Lecture February 8

Chap. 16 – Sec. 16.8 and then Sec. 16.7
(Le Chatelier’s Principle)

Next up – Chapter 17

Chap. 16 SmartWork HW and Quiz
due Monday Feb. 13
The equilibrium constant $K_P$ for the thermal decomposition of NO$_2$ is $6.5 \times 10^{-6}$ at 450.°C. What is $K_C$ at this temperature?

$$2 \text{ NO}_2(g) \rightleftharpoons 2 \text{ NO}(g) + \text{ O}_2(g)$$

**ANS:**

$$K_P = \frac{P_{\text{NO}_2^2}P_{\text{O}_2}}{P_{\text{NO}_2^2}}$$

$$P = [\text{RT}]$$

$$K_P = \frac{[\text{NO}]^2[\text{O}_2]/[\text{NO}_2]^2}(\text{RT})^3/\text{RT}^2$$

$$K_P = K_C(\text{RT})$$

$$K_C = \frac{(6.5 \times 10^{-6})}{(0.08206)(723)} = 1.1 \times 10^{-7}$$

$$T = 450 + 273 = 723$$
Example p. 792–793

\[ \text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{NO}(g) \quad \text{K}_P = 1.00 \times 10^{-5} \]

Start with \( \text{P}_{\text{N}_2} = 0.79 \text{ atm} \), \( \text{P}_{\text{O}_2} = 0.21 \text{ atm} \) and no NO

What is the equilibrium pressure of NO?

Set up ICE table on the Board

Can use the small \( x \) approximation

\[ \frac{(2x)^2}{(0.79-x)(0.21-x)} = 1.00 \times 10^{-5} \]

\[ x = 6.44 \times 10^{-4} \quad \text{P}_{\text{NO}} = 2x = 1.3 \times 10^{-3} \]
Example Using Quiz System

2 NO₂(g) ⇌ 2 NO(g) + O₂(g) \quad K_P = 6.5 \times 10^{-6}

What are the final pressures of each component at equilibrium in the vessel if you start with 1.00 atm of NO₂ (at a constant temperature of 450°C)?

This is now equilibrium problem!!

ICE Table on board

\[ 6.5 \times 10^{-6} = \frac{(2x)^2(x)}{(1.00-2x)^2} \quad \Rightarrow \quad x = 1.2 \times 10^{-2} \]

\begin{align*}
P_{NO_2} &= 1.00-2x = 0.98 \text{ atm} \\
P_{NO} &= 2x = 2.4 \times 10^{-2} \text{ atm} \\
P_{O2} &= x = 1.2 \times 10^{-2} \text{ atm}
\end{align*}
Le Chatelier’s Principle

A system will respond to a change in conditions that determine an equilibrium to reduce the effect of the change.

Can:

✮ add or subtract a reactant (change [ ])
✮ add or subtract a product (change [ ])
✮ change the volume of a container (change [ ])
✮ change temperature – changes $K$

✮ These are really Q questions
More Le Chatelier – Temperature

If a reaction generates heat (\(\Delta H\) is negative as written) then heating will favor the reactants and cooling will favor the products.

If the reaction requires heat (\(\Delta H\) positive as written) heating will favor the products and cooling will favor the reactants.

Actually changes the equilibrium constant \(K\)
Changes of Pressure/Volume

Decrease in volume favors fewer moles of gas

Increase in volume favors more moles of gas

Has no effect if the moles of gas do not change between reactants and products

Again this is really Q – no change in equilibrium constant – all the concentrations change and the equilibrium in reestablished.
Example

\[ N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \]

4 moles of gas \hspace{1cm} 2 moles of gas

Increase volume \rightarrow more reactant

Removal of the product through condensation

more product

Equilibrium constant = 3.5 \times 10^8 \text{ at } 25^\circ C

\[ \Delta H = -91.8 \text{ kJ/mol} \]

Exothermic – gives off heat

Exothermic – gives off heat

Increase temperature \rightarrow to reactants

DECREASE the K – only 0.16 at 450^\circ C
Quiz of the Day

For the reaction

\[
\text{PH}_3\text{BCl}_3(s) \leftrightharpoons \text{PH}_3(g) + \text{BCl}_3(g)
\]

\[
K_P = 0.052 \text{ at } 60.0^\circ\text{C}
\]

If you put solid PH$_3$BCl$_3$ in a closed vessel, what is the total pressure of gas at equilibrium at 60$^\circ$C?

Ans: \[x^2 = 0.052 \quad x = 0.228\]

Total pressure = \[x + x = 0.46 \text{ atm}\]