15 • Chemical Equilibrium

15.4- 15.5 Calculating Equilibrium Concentrations and Constants

Some Calculations of rate constants and equilibrium concentrations are simple, as we noticed in the previous sections. Others, however, require a more structured means to solve the problem, especially is we don't know all of the concentrations of the species at equilibrium.

Here are some examples that are typically on the Free Response section of the AP Exam

EXAMPLE #1 Equilibrium Constant Calculation: Given:

- Initial concentrations of reactants,
- Concentration of product at equilibrium
- **Find**: Determine the rate constant at this temperature

1. A mixture of 5.000×10^{-3} mol of H_2 and 1.000×10^{-2} mol of I_2 is placed in a 5.000-L container at 448°C and allowed to come to an equilibrium. Analysis of the equilibrium mixture shows that the concentration of HI is 1.87×10^{-3} M. Calculate the Kc at 448°C for the reaction:

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$$

Step 1: Make a Table: ALL CONCENTRATIONS NEED TO BE IN MOLARITY

Initial			
Change			
Equilibrium			

Step 2: Complete the table using equilibrium expression and stoichiometry

EXAMPLE #2: **Equilibrium Concentration Calculation Using Partial Pressures: Given** (Easier problem)

- No Starting Concentrations (partial pressures) are provided
- Equilibrium constant
- Concentration (Partial Pressures) of Reactants at equilibrium
- **Find**: Concentration (partial pressure) of product at equilibrium

2.) For the Haber process, $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, $K_p = 1.45 \times 10^{-5}$ at 500°C. In an equilibrium mixture of the three gases at this temperature, the partial pressure of H_2 is 0.928 atm and that of N_2 is 0.432 atm. What is the partial pressure of NH_3 in this equilibrium mixture?

Step 1: Make a Table: ALL CONCENTRATIONS NEED TO BE IN PARTIAL PRESSURE

Initial			
Change			
Equilibrium			

EXAMPLE #3: Equilibrium Concentration Calculation: Given: (Quadratic Equation Problem..difficult)

A 1.000-L flask is filled with 1.000 mol of H_2 and 2.000 mol of I_2 at 448°C. The value of the equilibrium constant, Kc, for the reaction is 50.5. What are concentrations of H_2, I_2 and HI in the flask at equilibrium?

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$$

Step 1: Make a Table: ALL CONCENTRATIONS NEED TO BE IN MOLARITY

Initial			
Change			
Equilibrium			

** Let x represent the change in concentration of H_2 **

15 • Chemical Equilibrium

15.4- 15.5 Calculating Equilibrium Concentrations and Constants

(3) Practice Problems

1. Solve for Equilibrium Constant. Similar to EXAMPLE #1

Sulfur trioxide decomposes at high temperature in a sealed container:

$$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$$

Initially the vessel is charged at 1000K with $SO_3(g)$ at a concentration of 6.09×10^{-3} M. At equilibrium the SO_3 concentration is 2.44×10^{-3} M. Calculate the value of Kc at 1000K.

Initial			
Change			
Equilibrium			

15 • Chemical Equilibrium

15.4- 15.5 Calculating Equilibrium Concentrations and Constants

(3) Practice Problems

2. Solve for partial pressure of the product. Similar to EXAMPLE #2

At 500 K the reaction $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$ has K*p* = 0.497. In an equilibrium mixture at 500 K, the partial pressure of PCl_5 is 0.860 atm and that of PCl_3 is 0.350 atm. What is the partial pressure of Cl_2 in the equilibrium mixture?

Initial			
Change			
Equilibrium			

15 • Chemical Equilibrium

15.4- 15.5 Calculating Equilibrium Concentrations and Constants

(3) Practice Problems

3. Solve for the equilibrium pressure of all three gases. Similar to EXAMPLE #3

For the equilibrium $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$ the equilibrium constant, $K_p = 0.497$ at 500 K. A gas cylinder at 500 K is charged with $PCl_5(g)$ at an initial pressure of 1.66 atm. What are the equilibrium pressures of the three gases at this temperature?

Initial			
Change			
Equilibrium			