Chemistry 12: Equilibrium

Worksheet #2: Expressions, "At Equilibrium" and Beginner's ICE Table Calculations

Complete the following assignment on a separate sheet of paper.

1) Write the equilibrium expression (K_{eq}) for the following reactions. (1 mark each)
   a. $PCl_3(g) + Cl_2(g) \leftrightarrows PCl_5(g)$
   b. $CH_4(g) + H_2O(g) + 49.3\ kJ \leftrightarrows CO(g) + 3\ H_2(g)$
   c. $2\ NO(g) + O_2(g) \leftrightarrows 2\ NO_2(g)$
   d. $BaSO_4(s) \leftrightarrows Ba^{2+}(aq) + SO_4^{2-}(aq)$
   e. $2\ Hg(s) + O_2(g) \leftrightarrows 2\ HgO(s)$
   f. $2\ NaHCO_3(s) \leftrightarrows Na_2CO_3(s) + CO_2(g) + H_2O(g)$
   g. $CaCO_3(s) + 2\ HCl(aq) \leftrightarrows CaCl_2(aq) + CO_2(g) + H_2O(l)$
   h. $4\ NH_3(g) + 5\ O_2(g) \leftrightarrows 4\ NO(g) + 6\ H_2O(g)$
   i. $CaCO_3(s) \leftrightarrows CaO(s) + CO_2(g)$
   j. $4\ NH_3(g) + 7\ O_2(g) \leftrightarrows 4\ NO_2(g) + 6\ H_2O(g) +$ energy

For each of the following, you MUST write the K_{eq} expression, substitute in the values, then solve. SHOW ALL WORK and watch Sig Figs and units (where appropriate) for your final answer.

<u>At Equilibrium</u>

2) $SO_3(g) + H_2O(g) \leftrightarrows H_2SO_4(l)$
   At equilibrium, the $[SO_3] = 0.400$ M and the $[H_2O] = 0.480$ M. Calculate the value of the equilibrium constant. (2 marks)

3) $PCl_5(s) + H_2O(g) \leftrightarrows 2\ HCl(g) + POCl_3(g)$
   A 2.0 L flask at equilibrium at 100°C contains 0.075 mol of PCl_5, 0.050 mol of H_2O, 0.750 mol of HCl, and 0.500 mol of $POCl_3$. Calculate the K_{eq} for the reaction. (5 marks)

4) $2\ NO_2(g) \leftrightarrows N_2O_4(g)$.
   If 2.00 moles of NO_2 and 1.60 moles of N_2O_4 are present in a 4.00 L flask at equilibrium, what is the equilibrium constant? (4 marks)

5) $H_2(g) + I_2(g) \leftrightarrows 2\ HI(g)$.
   If, at equilibrium, $[H_2] = 0.200$ M and $[I_2] = 0.200$ M, what is the concentration of HI in the 5.0 L flask? $K_{eq} = 55.6$ at 250°C. (2 marks)

6) $CO(g) + H_2O(g) \leftrightarrows CO_2(g) + H_2(g)$

An 8.00 L container at 690°C is found to contain 1.60 moles of CO, 1.60 moles of H_2O, 4.00 moles of CO_2, and 4.00 moles of H_2. Calculate the equilibrium constant for the reaction at this temperature. (4 marks)

7) $2\ SO_2(g) + O_2(g) \leftrightarrows 2\ SO_3(g)$. $K_{eq} = 798$

Calculate the $[O_2]$ if the $[SO_2] = 4.20$ M and $[SO_3] = 11.0$ M. (2 marks)

For each of the following, you MUST include an ICE table and the K_{eq} expression. SHOW ALL WORK and watch Sig Figs and units (where appropriate) for your final answer.

Beginners ICE boxes

8) A reaction vessel had 1.95 M CO and 1.25 M H_2O introduced into it. After an hour, equilibrium was reached according to the equation:

$$CO_2(g) + H_2(g) \leftrightarrows CO(g) + H_2O(g)$$

Analysis showed that 0.85 M of CO_2 was present at equilibrium. What is the equilibrium constant for this reaction? (4 marks)

9) $2\ SO_2(g) + O_2(g) \leftrightarrows 2\ SO_3(g)$

Into a 2.00 L container is placed 1.00 mol of $SO_2(g)$ and 1.00 mol of $O_2(g)$. At equilibrium, $[SO_3] = 0.150$ M. Calculate the equilibrium constant for this reaction. (5 marks)

10) $2\ NOCl(g) \leftrightarrows 2\ NO(g) + Cl_2(g)$

When 0.50 mol of $NOCl$ was put into a 1.0 L flask and allowed to reach equilibrium, 0.10 mol of Cl_2 was found. What is K_{eq} for this reaction? (4 marks)

11) Consider the following equilibrium:

$$3\ I_2(g) + 6\ F_2(g) \leftrightarrows 2\ IF_5(g) + I_4F_2(g)$$

a) At a certain temperature, 2.0 mol of I_2 and 3.0 mol of F_2 are introduced into a 10.0 L container. At equilibrium, the concentration of I_4F_2 is 0.020 M. Calculate K_{eq} for the reaction at this temperature. (4 marks)

b) At a higher temperature, 6.0 mol of IF_5 and 8.0 mol of I_4F_2 are put into a 5.0 L container. At equilibrium, 6.0 mol of I_4F_2 exist. Calculate K_{eq} for the reaction at this second temperature. (5 marks)

c) Based on the values calculated above, predict whether the reaction is endothermic or exothermic. Explain your reasoning. (1 mark)

12) Consider the following equilibrium:

$$N_2(g) + 3\ H_2(g) \leftrightarrows 2\ NH_3(g)$$

a) When a 4.0 L reaction vessel was filled with 2.00 mol of NH_3 and allowed to reach equilibrium, the ammonia concentration was found to be 0.10 M. Calculate the equilibrium constant for the reaction. (5 marks)

b) Using your answer from above, calculate the $[H_2]$ for a new vessel at the same temperature. The equilibrium concentration of $[N_2] = 0.45$ M and $[NH_3] = 0.010$ M for this new vessel. (1 mark)