Chemistry 12

Equilibrium V

II.8 (pg 63-72)

Name:
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1. **ICE Tables (cont'd)**
2. **Trial K_{eq}**

ICE Tables

Determining Initial Concentrations from K_{eq} and the Equilibrium Concentrations

(1) Some CH_3OH was injected into a flask where it established equilibrium with a [CO]=0.15M. What was the initial concentration of CH_3OH?

$$\_\_\_\_ CH_3OH_{(g)} \leftrightharpoons \_\_\_\_ H_{2(g)} + \_\_\_\_ CO_{(g)} \qquad K_{eq} = 0.040$$

	____ $CH_3OH_{(g)}$	⇋	2 $H_{2(g)}$	+	____ $CO_{(g)}$
I	x		0M		0M
C	−0.15M		+0.30M		+0.15M
E	x − 0.15		0.30M		0.15M

$$K_{eq} = \frac{(0.30)^2(0.15)}{(x-0.15)} = 0.040$$

$$0.040x - 0.006 = 0.0135$$
$$+0.006 \qquad +0.006$$
$$\frac{0.040x}{0.040} = \frac{0.0195}{0.040} \qquad x = 0.4875$$

$$[CH_3OH] = 0.49M$$

(2) NiS reacted with O_2 in a 2.0L flask. When equilibrium was achieved, 0.36 mol of SO_2 were found in the flask. What was the original $[O_2]$ in the flask? $K_{eq} = 0.30$

	2 $NiS_{(s)}$	+	3 $O_{2\ (g)}$	⇋	2 $SO_{2\ (g)}$	+	2 $NiO_{(s)}$
Initial			x		0M		
Change			−0.27M		+0.18M		
Equilibrium			x − 0.27M		0.18M		

$$K_{eq} = \sqrt[3]{\frac{(0.18)^2}{(x-0.27)^3}} = \sqrt[3]{0.30}$$

$$\frac{0.318797}{x-0.27} = 0.6694$$

$$0.6694x - 0.1807 = 0.318797$$
$$+0.1807 \qquad +0.1807$$
$$0.6694x = 0.499535$$

$$x = 0.7462$$

$$[O_2] = 0.75M$$

(3) Some HI is pumped into a flask. At equilibrium, the [HI] = 0.60 mol/L. What is the initial [HI]?

$2\,HI_{(g)} \leftrightharpoons \_\_\_\, H_{2\,(g)} + \_\_\_\, I_{2\,(g)}$ $K_{eq} = 0.25$

	$2\,HI$	H_2	I_2
I	x	0M	0M
C	$-2y$	$+y$	$+y$
E	0.60M	y	y

$$K_{eq} = \frac{(y)^2}{(0.60)^2} = 0.25$$

$$\sqrt{0.09} = \sqrt{y^2}$$

$$0.3 = y$$

$$x - 2y = 0.60$$

$$x - 2(0.3) = 0.60$$

$$x - 0.6 = 0.6$$

$$x = 1.2$$

$$[HI] = x = 1.2M$$

(4) Some SO_2 and O_2 are injected into a flask. At equilibrium, the $[SO_2]$ = 0.050M and the $[O_2]$ = 0.040 M. What was the initial $[O_2]$?

$2\,SO_{2\,(g)} + \_\_\_\, O_{2\,(g)} \leftrightharpoons 2\,SO_{3\,(g)}$ $K_{eq} = 100.$

	$2\,SO_2$	O_2	$2\,SO_3$
I		x	0M
C	$-2y$	$-y$	$+2y$
E	0.050M	0.040M	$2y$

$$K_{eq} = \frac{(2y)^2}{(0.050)^2(0.040)} = 100$$

$$\sqrt{0.01} = \sqrt{2y^2}$$

$$\frac{0.1}{2} = \frac{2y}{2}$$

$$0.05 = y$$

$$x - y = 0.040$$

$$x - 0.05 = 0.040$$

$$x = 0.09$$

$$[O_2] = x = 0.090$$

Trial K_{eq}

With any given values of the concentration of product or reactant, a trial K_{eq} can be found. From this value, it can be predicted whether the reaction will proceed to the left or right to reach equilibrium.

Trial K_{eq} is also called the reaction quotient, Q.

$$\text{Trial } K_{eq} = \frac{[\text{products}]}{[\text{reactants}]} \text{ @ any time}$$

Remember…
The [reactants] and [products] will shift in order to reach equilibrium.

