Worksheet A **Equilibrium Calculations**

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Solve each problem and show all of your work.

1. $SO_{3(g)} + H_2O_{(g)} \rightleftarrows H_2SO_{4(l)}$

At equilibrium $[SO_3] = 0.400M$ $[H_2O] = 0.480M$ $[H_2SO_4] = 0.600M$

Calculate the value of the equilibrium constant.

2. At equilibrium at 100°C, a 2.0L flask contains:

0.075 mol of PCl_5 (÷2 = .0375) 0.050 mol of H_2O (÷2 = .025) 0.750 mol 0f HCl (÷2 = .375) 0.500 mol of $POCl_3$ (÷2 = .25)

Calculate the Keq for the reaction:

$PCl_5(s) + H_2O(g) \rightleftarrows 2HCl(g) + POCl_3(g)$

3. Keq= 798 at 25°C for the reaction: **$2SO_2(g) + O_2(g) \rightleftarrows 2SO_3(g)$.**

In a particular mixture at equilibrium, $[SO_2]$= 4.20 M and $[SO_3]$=11.0M. Calculate the equilibrium $[O_2]$ in this mixture at 25°C.

4. Consider the following equilibrium:

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

0.600 moles of SO_2 and 0.600 moles of O_2 are present in a 4.00 L flask at equilibrium at 100°C. If the Keq = 680, calculate the SO_3 concentration at 100°C.

5. Consider the following equilibrium:

$2\ NO_{2(g)} \rightleftarrows N_2O_{4(g)}$

2.00 moles of NO_2 and1.60 moles of N_2O_4 are present in a 4.00 L flask at equilibrium at 20°C. Calculate the Keq at 20°C.

6. **$2\ SO_{3(g)} \rightleftarrows 2\ SO_{2(g)} + O_{2(g)}$**

4.00 moles of SO_2 and 5.00 moles O_2 are present in a 2.00 L container at 100°C and are at equilibrium. Calculate the equilibrium concentration of SO_3 and the number of moles SO_3 present if the Keq = 1.47×10^{-3}.

7. If at equilibrium $[H_2] = 0.200M$ and $[I_2] = 0.200M$ and Keq=55.6 at 250°C, calculate the equilibrium concentration of HI.

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

8. 1.60 moles CO, 1.60 moles H_2O, 4.00 moles CO_2, 4.00moles H_2 are found in a 8.00L container at 690°C at equilibrium.

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

Calculate the value of the equilibrium constant.

Worksheet B **Equilibrium Calculations**

Solve each problem and show all of your work.

1. At equilibrium, a 5.0L flask contains: 0.75 mol of PCl_5 0.50 mol of H_2O 7.50 mol of HCl 5.00 mol of $POCl_3$

Calculate the Keq for the reaction: $\mathbf{PCl_{5\,(s)} + H_2O_{\,(g)} \rightleftarrows 2HCl_{\,(g)} + POCl_{3\,(g)}}$

2. Keq= 798 for the reaction: $\mathbf{2SO_{2\,(g)} + O_{2\,(g)} \rightleftarrows 2SO_{3\,(g)}}$.

In a particular mixture at equilibrium, $[SO_2]$= 4.20 M and $[SO_3]$=11.0 M. Calculate the equilibrium $[O_2]$ in this mixture.

3. Consider the following equilibrium: $\mathbf{2SO_2\,(g) + O_2\,(g) \rightleftarrows 2SO_3\,(g)}$

When a 0.600 moles of SO_2 and 0.600 moles of O_2 are placed into a 1.00 litre container and allowed to reach equilibrium, the equilibrium $[SO_3]$ is to be 0.250M. Calculate the Keq value.

4. Consider the following equilibrium: $\mathbf{2\,NO_{2(g)} \rightleftarrows N_2O_{4(g)}}$

If 2.00 moles of NO_2 are placed in a 1.00 L flask and allowed to react. At equilibrium 1.80 moles NO_2 are present. Calculate the K_{eq}.

5. $\mathbf{2\,SO_{2(g)} + O_{2(g)} \rightleftarrows 2\,SO_{3(g)}}$

4.00 moles of SO_2 and 5.00 moles O_2 are placed in a 2.00 L container at 200°C and allowed to reach equilibrium. If the equilibrium concentration of O_2 is 2.00 M, calculate the Keq

6. If the initial $[H_2]$ = 0.200M, $[I_2]$ = 0.200M and Keq = 55.6 at 250°C calculate the equilibrium concentrations of all molecules.

