AP CHEMISTRY

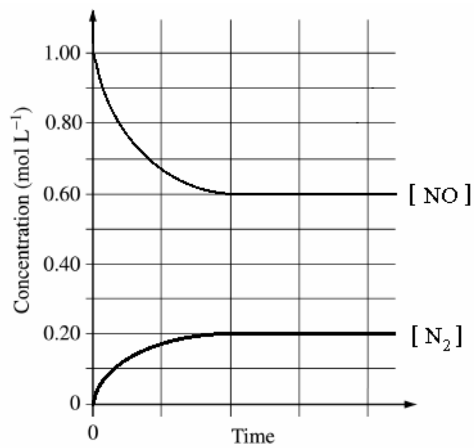
TOPIC 6: EQUILIBRIUM, REVIEW

Day 70:

- Chemical Equilibrium
- Heterogeneous Equilibria
- Applications of the Equilibrium Constant
- Solving Equilibrium Problems
- Equilibrium position
- Reaction Quotient
- Calculating Equilibrium Pressures
- Le Chatelier's Principle.
- Equilibrium expression
- Equilibrium (pressures)

$$2\,NO_{(g)} \rightleftharpoons N_{2\,(g)} + O_{2\,(g)}$$

1. After a 1.0 mole sample of $NO_{(g)}$ is placed into an evacuated 1.0 L container at 500. K, the reaction represented above occurs. The concentration of $NO_{(g)}$ as a function of time is shown below.



[N_2] curve is for 1(d)

(a) Write the expression for the equilibrium constant, K_c , for the reaction.

Answers:

$$K_c = \frac{[N_2][O_2]}{[NO]^2}$$

1 point for correct expression

(b) What is [NO] at equilibrium?

Answers:

1 point for equilibrium of [NO]

From the graph, [NO] = 0.60 M

(c) Determine the equilibrium concentrations of $N_{2\,(g)}$ and $O_{2\,(g)}$.

Answers:

	2 NO	⇌	N_2	+	O_2
I	1.00 *M*		0		0
C	- 2*x* = - 0.40 *M*		*x* = + 0.20 *M*		*x* = + 0.20 *M*
E	1.0 – 2*x* = 0.60 *M*		*x* = 0.20 *M*		*x* = 0.20 *M*

$[N_2] = [O_2] = 0.20\ M$

1 point for stoichiometric relationship between NO reacting and $N_{2\,(g)}$ and $O_{2\,(g)}$ forming

1 point for $[N_2]_{eq}$ and $[O_2]_{eq}$

(d) On the graph, make a sketch that shows how the concentration of $N_{2\,(g)}$ changes as a function of time.

From the graph, $[\,N_2\,]_{eq}$ is 0.20 *M* The curve should have the following characteristics: - start at 0 *M*; - increase to 0.20 *M*; - reach equilibrium at the same time [NO] reaches equilibrium	1 point for any two characteristics 2 points for all three characteristics

(e) Calculate the value of the following equilibrium constants for the reaction at 500 K:

(i) K_c

Answers:

$$K_c = \frac{\left[\ 0.20\ M\ \right]\left[\ 0.20\ M\ \right]}{\left[\ 0.60\ M\ \right]^2} = 0.11$$

1 point for correct substitution (must agree with parts (b) and (c))

(ii) K_p

$K_p = K_c(RT)^{\Delta n}$ *The number of moles on the product side is equal to the number of moles on the reactant side.* $\Delta n = 2 - 2 = 0$ $K_p = K_c(RT)^0$; $(RT)^0 = 1$; $K_p = K_c(\,1\,)$; $K_p = K_c = 0.11$	1 point for $K_p = K_c$ (with verification)

(f) At 1300 K, the value of K_c for the reaction is 9.9×10^{-2}. In an experiment, 2.20 mol of $NO_{(g)}$, 0.333 mol of $N_{2\,(g)}$, and 0.934 mol of $O_{2\,(g)}$ are placed in a 1.50 L container and allowed to reach equilibrium at 1300 K. Determine whether the equilibrium concentration of $NO_{(g)}$ will be greater than, equal to, or less than the initial concentration of $NO_{(g)}$. Justify your answer.