Comparing trial K_{eq} and actual K_{eq}…

1. If trial K_{eq} is greater than actual K_{eq}…

$$\text{Trial } K_{eq} = \frac{[\text{products}]}{[\text{reactants}]} \qquad K_{eq} = \frac{[\text{products}]}{[\text{reactants}]}$$

- More reactant will need to be formed.
- The reaction will shift left.

2. If trial K_{eq} is less than actual K_{eq}…

$$\text{Trial } K_{eq} = \frac{[\text{products}]}{[\text{reactants}]} \qquad K_{eq} = \frac{[\text{products}]}{[\text{reactants}]}$$

- More product will need to be formed.
- The reaction will shift right.

Example:
(1) The following gases are introduced into a closed flask: 0.057M SO_2, 0.057M O_2 and 0.12M SO_3. In which direction will the reaction proceed to establish equilibrium?

$$2\, SO_{2\,(g)} + \_\_\, O_{2\,(g)} \leftrightharpoons 2\, SO_{3\,(g)} \qquad K_{eq} = 85$$

$$\text{Trial } K_{eq} = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{(0.12)^2}{(0.057)^2(0.057)} = 78$$

Trial Keq < Actual Keq

78 < 85

Rxn will shift right

(2) The following gases are introduced into a closed 1.50 L flask: 1.5 mol of NO_2 and 4.0 mol N_2O_4. In which direction will the reaction proceed to achieve equilibrium?

$$\underline{2}\ NO_{2\,(g)} \leftrightharpoons \underline{\quad}\ N_2O_{4\,(g)} \qquad K_{eq} = 0.940$$

$$\text{Trial } K_{eq} = \frac{[N_2O_4]}{[NO_2]^2} = \frac{(2.667)}{(1)^2} = 2.667$$

Trial Keq > Actual Keq

2.667 > 0.0940

Rxn will shift LEFT

(3) A mixture contains 0.025M CH_4, 0.045M H_2O, 0.10M CO and 0.30M H_2. In which direction will the reaction proceed to reach equilibrium?

$$\underline{\quad}\ CH_{4\,(g)} + \underline{\quad}\ H_2O_{\,(g)} \leftrightharpoons \underline{\quad}\ CO_{\,(g)} + \underline{3}\ H_{2\,(g)} \qquad K_{eq} = 4.7$$

$$\text{Trial } K_{eq} = \frac{[CO][H_2]^3}{[CH_4][H_2O]} = \frac{(0.10)(0.30)^3}{(0.025)(0.045)} = 2.4$$

Trial Keq < Actual Keq

2.4 < 4.7

Rxn will shift RIGHT

(4) At a certain temperature the reaction:

$$\underline{\quad}\ CO_{(g)} + \underline{\quad}\ H_2O_{(g)} \leftrightharpoons \underline{\quad}\ CO_{2(g)} + \underline{\quad}\ H_{2(g)}$$

has a K_{eq} = 0.400. Exactly 1.00 mol of each gas was placed in a 100. L vessel and the mixture was allowed to react. Find the equilibrium concentration of each gas.

$$\text{Trial } K_{eq} = \frac{(0.01)(0.01)}{(0.01)(0.01)} = 1$$

Trial Keq > Actual Keq

1 > 0.400

Shift left

	CO	+ H_2O	⇌ CO_2	+ H_2
I	0.01M	0.01M	0.01M	0.01M
C	+x	+x	−x	−x
E	0.01+x	0.01+x	0.01−x	0.01−x

$$K_{eq} = \sqrt{0.400} = \sqrt{\frac{(0.01-x)^2}{(0.01+x)^2}}$$

$$0.632 = \frac{0.01-x}{0.01+x}$$

Hebden Workbook Pg. 72 #50-52, 54, 58, 61-66

$$0.00632 + 0.632x = 0.01 - x$$

$$-0.00632 \quad +x \quad -0.00632 \quad +x$$

$$\frac{1.632x}{1.632} = \frac{0.00368}{1.632}$$

$$x = 0.00225$$

$[CO_2] = [H_2]$

$= 0.01 - 0.00225$

$= 0.00775 M$

$[CO] = [H_2O]$

$= 0.01 + 0.00225$

$= 0.0123 M$