Key

K_{eq} and ICE Problems Worksheet

1. Calculate the equilibrium constant, K_{eq}, for the following reaction at 25°C, if $[NO]_{eq} = 0.106$ M, $[O_2]_{eq} = 0.122$ M and $[NO_2]_{eq} = 0.129$ M.

$2NO(g) + O_2(g) \leftrightarrow 2\,NO_2(g)$

$$K_{eq} = \frac{[NO_2]}{[NO]^2[O_2]} = \frac{(0.129)^2}{(0.106)^2(0.122)} = \boxed{12.1}$$

2. Given the balanced equation and the value for K_{eq} from #1, calculate new value of K_{eq} for the following:

a. $\frac{1}{2}\,NO(g) + \frac{1}{4}\,O_2(g) \leftrightarrow \frac{1}{2}\,NO_2(g)$

$$K_{eq} = \frac{[NO_2]^{1/2}}{[NO]^{1/2}[O_2]^{1/4}} = \frac{(0.129)^{1/2}}{(0.106)^{1/2}(0.122)^{1/4}} = \boxed{1.87}$$

b. $2NO_2(g) \leftrightarrow 2NO(g) + O_2(g)$

$$K_{eq} = \frac{[NO]^2[O_2]}{[NO_2]^2} = \frac{(0.106)^2(0.122)}{(0.129)^2} = \boxed{0.0824}$$

c. $NO_2(g) \leftrightarrow NO(g) + \frac{1}{2}\,O_2(g)$

$$K_{eq} = \frac{[NO][O_2]^{1/2}}{[NO_2]} = \frac{(0.106)(0.122)^{1/2}}{(0.129)} = \boxed{0.287}$$

3. Find the equilibrium constant, K_{eq}, for the following equilibrium. The initial concentrations of AB and A_2D are 0.30 M before they are mixed and when equilibrium is reached, the equilibrium concentration of A_2D is 0.20 M. Use an ICE table for your calculation.

$2AB(g) + C_2D(s) \leftrightarrow A_2D(g) + 2CB(s)$

I	0.30	X	0.30	X
C	+0.20	X	-0.10	X
E	0.50	X	0.20	X

$$K_{eq} = \frac{[A_2D]}{[AB]^2} = \frac{(0.20)}{(0.50)^2} = \boxed{0.80}$$

4. If 0.50 mol of NO_2 is placed in a 2.0L flask to create NO and O_2, calculate $[\,]_{eq}$ if $K_{eq} = 1.2 \times 10^{-5}$.

$2NO_2 \rightleftharpoons 2NO + O_2$

I	0.250	0	0
C	-2x	+2x	+x
E	0.250 -2x	2x	x

$$K_{eq} = \frac{[NO]^2[O_2]}{[NO_2]^2} = \frac{(2x)^2(x)}{(0.250 - \cancel{2x})^2}$$

$K_{eq} = 1.2 \times 10^{-5} \ll 0.250 = [NO_2]$, so $\cancel{2x}$ is insignificant and can be ignored.

$$1.2 \times 10^{-5} = \frac{4x^3}{0.0625}$$

$$4x^3 = 7.5 \times 10^{-7}$$

$$x = 5.72 \times 10^{-3}$$

$[NO_2] = 0.24$ M
$[NO] = 0.011$ M
$[O_2] = 0.0057$ M

Answers: 1. $K_{eq} = 12.1$; 2. a. $K_{eq} = 1.87$, b. $K_{eq} = 0.0826$, $K_{eq} = 0.287$; 3. $K_{eq} = 0.80$;
4. $[O_2]_{eq} = 0.0057$ M, $[NO]_{eq} = 0.0114$ M, $[NO_2]_{eq} = 0.24$ M

5. For the system, if we start with 0.100mol/L of CO_2 and H_2, what are the concentrations of the reactants and products at equilibrium given that $K_{eq} = 0.64$ at 900K?

