PLI 30
Wednesday 13, 2016
Chapter 15 (chemical equilibrium)

Helpful: Once you are *sure* that you can solve quadratic equations by hand with your calculator (as you will need to do on exams), you can save time on future PLI and Sapling problems by typing your equation into wolframalpha.com, which will solve it for you.

1. (Similar to in class problem, but at different temperature) - Consider the chemical equation and equilibrium constant for the synthesis of ammonia at 25 ºC:

$$N_2\,\mathbf{(g)} + 3\,H_2\,\mathbf{(g)} \rightleftharpoons 2\,NH_3\,\mathbf{(g)} \quad Kc_1 = 3.7 \times 10^8$$

What is the equilibrium constant, Kc_2, for the following reaction at 25 ºC?

$$NH_3\,\mathbf{(g)} \rightleftharpoons \tfrac{1}{2}\,N_2\,\mathbf{(g)} + 3/2\,H_2\,\mathbf{(g)}$$

original equation was flipped and multiplied by ½. so $Kc_2 = \left(\frac{1}{Kc_1}\right)^{1/2} = \left(\frac{1}{(3.7\times10^8)}\right)^{1/2} = \boxed{5.2\times10^{-5}}$

2. An important exothermic reaction in the commercial production of hydrogen is:

$$CO\,\mathbf{(g)} + H_2O\,\mathbf{(g)} \rightleftharpoons H_2\,\mathbf{(g)} + CO_2\,\mathbf{(g)} + \text{heat}$$

At equilibrium, how will the system shift (left, right, or no shift) in the five following cases?

a) Gaseous carbon dioxide is removed: right
b) Water vapor is added: right
c) The temperature is increased: left
d) The pressure is increased by decreasing the volume of the reaction container: no change - there are equal amount of gas moles on both sides.

3. The reaction of hydrogen and iodine to give hydrogen iodide has an equilibrium constant, K_c, of 56 at 435 ºC. What is the value of K_p?

$$H_2(g) + I_2(g) \leftrightarrows 2\,HI(g)$$

$K_p = K_c \times (RT)^{\Delta n}$

Δn = moles gas products - moles gas reactants

$\Delta n = 2 - (1+1) = 0$

$K_p = K_c \times (RT)^0 = K_c \times 1 = \boxed{56}$

4. You place 9.61 mol of pure SO_3 in an 8.0 L flask at 1000 K. At equilibrium, 0.78 mol of O_2 has been formed. Calculate K_c for the reaction at 1000 K:

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

$M\ SO_3 = \frac{9.61 \text{ moles}}{8.0 L} = 1.20\ M$ $\quad M\ O_2 = \frac{0.78 \text{ moles}}{8.0 L} = 0.0975\ M$

	$2[SO_3]$	$\rightleftharpoons$	$2[SO_2]$	+	$[O_2]$
I	1.20		0		0
C	$-2x$		$+2x$		$+x$
E	$1.20-2x$		$2x$		0.0975

$\therefore x = 0.0975$

equilb concentrations:

$[SO_3] = 1.20 - 2(0.0975) = 1.0$

$[SO_2] = 0 + 2(0.0975) = 0.20$

$[O_2] = 0.0975$

5. Consider the following reaction:

$$NiO\ (s) + CO\ (g) \rightleftharpoons Ni\ (s) + CO_2\ (g)\ K_c = 4.0 \times 10^5 \text{ at } 1500\ K$$

If a mixture of solid nickel(II) oxide and 0.20 M carbon monoxide is allowed to come to equilibrium at 1500 K, what will be the equilibrium concentration of CO_2?

$K_c = \frac{[CO_2]}{[CO]} = 4.0 \times 10^5$

	$[CO]$	$\rightleftharpoons$	$[CO_2]$
I	0.20		0
C	$-x$		$+x$
E	$0.20-x$		x

$\frac{x}{0.20-x} = 4.0 \times 10^5$

$x = -4.0 \times 10^5 + 8.0 \times 10^4 x$

$x = 0.1999\ldots$

so new $[CO_2]$ will be 0.20 M, meaning rxn nearly went to completion.

$K_c = \frac{[SO_2]^2[O_2]}{[SO_3]^2}$

$K_c = \frac{(0.20)^2(0.0975)}{(1.0)^2}$

$\boxed{K_c = 0.0039}$

6. Consider the following reaction:

$$N_2O_4\ (g) \rightleftharpoons 2\ NO_2\ (g)\ K_C = 0.36 \text{ at } 100°C$$

A reaction mixture at 100°C initially contains $[NO_2] = 0.100$ M. Find the equilibrium concentrations of NO_2 and N_2O_4 at this temperature:

$N_2O_4 \rightleftharpoons 2NO_2 \quad K_c = 0.36$ $\xrightarrow{\text{flip}}$ $2NO_2 \rightleftharpoons N_2O_4 \quad K_c = 2.78$

	$2[NO_2]$	$\rightleftharpoons$	$[N_2O_4]$
I	0.100		0
C	$-2x$		$+x$
E	$0.100-2x$		x

$K_c = 2.78 = \frac{[N_2O_4]}{[NO_2]^2}$

$2.78 = \frac{x}{(0.100-2x)^2}$

$2.78(0.0100 - 0.400x + 4x^2) = x$

$0.02780 - 2.112x + 11.12x^2 = 0$

$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$

$x = \frac{-(-2.112) \pm \sqrt{(-2.112)^2 - 4(11.12 \times 0.0278)}}{2(11.12)}$

$x = 0.014$ or ~~0.178~~ (would lead to $[NO_2]$ of less than zero)

ANS

$[N_2O_4] = 0.014$

$[NO_2] = 0.100 - 2(0.014) = 0.072$