

Fall solutions

EQUILIBRIUM Calculations Practice

#1
$$K_{eq} = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

$$= \frac{(0.25M)^2}{(0.1M)(0.2M)^3}$$

$$= \boxed{78.1}$$

#2

	$2NO_2(g)$	\leftrightarrow	$2NO(g)$	$+ O_2(g)$
I	5M		\emptyset	\emptyset
C	-3M		+3.0M	+1.5M
E	2.0M		3.0M	1.5M

Concentrations

① $C = \frac{n}{V} = \frac{5 \text{ mol}}{1 L} = 5M$

② $[O_2] = 1.5 \text{ mol} / 1L = 1.5M$

$1.5M O_2 \times \frac{2 \text{ mol NO}}{1 \text{ mol } O_2} = 3M$

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

$$K_c = \frac{(3M)^2 (1.5M)}{(2)^2}$$

$$= \boxed{3.375}$$

#3

	$4NH_3(g)$	$+ 3O_2(g)$	\leftrightarrow	$2N_2(g)$	$+ 6H_2O(g)$
I	0.0150M	0.0150M		\emptyset	\emptyset
C	-0.00392	-0.00294		$+1.96 \times 10^{-3}$	$+0.00588M$
E	0.01108M	0.01206M		1.96×10^{-3}	0.00588M

$1.96 \times 10^{-3} M N_2 \times \frac{6 \text{ mol } H_2O}{2 \text{ mol } N_2}$

$= 0.00588M H_2O$

$$K_c = \frac{[N_2]^2 [H_2O]^6}{[NH_3]^4 [O_2]^3}$$

$$K_c = \frac{(1.96 \times 10^{-3})^2 (0.00588)^6}{(0.01108)^4 (0.01206)^3} = \boxed{6 \times 10^{-6}}$$

#4	$2\text{H}_2(\text{g}) + 2\text{NO}(\text{g}) \leftrightarrow \text{N}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$			Concentrations
I	2M	2M	\emptyset	Initially, $[\text{H}_2]/[\text{NO}]$ $C = \frac{n}{V} = \frac{4\text{ mol}}{2\text{ L}} = 2\text{ M}$ At equilibrium, $\frac{0.8\text{ mol}}{2\text{ L}} = 0.4\text{ M}$
C	-0.8M	-0.8M	+0.4M	
E	1.2M	1.2M	0.4M	

$$0.4\text{ M N}_2 \times \frac{2\text{ mol NO}}{1\text{ mol N}_2} = 0.8\text{ M}$$

$$K_c = \frac{[\text{N}_2]}{[\text{H}_2]^2[\text{NO}]^2}$$

$$K_c = \frac{(0.4\text{ M})}{(1.2\text{ M})^2(1.2\text{ M})^2}$$

$$K_c = \boxed{0.19}$$

#6	$\text{CO}(\text{g}) + 2\text{H}_2(\text{g}) \leftrightarrow \text{CH}_3\text{OH}(\text{g})$		
I	1M	2.25M	\emptyset
C	-0.5M	-1M	+0.5M
E	0.5M	1.25M	0.5M

Concentrations
 $[\text{CO}] = \frac{4\text{ mol}}{4\text{ L}} = 1\text{ M}$
 $[\text{H}_2] = \frac{9\text{ mol}}{4\text{ L}} = 2.25\text{ M}$
 at equil.,
 $[\text{CO}] = \frac{2\text{ mol}}{4\text{ L}} = 0.5\text{ M}$

$$0.5\text{ M CH}_3\text{OH} \times \frac{2\text{ mol H}_2}{1\text{ mol CH}_3\text{OH}} = 1\text{ M}$$

$$K_{eq} = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}][\text{H}_2]^2}$$

$$= \frac{(0.5\text{ M})}{(0.5\text{ M})(1.25\text{ M})^2} = \boxed{0.64}$$

#5	$2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \leftrightarrow 2\text{SO}_3(\text{g})$		
I	0.3M	0.25M	\emptyset
C	-0.2M	-0.1M	+0.2M
E	0.1	0.15M	0.2M

Concentration:

$$n = cV$$

Initially, $[\text{SO}_2] = \frac{1.2\text{ mol}}{4\text{ L}} = 0.3\text{ M}$

$[\text{O}_2] = \frac{1\text{ mol}}{4\text{ L}} = 0.25\text{ M}$

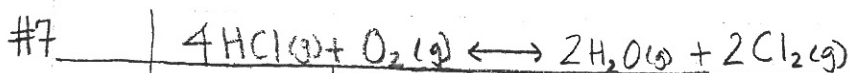
At equil.,

$[\text{SO}_2] = \frac{0.4\text{ mol}}{4\text{ L}} = 0.1\text{ M}$

$[\text{SO}_2]$

$$0.2\text{ M SO}_2 \times \frac{1\text{ mol O}_2}{2\text{ mol SO}_2} = 0.1\text{ M}$$

$$K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]} = \frac{(0.2\text{ M})^2}{(0.1\text{ M})^2(0.15\text{ M})} = \boxed{27}$$