$\mathbf{H_2\,(g) + I_2\,(g) \rightleftarrows 2HI\,(g)}$

7. 1.60 moles CO and1.60 moles H_2O are placed in a 2.00L container at 690 °C (Keq=10.0).

Calculate all equilibrium concentrations. $\mathbf{CO\,(g) + H_2O\,(g) \rightleftarrows CO_2\,(g) + H_2\,(g)}$

8. $\mathbf{SO_{3(g)} + NO_{(g)} \rightleftarrows NO_{2(g)} + SO_{2(g)}}$

K_{eq} = 0.800 at 100°C. If 4.00 moles of each reactant are placed in a 2.00L container, calculate all equilibrium concentrations at 100°C.

9. Consider the following equilibrium system: $2NO_{2(g)} \rightleftharpoons N_2O_4$

Two sets of equilibrium data are listed for the same temperature.

Container 1	2.00 L	0.12 moles NO_2	0.16 moles N_2O_4
Container 2	5.00 L	0.26 moles NO_2	? moles N_2O_4

Determine the number of moles N_2O_4 in the second container. Get a Keq from the first container and use it for the second container.

Worksheet C Equilibrium Calculations

Solve each problem and show all of your work in your portfolio.

1. At equilibrium, a 2.0 L flask contains: 0.200 mol of PCl_5 0.30 mol of H_2O 0.60 mol of HCl 0.300 mol of $POCl_3$

Calculate the Keq for the reaction: $PCl_{5\,(g)} + H_2O_{\,(g)} \rightleftarrows 2HCl_{\,(g)} + POCl_{3\,(g)}$

2. Keq= 798 for the reaction: $2SO_{2\,(g)} + O_{2\,(g)} \rightleftarrows 2SO_{3\,(g)}$.

In a particular mixture at equilibrium, $[SO_2]$= 4.20 M and $[SO_3]$= 11.0M. Calculate the equilibrium $[O_2]$ in this mixture.

3. Consider the following equilibrium: $2SO_{2\,(g)} + O_{2\,(g)} \rightleftarrows 2SO_{3\,(g)}$

When a 0.600 moles of SO_2 and 0.600 moles of O_2 are placed into a 2.00 litre container and allowed to reach equilibrium, the equilibrium $[SO_3]$ is to be 0.250M. Calculate the Keq value.

4. $H_{2\,(g)} + S_{\,(s)} \rightleftarrows H_2S_{\,(g)}$ Keq= 14

0.60 moles of H_2 and 1.4 moles of S are placed into a 2.0L flask and allowed to reach equilibrium. Calculate the $[H_2]$ at equilibrium.

5. Keq=0.0183 for the reaction: $2HI_{\,(g)} \rightleftarrows H_{2\,(g)} + I_{2\,(g)}$

If 3.0 moles of HI are placed in a 5.00L vessel and allowed to reach equilibrium, what is the equilibrium concentration of H_2?

6. Consider the equilibrium: $I_{2\,(g)} + Cl_{2\,(g)} \rightleftarrows 2ICl_{(g)}$ Keq= 10.0

The same number of moles of I_2 and Cl_2 are placed in a 1.0L flask and allowed to reach equilibrium. If the equilibrium concentration of ICl is 0.040 M, calculate the initial number of moles of I_2 and Cl_2.

7. Consider the equilibrium: $2ICl_{(g)} \rightleftarrows I_{2\,(g)} + Cl_{2\,(g)}$ Keq= 10.0

If x moles of ICl were placed in a 5.0 L container at 10 °C and if an equilibrium concentration of I_2 was found to be 0.60 M, calculate the number of moles ICl initially present.

8. A student places 2.00 moles SO_3 in a 1.00 L flask. At equilibrium $[O_2]$ = 0.10 M at 130 °C. Calculate the K_{eq}.

Worksheet D **Review, Ktrial, & Size of Keq**

1. $2\ CrO_4^{-2}{}_{(aq)} + 2H^+{}_{(aq)} \rightleftarrows Cr_2O_7^{-2}{}_{(aq)} + H_2O_{(l)}$

   Calculate the Keq if the following amounts were found at equilibrium in a 2.0L volume.

