ⇔ $2SO_3$ (g)
   $K_{eq} = 2.8 \times 10^2$
   $K_{eq} = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = 2.8 \times 10^2$
   $\frac{1}{[O_2]} = 2.8 \times 10^2$ so $[O_2] = 3.57 \times 10^{-3}$ M
5. An equilibrium is established in the reversible reaction: N_2O_4 (g) ⇔ $2NO_2$ (g) at 25 ºC. The amounts of reactant and product present in a 3.0 liter flask are found to be 1.56 g of NO_2 and 7.64 g of N_2O_4. What is the value of K_{eq} for this reaction?
   $K_{eq} = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(0.011)^2}{(0.027)} = 4.73 \times 10^{-3}$
   1.56 g NO_2 ÷ 46 g/mol ÷ 3.0 L
   7.64 g N_2O_4 ÷ 92 g/mol ÷ 3 L
6. Continuous removal of one of the products of a chemical reaction has the effect of causing the reaction to go to completion. Explain.
   As you are continually removing one of the products the equilibrium continues to shift in the forward direction to produce more of what is being removed, eventually running out of reactants.