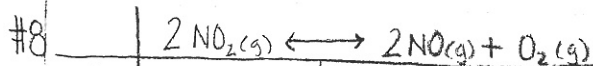
I	1M	1M	∅	∅
C	-0.4M	-0.1M	+0.2M	+0.2M
E	0.6M	0.9M	0.2M	0.2M

$$0.2\text{M H}_2\text{O} \times \frac{4\text{ mol HCl}}{2\text{ mol H}_2\text{O}} = 0.4\text{M}$$

$$K_c = \frac{[\text{H}_2\text{O}]^2 [\text{Cl}_2]^2}{[\text{HCl}]^4 [\text{O}_2]}$$

$$K_c = \frac{(0.2)^2 (0.2)^2}{(0.6)^4 (0.9)}$$

$$= \boxed{0.0137}$$



I	2.5	∅	∅
C	-1.5M	+1.5M	+0.75M
E	1M	1.5M	0.75M

Concentration

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

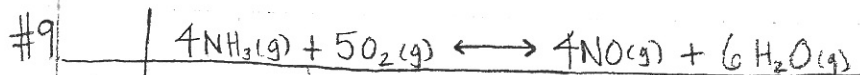
Initially, $[\text{NO}_2] = 5\text{ mol}/2\text{L} = 2.5\text{M}$

equil, $[\text{O}_2] = 1.50/2\text{L} = 0.75\text{M}$

$$K_{eq} = \frac{[\text{NO}]^2 [\text{O}_2]}{[\text{NO}_2]^2}$$

$$= \frac{(1.5)^2 (0.75\text{M})}{(2.5)^2}$$

$$= \boxed{1.7}$$



I	2.5M	2.5M	∅	∅
C	-1.6M	-2M	+1.6M	+2.4M
E	0.9M	0.5M	1.6M	2.4M

$$2.4\text{M H}_2\text{O} \times \frac{4\text{ mol NO}}{6\text{ mol H}_2\text{O}} = 1.6\text{M}$$

$$K_{eq} = \frac{[\text{NO}]^4 [\text{H}_2\text{O}]^6}{[\text{NH}_3]^4 [\text{O}_2]^5}$$

$$K_{eq} = \frac{(1.6)^4 (2.4)^6}{(0.9)^4 (0.5)^5}$$

$$K_{eq} = \boxed{6.1 \times 10^4}$$

#10

	$\text{SO}_2(\text{g})$	\rightleftharpoons	$\text{S}_2(\text{s}) + \text{O}_2(\text{g})$
I	0.05M		\emptyset
C	-X		+X
E	0.05-X		X

$$C = \frac{n}{V} = \frac{0.50 \text{ mol}}{10 \text{ L}} = 0.05 \text{ M}$$

$$K_{\text{eq}} = \frac{[\text{O}_2]}{[\text{SO}_2]}$$

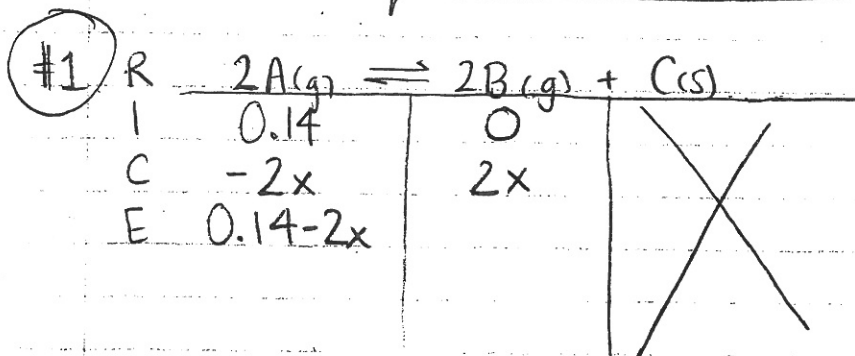
$$2.4 \times 10^{-2} = \frac{X}{0.05 - X}$$

$$X = \boxed{0.0012 \text{ M}}$$

At equil,

$$[\text{SO}_2] = 0.05 - 0.0012 = \boxed{0.0488 \text{ M}}$$

Equilibrium Part Deux.



$$C = \frac{n}{V} = \frac{0.42 \text{ mol}}{3L} = 0.14 M$$

$$K_{eq} = \frac{[B]^2}{[A]^2}$$

$$6.8 \times 10^2 = \frac{(2x)^2}{(0.14-2x)^2}$$

$$\sqrt{6.8 \times 10^2} = \frac{2x}{(0.14-2x)}$$

$$+26.08 = \frac{2x}{0.14-2x}$$

$$3.65 - 52.16x = 2x$$

$$3.65 = 54.16x$$

$$x = 0.06739$$

$$-26.08 = \frac{2x}{0.14-2x}$$

$$-3.65 + 52.16x = 2x$$

$$-3.65 = -50.16x$$

$$x = 0.073$$

Check

$$0.14 - 2(0.06739) = 0.005$$

check

$$0.14 - 2(0.073) = -0.006$$

NOT POSSIBLE

Answer $[B] = 2(0.06739) = \boxed{0.135} M$

#2

	$\text{COCl}_2(\text{g})$	\leftrightarrow	$\text{CO}(\text{g})$	+	$\text{Cl}_2(\text{g})$
I	0.25		0		0
C	-X		+X		+X
E	0.25 - X		X = 0.011M		X = 0.011M
	0.239M				