   CrO_4^{-2} = .030 mol, H^+ = .020 mol, $Cr_2O_7^{-2}$ = 0.32 mol, H_2O = 110 mol

2. $PCl_{5\,(s)} + H_2O_{(g)} \rightleftarrows 2HCl_{(g)} + POCl_{3\,(g)}$ Keq= 11

   At equilibrium the 4.0L flask contains the indicated amounts of the three chemicals.

   PCl_5 .012 mol H_2O .016 mol HCl .120 mol Calculate $[POCl_3]$.

3. 6.0 moles H_2S are placed in a 2.0L container. At equilibrium 5.0 moles H_2 are present. Calculate the Keq

4. 4.0 moles H_2 and 2.0 moles Br_2 are placed in a 1.0L container at 180°C. If the [HBr] = 3.0 M at equilibrium, calculate the Keq.

5. At 2000C Keq= 11.6 for $2NO_{(g)} \rightleftarrows N_{2\,(g)} + O_{2\,(g)}$. If some NO is placed in a 2.0 L vessel and the equilibrium $[N_2]$ = 0.120 M, calculate all other equilibrium concentrations

6. At 800°C, Keq = 0.279 for $CO_{2\,(g)} + H_{2\,(g)} \rightleftarrows CO_{(g)} + H_2O_{(g)}$.

   If 2.00 moles $CO_{(g)}$ and 2.00 moles $H_2O_{(g)}$ are placed in a 500 ml container, calculate all equilibrium concentrations.

   Note that when two products are placed in a container it shifts to the left to get to equilibrium.

7. $CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2\,(g)} + H_{2\,(g)}$ Keq= 10.0 at 690°C. If at a certain time [CO] = 0.80M, $[H_2O]$ = 0.050M, $[CO_2]$ = 0.50M and $[H_2]$ = 0.40M, is the reaction at equilibrium? If not, how will it shift in order to get to equilibrium?

8. For the reaction: $CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2\,(g)} + H_{2\,(g)}$ Keq= 10.0 at 690°C. The following concentrations were observed: [CO] =2.0M, $[H_2]$ = 1.0M, $[CO_2]$=2.0M, $[H_2O]$ = 0.10M. Is the reaction at equilibrium? If not, how will it shift in order to get to equilibrium?

$Q_c = \frac{2(1)}{2(0.1)} = \frac{2}{0.2} = 10$ @ equilibrium

9. For the same equation above the following concentrations were observed: [CO] = 1.5M, $[H_2]$ = 1.2, $[CO_2]$ = 1.0M, $[H_2O]$ = .10M. Is the reaction at equilibrium? If not, how will it shift in order to get to equilibrium?

$Q_c = \frac{(1)(1.2)}{(1.5)(0.1)} = \frac{1.2}{.15} = 8 < K_c$ ∴ shift Right

10. At a certain temperature the Keq for a reaction is 75. $2O_{3(g)} \rightleftarrows 3O_{2(g)}$

$K_c = \frac{[O_2]^3}{[O_3]^2}$

Predict the direction in which the equilibrium will proceed, if any, when the following amounts are introduced to a 10 L vessel.

a) 0.60 mole of O_3 and 3.0 mol of O_2 $Q_c = \frac{(.3)^3}{(.06)^2} = 7.5 < K_c$ shift right

b) 0.050 mole of O_3 and 7.0 mol of O_2 $Q_c = \frac{(.7)^3}{(.005)^2} = \frac{.343}{.005^2} = 13720$ Q_c ⇒ shift left

c) 1.5 mole of O_3 and no O_2 Q_c ⇒ shift right

11. Consider the following equilibrium:

a) $2NO_{2\,(g)} \rightleftarrows N_2O_{4\,(g)}$	Keq = 2.2
b) $Cu^{2+}{}_{(aq)} + 2Ag_{(s)} \rightleftarrows Cu_{(s)} + 2Ag^+{}_{(aq)}$	Keq = 1×10^{-15}
c) $Pb^{2+}{}_{(aq)} + 2\ Cl^-{}_{(aq)} \rightleftarrows PbCl_{2(s)}$	Keq = 6.3×10^4
d) $SO_{2(g)} + O_{2\,(g)} \rightleftarrows SO_{3\,(g)}$	Keq = 110

Which equilibrium favors products to the greatest extent? c)

Which equilibrium favors reactants to the greatest extent? b)

A

1.

