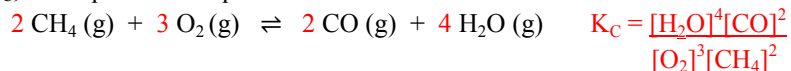


CHM152 – Chapter 13: Chemical Equilibrium – Homework-KEY

- Which one of these statements does not describe the equilibrium state?
 - Equilibrium is dynamic and there is no net conversion to reactants and products.
 - The concentration of the reactants is equal to the concentration of the products.**
 - The concentration of the reactants and products reach a constant level.
 - The rate of the forward reaction is equal to the rate of the reverse reaction.

- Write K_C , the equilibrium equation for the forward reaction:

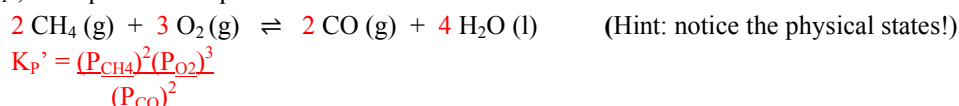


- Nitric oxide (NO) reacts with oxygen to form nitrogen dioxide. What is K_C for the forward reaction if the equilibrium concentration of NO is 0.200 M, O_2 is 0.100 M, and NO_2 is 0.250 M at 25°C?

$$K_C = \frac{(0.250)^2}{(0.200)^2(0.100)} = 15.6$$

- If $K_C = 1.5 \times 10^{-5}$ at 35°C is the equilibrium constant for the forward reaction what is K_C' for the reverse reaction at the same temperature? $K_C' = \frac{1}{K_C} = 6.7 \times 10^4$

- Write K_P' , the equilibrium equation for the reverse reaction:



- Calculate K_P' for the reaction in question #5 if the partial pressures are 0.122 atm for CH_4 , 0.333 atm for O_2 , and 0.564 atm for CO.

$$K_P' = \frac{(P_{\text{CH}_4})^2(P_{\text{O}_2})^3}{(P_{\text{CO}})^2} = \frac{(0.122)^2(0.333)^3}{(0.564)^2} = 1.73 \times 10^{-3}$$

- What is K_C at 25°C for the reaction in problem #6?

$$\text{First find } K_P = 579. \quad K_C = \frac{K_P}{(RT)^{\Delta n}} \quad \text{Recall } \Delta n = (2) - (2 + 3) = -3$$

- At a certain temperature, the reaction $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$ has an equilibrium constant $K_C = 5.8 \times 10^{-2}$. If the initial concentrations are 0.200 M for PCl_5 , 0.100 M for PCl_3 , and 0.040 M for Cl_2 , which direction will the reaction shift until it reaches equilibrium? What are the equilibrium concentrations of all the species?

$Q_C = 0.0200$ which is smaller than K_C so the reaction will shift towards the products until equilibrium is reached.

Set up an ICE table: $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$

$$\begin{array}{ccc} 0.200\text{M} & 0.100\text{M} & 0.040\text{M} \\ -x & +x & +x \\ (0.200 - x) & (0.100 + x) & (0.040 + x) \end{array}$$

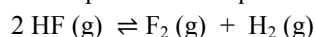
$$K_C = 5.8 \times 10^{-2} = \frac{(0.100 + x)(0.040 + x)}{(0.200 - x)} \quad \text{Use the quadratic formula to solve for } x. \quad x = 0.033\text{ M}$$

Substitute x in and $[\text{PCl}_5] = 0.167\text{ M}$, $[\text{PCl}_3] = 0.133\text{ M}$, $[\text{Cl}_2] = 0.073\text{ M}$

- The decomposition of sulfur trioxide is: $2 \text{SO}_3(\text{g}) \rightleftharpoons \text{O}_2(\text{g}) + 2 \text{SO}_2(\text{g})$. If K_C is 0.200 at 1300 K, what is the partial pressure of SO_3 at equilibrium when $\text{O}_2(\text{g})$ is 0.18 atm and $\text{SO}_2(\text{g})$ is 0.25 atm?

$$\text{Find } K_P \text{ first: } K_P = K_C(RT)^{\Delta n} = 21.3 \quad 21.3 = \frac{(0.25)^2(0.18)}{x^2} \quad \text{so } x = 0.023\text{ atm}$$

- At a certain temperature the equilibrium constant, K_C , equals 0.11 for the reaction:



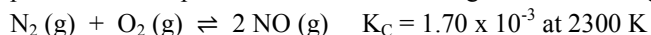
What is the equilibrium concentration of HF if 0.75 mol of H_2 and 0.75 mol of F_2 are initially mixed in a 2.0 L flask?

