Name: Date:

**Chemistry 12: Lesson 9 – Equilibrium**
**Equilibrium Calculations Part 2**

a)

**Example 4: Predicting which way a reaction will shift**

$K_{eq}$ = 49 for 2 NO(g) + $O_2$ (g) ←→ 2 $NO_2$ (g). If 2.0 mol of NO(g), 0.20 mol of $O_2$(g) and 0.40 mol of $NO_2$(g) are put into a 2.0 L bulb which way will the reaction shift in order to reach equilibrium?

***When making predictions you need to calculate the Reaction Quotient (Q), this is to see where about your [Product]:[Reactant] ratio is compared to where it should be at equilibrium***

Trial Keq

Expressions for Q are the same as your equilibrium constant.

STEP 1: Write out the equilibrium expression

$$K_{eq} = \frac{[NO_2]^2}{[O_2][NO]^2}$$

$$C = \frac{n}{V}$$

STEP 2: Calculate all starting concentrations

$$[NO]_{start} = \frac{2.0\,mol}{2.0\,L} \qquad [O_2]_{start} = \frac{0.2\,mol}{2.0\,L} \qquad [NO_2] = \frac{0.4\,mol}{2.0\,L}$$

$$[NO]_{start} = 1.0\,M \qquad [O_2]_{start} = 0.10\,M \qquad [NO_2] = 0.20\,M$$

STEP 3: Solve for Q

$$Q = \frac{[NO_2]^2_{start}}{[NO]^2_{start}[O_2]_{start}} = \frac{(0.20)^2}{(1.0)^2(0.1)} \qquad Q = 0.40$$

STEP 4: Make a prediction

$Q = 0.40$

$K_{eq} = 49$

$Q < K_{eq}$

$R \rightarrow P$

$$K_{eq} = \frac{P\uparrow}{R}$$

Q needs to increase to reach eq.
∴ ↑ Products so shift to products (right)

**Example 5: Finding all concentrations at equilibrium**

$K_{eq}$ = 3.5 for $SO_2(g) + NO_2(g) \leftrightarrow SO_3(g) + NO(g)$. If 4.0 mol of $SO_2(g)$ and 4.0 mol of $NO_2(g)$ are placed in a 5.0 L bulb and allowed to come to equilibrium, what concentration of all species will exist at equilibrium?

STEP 1: Write out the equilibrium expression

$$K_{eq} = \frac{[SO_3][NO]}{[NO_2][SO_2]}$$

$$[SO_2]_i = \frac{4 \text{ mol}}{5} = 0.8 \qquad [NO_2] = \frac{4}{5} = 0.8$$

STEP 2: Set up ICE box

| | $SO_{2(g)}$ + | $NO_{2(g)}$ ⇌ | $SO_{3(g)}$ + | $NO_{(g)}$ |
|---|---|---|---|---|
| I | 0.8 | 0.8 | 0 | 0 |
| C | −x | −x | +x | +x |
| E | 0.8−x | 0.8−x | x | x |

STEP 3: Solve

$$K_{eq} = 3.5 = \frac{(x)(x)}{(0.8-x)(0.8-x)}$$

$$\sqrt{3.5} = \sqrt{\frac{x^2}{(0.8-x)^2}}$$

$$1.87 = \frac{x}{0.8-x}$$

$$1.87(0.8-x) = x$$

$$1.496 - 1.87x = 1x$$
$$+1.87x \quad +1.87x$$

$$\frac{1.496}{2.87} = \frac{2.87x}{2.87}$$

$$0.521\,M = x$$

$$[SO_3] = [NO] = 0.521\,M$$

$$[SO_2] = [NO_2] = 0.8 - x = 0.8 - 0.521 = 0.28\,M$$

**EXAMPLE 6: A shift back to equilibrium**

A 1.0 L reaction vessel contained 1.0 mol of $SO_2$, 4.0 mol of $NO_2$, 4.0 mol of $SO_3$ and 4.0 mol of NO at equilibrium according to $SO_2(g) + NO_2(g) \leftrightarrow SO_3(g) + NO(g)$. If 3.0 mol of $SO_2$ is added to the mixture, what will be the new concentration of NO when equilibrium is re-attained

STEP 1: Find $K_{eq}$ for the reaction

$$K_{eq} = \frac{[SO_3][NO]}{[SO_2][NO_2]}$$

$$K_{eq} = \frac{(4)(4)}{(1)(4)} = 4$$

STEP 2: Make ICE box. Remember the addition of the reactant is part of the initial concentration.

| | $SO_{2(g)}$ + | $NO_{2(g)}$ ⇌ | $SO_{3(g)}$ + | $NO_{(g)}$ |
|---|---|---|---|---|
| I | 1.0 + 3.0 | 4 | 4 | 4 |
| C | −x | −x | +x | +x |
| E | 4−x | 4−x | 4+x | 4+x |

STEP 3: Solve

$$K_{eq} = 4.0 = \frac{(4+x)^2}{(4-x)^2}$$

$x = 1.33$

$[NO] = 4 + x$

$= 5.33$ M