1. $K_c = \frac{1}{[SO_3][H_2O]}$

$= \frac{1}{(0.4)(0.48)}$

$= 5.21$

2. $K_c = \frac{[POCl_3][HCl]^2}{[PCl_5][H_2O]}$ ✓

$= \frac{(.25)(.375)^2}{(.1)(.025)}$ ✓

$= 1.41$ ✓

1/3

3. $2\,SO_2 + O_2 \leftrightarrow 2\,SO_3$

I

C

E 4.2 ? 11

$K_c = 798$

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

$798 = \frac{(11)^2}{(4.2)^2(x)}$ $\quad x = \frac{(11)^2}{(4.2)^2(798)}$

$798 = \frac{121}{17.64\,x}$

$x = \frac{121}{798(17.64)}$

$x = 8.596 \times 10^{-3}$

$= 0.0086$ mol/L

1/3

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

$680 = \frac{x^2}{(.15)^2(.15)}$

$x^2 = 2.295$

$x = 1.515$

$\therefore [SO_3] = 1.515 \text{ mol/L}$

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

$= \frac{1.6/4}{(2/4)^2}$

$= \frac{0.4}{.25}$

$= 1.6$

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

$1.47 \times 10^{-3} = \frac{2^2(2.5)}{x^2}$ ✓

$x^2 = 6802.7$

$x = 82.4786$ ✓

B

T1 $\therefore [SO_3] = 82.4786 \text{ mol/L}$ ✓

$\therefore$ in 2L; 164.9572 mol

7. $K_c = \frac{[HI]^2}{[H_2][I_2]}$

$55.6 = \frac{x^2}{(.2)(.2)}$

1

3

$x^2 = 2.224$

$x = 1.49$

$\therefore [HI] = 1.49 \text{ mol/L}$

8. $K_c = \frac{[CO_2][H_2]}{[CO][H_2O]}$

$K_c = \frac{(4/8)(4/8)}{(1.6/8)(1.6/8)}$

1

3

$= \frac{(.5)(.5)}{(0.2)(0.2)} = \frac{.25}{.04}$

$= 6.25$

(B)

4.

	$2\,NO_2$	$\rightleftharpoons$	N_2O_4
I	2 mol/L		0
C	$-2x$		$+x$
E	1.8 mol		x

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

$= \frac{0.1}{(1.8)^2}$

$K_c = 0.031$

$2 - 2x = 1.8$

$\frac{2-1.8}{2} = \frac{2x}{2}$

$0.1 = x$

6

5. $2\,SO_2 + O_2 \leftrightarrow 2\,SO_3$

	$2\,SO_2$	O_2	$2\,SO_3$
I	$4/2 = 2$	$5/2 = 2.5$	0
C	$-2x$	$-x$	$+2x$
E	$2-2x$	$\boxed{2}$	$2x = \boxed{1}$
	$= 2-1$	$2.5 - x = 2$	
	$= \boxed{1}$	$x = 0.5$	

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

$$= \frac{1^2}{1^2(2)}$$

$$= \frac{1}{2} = \boxed{0.5}$$

6. $H_2 + I_2 \leftrightarrow 2HI$

	H_2	I_2	$2HI$	
I	0.2	0.2	0	$K_c = 55.6$
C	$-x$	$-x$	$+2x$	
E	$0.2-x$	$0.2-x$	$2x$	

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

$$\sqrt{55.6} = \sqrt{\frac{(2x)^2}{(0.2-x)^2}}$$

$$7.45654 = \frac{2x}{0.2-x}$$

$$1.49131 - 7.45654x = 2x$$

$$1.49131 = 9.45654x$$

$$x = 0.1577$$

$[H_2] = [I_2] = 0.2 - x$

$= 0.2 - 0.1577$

$= \boxed{0.0423\ mol/L}$

$[HI] = 2x$

$= 2(.1577)$

$= \boxed{0.3154\ mol/L}$

7. $CO + H_2O \leftrightarrow CO_2 + H_2$

	CO	H_2O	CO_2	H_2
I	$1.6/2$	$1.6/2$	0	0
C	$-x$	$-x$	$+x$	$+x$
E	$0.8-x$	$0.8-x$	x	x