$$Q = \frac{\left[\ N_2\ \right]\left[\ O_2\ \right]}{\left[\ NO\ \right]^2} = \frac{\left[\dfrac{0.333\ mol}{1.50\ L}\right]\left[\dfrac{0.934\ mol}{1.50\ L}\right]}{\left[\dfrac{2.20\ mol}{1.50\ L}\right]^2} = 6.4 \times 10^{-2}$$

$$K_c = 9.9 \times 10^{-2}$$

$$Q < K_c$$

1 point for calculating Q and comparing to = K_c 1 point for predicting correct change in [NO]

Justification (defined: explanation):

To establish equilibrium, the numerator must increase and the denominator must decrease. Therefore, [NO] will decrease in order for Q and K to be equal.

2. At a certain temperature, $K = 9.1 \times 10^{-4}$ mol L^{-1} for the reaction

$$FeSCN^{+2}{}_{(aq)} \rightleftharpoons Fe^{+3}{}_{(aq)} + SCN^{-1}{}_{(aq)}$$

Calculate the concentrations of Fe^{+3}, SCN^{-1} and $FeSCN^{+2}$ in a solution which is initially 2.0 M $FeSCN^{+2}$.

Answers:

	$[FeSCN^{+2}]$	$\rightleftharpoons$	$[Fe^{+3}]$	+	$[SCN^{-1}]$
I	2.0 mol / 1.0 L		0		0
C	$- x$		$+ x$		$+ x$
E	$2.0 - x$		x		x

$$9.1\times10^{-4} = \frac{\left[Fe^{+3} \right]\left[SCN^{-1} \right]}{\left[FeSCN^{+2} \right]} = \frac{x^{2}}{\left(2.0 - x \right)} = \frac{x^{2}}{2.0} \quad (\text{ assuming } 2.0 - x \approx 2.0)$$

$$\left(2.0 \right)\left(9.1\times10^{-4} \right) = x^{2} \;;\; \sqrt{1.82\times10^{-3}} = x = 4.3\times10^{-2}$$

$$4.3\times10^{-2} = x, \quad \text{Assumption good}$$

$$\left[Fe^{+3} \right] = \left[SCN^{-1} \right] = x = 4.3\times10^{-2} \;\; ; \;\; \left[FeSCN^{+2} \right] = 2.0$$

3. At a certain temperature, $K = 3.74 \times 10^{-6}$ for the reaction

$$2\ SO_{3\,(g)} \rightleftharpoons 2\ SO_{2\,(g)} + O_{2\,(g)}$$

Calculate the concentrations of each in which there are initially 2.5 mol SO_3 and 3.7 mol of O_2 in a one liter container.

Answers:

	$2 [SO_3]$	$\rightleftharpoons$	$2 [SO_2]$	+	$[O_2]$
I	2.5 mol / 1.0 L		0		3.7 mol / 1.0 L
C	$- 2x$		$+ 2x$		$+ x$
E	$2.5 - 2x$		$2x$		$3.7 + x$

$$3.74\times10^{-6} = \frac{\left[SO_2 \right]^{2}\left[O_2 \right]}{\left[SO_3 \right]^{2}} = \frac{\left(2x \right)^{2}\left(3.7 + x \right)}{\left(2.5 - x \right)^{2}}$$

$$(\text{ assuming } 3.7 + x \approx 3.7, \text{ and } 2.5 - x \approx 2.5)$$

$$3.74\times10^{-6} = \frac{\left(2x \right)^{2}\left(3.7 \right)}{\left(2.5 \right)^{2}} \;;\; \frac{\left(3.74\times10^{-6} \right)\left(2.5 \right)^{2}}{\left(3.7 \right)} = \left(2x \right)^{2} \;;\; 6.32\times10^{-6} = 4x^{2}$$

$$\frac{6.32\times10^{-6}}{4} = x^{2} \;;\; \sqrt{1.58\times10^{-6}} = x = 0.00126$$

$$\left[SO_3 \right] = 2.5 \;;\; \left[O_2 \right] = 3.7 \;;\; \left[SO_2 \right] = 0.00251$$