$CO_2(g) + H_2(g) \leftrightarrow CO(g) + H_2O(g)$

I	0.100	0.100	0	0
C	−x	−x	+x	+x
E	0.100 −x	0.100 −x	x	x

$K_{eq} = \frac{[CO][H_2O]}{[CO_2][H_2]}$

$\sqrt{0.64} = \sqrt{\frac{(x^2)}{(0.100-x)^2}}$

$0.80 = \frac{x}{0.100 - x}$

$0.080 - 0.80x = x$

$1.80x = 0.080$

$x = 0.0444$

$[CO] = [H_2O] = 0.0444\ M$

$[CO_2] = [H_2] = 0.0556 M$

6. For the system, if we start with 0.010 mol/L of H_2 and I_2 and 0.096 mol/L of HI, what are their concentrations at equilibrium given that $K_{eq} = 0.016$?

$Q = \frac{(0.010)^2}{(0.096)} = 0.0010$ Q < K, so rxn shifts →

$2HI(g) \leftrightarrow H_2(g) + I_2(g)$

I	0.096	0.010	0.010
C	−x	+x	+x
E	0.096 −x	0.010 +x	0.010 +x

$K_{eq} = \frac{[H_2][I_2]}{[HI]^2}$

$\sqrt{0.016} = \sqrt{\frac{(0.010+x)^2}{(0.096-x)^2}}$

$0.1265 = \frac{0.010 + x}{0.096 - x}$

$0.01214 - 0.1265x = 0.010 + x$

$1.1265x = 0.00214$

$x = 0.0019$

$[H_2] = [I_2] = 0.012 M$

$[HI] = 0.094 M$

7. At 650°C, the reaction below has a K_{eq} value of 0.771. If 2.00 mol of both hydrogen and carbon dioxide are placed in a 4.00 L container and allowed to react, what will be the equilibrium concentrations of all four gases?

$H_2(g) + CO_2(g) \leftrightarrow CO(g) + H_2O(g)$

I	0.500	0.500	0	0
C	−x	−x	+x	+x
E	0.500 −x	0.500 −x	x	x

$K_{eq} = \frac{[CO][H_2O]}{[H_2][CO_2]}$

$\sqrt{0.771} = \sqrt{\frac{x^2}{(0.500-x)^2}}$

$0.8781 = \frac{x}{0.500 - x}$

$0.4391 - 0.8781x = x$

$x = 0.234$

$[CO] = [H_2O] = 0.234 M$

$[H_2] = [CO_2] = 0.266 M$

8. Carbonyl bromide, $COBr_2$, can be formed by reacting CO with Br_2. A mixture of 0.400 mol CO, 0.300 mol Br_2, and 0.0200 mol $COBr_2$ is sealed in a 5.00L flask. Calculate equilibrium concentrations for all gases, given that the K_{eq} = 0.680.

$CO(g) + Br_2(g) \leftrightarrow COBr_2(g)$

I	0.0800	0.0600	0.00400
C	+x	+x	−x
E	0.0800 +x	0.0600 +x	0.00400 −x

$Q = \frac{(0.00400)}{(0.0800)(0.0600)} = 0.833$ Q > K, so rxn shifts ←

$K_{eq} = \frac{[COBr_2]}{[CO][Br_2]}$

$0.680 = \frac{(0.00400 - x)}{(0.0600 + x)(0.0800 + x)}$

$0.680(0.004800 + 0.140x + x^2) = (0.00400 - x)$

$3.264 \times 10^{-3} + 0.0952x + 0.680x^2 = 0.00400 - x$

$0.680x^2 + 1.0952x - 7.36 \times 10^{-4} = 0$

$x = 6.72 \times 10^{-4}$

$[COBr_2] = 0.00333 M$

$[CO] = 0.0807 M$

$[Br_2] = 0.0607 M$

Answers: 5. $[CO]_{eq} = [H_2O]_{eq} = 0.044$ M, $[CO_2]_{eq} = [H_2]_{eq} = 0.056$ M; 6. $[HI]_{eq} = 0.093$ M, $[H_2]_{eq} = [I_2]_{eq} = 0.012$ M;
7. $[CO]_{eq} = [H_2O]_{eq} = 0.234$ M, $[H_2]_{eq} = [CO_2]_{eq} = 0.266$ M; 8. $[CO]_{eq} = 0.0807$ M, $[Br_2]_{eq} = 0.0607$ M, $[COBr_2]_{eq} = 0.0033$ M