Set up an ICE table: $2 \text{HF}(\text{g}) \rightleftharpoons \text{F}_2(\text{g}) + \text{H}_2(\text{g})$

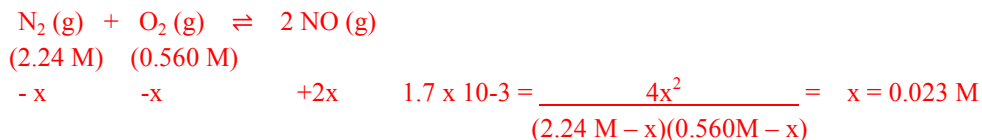
$$\begin{array}{ccc} 0 & 0.38\text{M} & 0.38\text{M} \\ +2x & -x & -x \\ 2x & (0.38 - x) & (0.38 - x) \end{array}$$

$$K_C = 0.11 = \frac{(0.38 - x)(0.38 - x)}{(2x)^2} \quad \text{Use the quadratic formula to solve for } x. \quad x = 0.223\text{ M (not } 0.64\text{ M - too big!)} \\ \text{Substitute } x \text{ in and } [\text{HF}] = 0.45\text{ M}$$

11. The air pollutant NO is produced in automobile engines from the high-temperature reaction

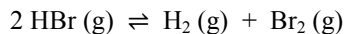


Calculate the equilibrium concentrations of N_2 , O_2 , and NO if 314 g of N_2 and 89.6 g of O_2 are initially placed in a 5.00 L flask.



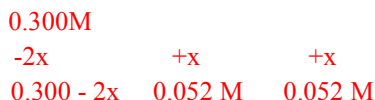
$$[\text{N}_2] = 2.24 - 0.023 = 2.22 \text{ M}, [\text{O}_2] = 0.54 \text{ M}, [\text{NO}] = 0.046 \text{ M}$$

12. Gaseous hydrogen bromide decomposes at elevated temperatures according to the following equation:



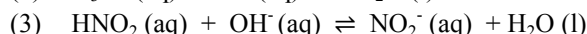
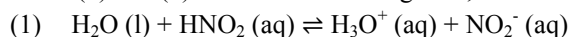
At a certain temperature a 5.00 L flask is initially filled only with 0.600 mol of HBr . What is the value of K_c at that temperature if the flask contains 0.104 mol of H_2 at equilibrium?

Set up an ICE table: $2\text{HBr}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{Br}_2(\text{g})$



$$K_c = \frac{(0.052 \text{ M})(0.052 \text{ M})}{(0.196 \text{ M})^2} = 7.04 \times 10^{-2}$$

13. When reaction (1) and (2) below are added together, the result is reaction (3).



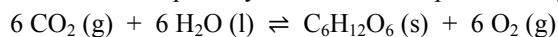
If $K_1 = 4.50 \times 10^{-4}$, and $K_2 = 1.00 \times 10^{14}$, find the equilibrium constant, K_3 .

$$(4.50 \times 10^{-4})(1.00 \times 10^{14}) = 4.50 \times 10^{10}$$

14. Which of the following changes in reaction conditions will not alter the equilibrium concentrations?

- addition of an inert gas to the reaction mixture
- addition of reactants or products
- decreasing the pressure or volume
- increasing the temperature

15. The overall reaction for photosynthesis can be represented by the following equation:

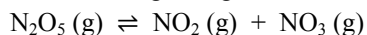


The enthalpy change for this reaction is 2802 kJ.

How will the equilibrium shift (right, left, no change) with the following changes:

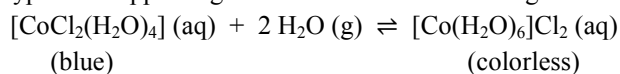
- increase in temperature **right**
- increase the pressure of O_2 **left**
- remove CO_2 **left**
- add $\text{C}_6\text{H}_{12}\text{O}_6$ **no change**

16. How will the following changes shift the equilibrium for the reaction:



- decreasing the amount of NO_3 **right**
- increasing the amount of N_2O_5 **right**
- increasing the pressure **left**
- increasing the volume **right**

17. A crude type of disappearing ink is based on the following exothermic equilibrium:



If the product solution is used to write on a piece of paper and the paper is allowed to partially dry, what can be done to bring out the colored handwriting?

- add water
- decrease the volume
- put the paper in the freezer
- put the paper in the oven**