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

$$\sqrt{10} = \frac{x^2}{(0.8-x)^2}$$

$$3.1623 = \frac{x}{0.8-x}$$

$$2.5298 - 3.1623x = x$$

$$2.5298 = 4.1623x$$

$$x = 0.6078$$

$[CO] = [H_2O]$
$= 0.8 - x$
$= 0.8 - 0.6078$
$= 0.1922 \text{ mol/L}$

$[CO_2] = [H_2]$
$= x$
$= 0.6078 \text{ mol/L}$

6

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

$= \frac{0.08}{(0.06)^2}$

$= 22.\bar{2}$

4

$22.\bar{2} = \frac{[N_2O_4]}{(0.052)^2}$

$\frac{0.26}{5} = 0.052$

$[N_2O_4] = 0.06 \text{ mol/L}$

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(C)

4. $H_2 + S \leftrightarrow H_2S \quad K_c = 14$

	H_2	S	H_2S
I	$\frac{0.6}{2} = 0.3$	$\frac{1.4}{2}$	0
C	$-x$	$-x$	$+x$
E	$0.3-x$	x	x

$K_c = \frac{[H_2S]}{[H_2]}$ ✓

$14 = \frac{x}{0.3-x}$ ✓

$4.2 - 14x = x$

$\frac{4.2}{15} = \frac{15x}{15}$

$x = 0.28$ ✓

$[H_2] = 0.3 - 0.28$

$= 0.02$ mol/L ✓

6

$5\overline{)3.0}$ .6

5. $2HI \leftrightarrow H_2 + I_2$

	HI	H_2	I_2
I	0.6 mol/L	0	0
C	$-2x$	$+x$	$+x$
E	$0.4-2x$	x	x

$K_c = 0.0183$

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

$\sqrt{0.0183} = \sqrt{\frac{x^2}{(0.4-2x)^2}}$

$[H_2] = x$

$= 0.064$ mol/0.064 L

$0.135275 = \frac{x}{0.4-2x}$

$0.0541111 - 0.270555x = x$

$0.0541111 = 1.270555x$

$x = 0.0425885$

$= 0.064$

6

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6. $I_2 + Cl_2 \leftrightarrow 2ICl$

	I_2	Cl_2	$2ICl$	
I	y	y	0	$K_c = 10$
C	$-x$	$-x$	$+2x$	
E	$y-x$	$y-x$	0.04	
	$= y-0.02$	$y-0.02$	$2x = 0.04$	
			$x = 0.02$	

$$K_c = \frac{[ICl]^2}{[I_2][Cl_2]}$$

$$\sqrt{10} = \sqrt{\frac{(0.04)^2}{(y-0.02)^2}}$$

$$3.16227766 = \frac{0.04}{y-0.02}$$

$$3.16227766y - 0.06324553 = 0.04$$

$$3.16227766y = 0.10324553$$

$$y = 0.03265$$

∴ Initial concentration is 0.03265 mol/L

7. $2ICl \leftrightarrow I_2 + Cl_2$

	$2ICl$	I_2	Cl_2	
I	x	0	0 ✓	$K_c = 10$
C	$-2y$	$+y$	$+y$	
E	$x-2y$	0.6	0.6 ✓	
	$= x-1.2$			

$y = 0.6$ ✓

$$\sqrt{10} = \sqrt{\frac{(0.6)^2}{(x-1.2)^2}}$$ ✓

$$3.16227766 = \frac{0.6}{x-1.2}$$ ✓

$$3.16227766x - 3.79473312 = 0.6$$

$$3.16227766x = 4.39473312$$

$$x = 1.38974 \text{ mol/L}$$

∴ $1.38974 \times 5L = 6.9487$ moles in 5L ✓

6 ✓

6

D

6.

	CO_2	+ H_2	⟷	CO	+ H_2O
I	0	0		4	4
C	$+x$	$+x$		$-x$	$-x$
E	x	x		$4-x$	$4-x$

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

$$0.279 = \frac{(4-x)^2}{x^2}$$

$$x(0.5282) = \frac{(4-x)x}{x}$$

$$1.5282x = 4$$

$$x = 2.61746$$

$[CO_2] = [H_2] = x = 2.61746 \text{ mol/L}$

$[CO] = [H_2O] = 4 - x = 4 - 2.61746 = 1.38254 \text{ mol/L}$

7.

$$Q_c = \frac{[CO_2][H_2]}{[CO][H_2O]} = \frac{(0.5)(0.4)}{(0.8)(0.05)} = \frac{0.2}{0.04} = 5$$

$K_c = 10$

$Q_c < K_c$

∴ shift to right

9