Concentration $c = \frac{n}{V}$
 $[\text{COCl}_2] = \frac{0.5 \text{ mol}}{2 \text{ L}} = 0.25$

$$4.93 \times 10^{-4} = \frac{x^2}{0.25 - x}$$

$$K_{eq} = \frac{[\text{CO}][\text{Cl}_2]}{[\text{COCl}_2]}$$

$$1.23 \times 10^{-4} - 4.93 \times 10^{-4} x = x^2$$

$$0 = 1x^2 + 4.93 \times 10^{-4} x - 1.23 \times 10^{-4}$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-4.93 \times 10^{-4} \pm \sqrt{(4.93 \times 10^{-4})^2 - 4(1)(-1.23 \times 10^{-4})}}{2(1)}$$

$$x = 0.0108$$

$$x = -0.012 \text{ NOT POSSIBLE}$$

#3

	$\text{SO}_3(\text{g})$	+	$\text{NO}(\text{g})$	\rightleftharpoons	$\text{NO}_2(\text{g})$	+	$\text{SO}_2(\text{g})$
I	0.15M		0.15M		0		0
C	-X		-X		+X		+X
E	0.15 - X		0.15 - X		0.062M		0.062M
	0.088M		0.088M				

Concentration $c = \frac{n}{V}$
 $[\text{SO}_3] = \frac{0.3 \text{ mol}}{2 \text{ L}} = 0.15 \text{ M}$
 $[\text{NO}] = \frac{0.3 \text{ mol}}{2 \text{ L}} = 0.15 \text{ M}$

$$0.5 = \frac{x^2}{(0.15 - x)^2}$$

$$+0.7071 = \frac{x}{0.15 - x}$$

$$0.7071(0.15 - x) = x$$

$$0.1061 - 0.7071x = x$$

$$0.1061 = 1.7071x$$

$$\frac{0.1061}{1.7071} = \frac{1.7071x}{1.7071}$$

$$-0.7071 = \frac{x}{0.15 - x}$$

$$-0.1061 + 0.7071x = x$$

$$-0.1061 = 0.2929x$$

$$\frac{-0.1061}{0.2929} = \frac{0.2929x}{0.2929}$$

$$x = -0.362 \text{ NOT POSSIBLE}$$

#4

	$2 \text{HI(g)} \rightleftharpoons \text{H}_2\text{(g)} + \text{I}_2\text{(g)}$		
I	0.09M	0	0
C	-2x	x	x
E	0.09-2x		<u>0.0096M</u>

Concentration
 $C = \frac{n}{V} = \frac{0.18 \text{ mol}}{2 \text{ L}} = 0.09 \text{ M}$

$$K_{eq} = \frac{[\text{H}_2][\text{I}_2]}{[\text{HI}]^2}$$

$$1.85 \times 10^{-2} = \frac{x^2}{(0.09-2x)^2}$$

$$+0.136 = \frac{x}{(0.09-2x)}$$

$$0.01224 - 0.272x = x$$

$$\frac{0.01224}{1.272} = \frac{1.272x}{1.272}$$

$$x = \boxed{0.0096 \text{ M}}$$

$$-0.136 = \frac{x}{(0.09-2x)}$$

$$-0.01224 + 0.272x = x$$

$$-0.01224 = 0.728x$$

$$\frac{0.728}{0.728} = \frac{0.728x}{0.728}$$

$$x = -0.00618 \text{ NOT POSSIBLE}$$

Answer : $[\text{I}_2] = \boxed{0.0096 \text{ M}}$

#5 a)

	$\text{CO(g)} + \text{H}_2\text{O(g)} \rightleftharpoons \text{CO}_2\text{(g)} + \text{H}_2\text{(g)}$			
I	2M	2M	∅	∅
C	-x	-x	+x	+x
E	2-x	2-x		

$$K_{eq} = \frac{[\text{CO}_2][\text{H}_2]}{[\text{CO}][\text{H}_2\text{O}]}$$

$$1.56 = \frac{x^2}{(2-x)^2}$$

$$+1.25 = \frac{x}{2-x}$$

$$2.5 - 1.25x = x$$

$$\frac{2.5}{2.25} = \frac{2.25x}{2.25}$$

$$x = 1.11$$

$$x = 1.11$$

OR

$$-1.25 = \frac{x}{2-x}$$

$$-2.5 + 1.25x = x$$

$$-2.5 = -0.25x$$

$$x = 10$$

$$[\text{CO}] / [\text{H}_2\text{O}] = 2 - 1.11 \text{ M} = 0.89 \text{ M}$$

$$[\text{CO}] / [\text{H}_2\text{O}] = 2 - 10 = -8 \text{ M}$$

NOT POSSIBLE

$$[\text{CO}_2] / [\text{H}_2] = \boxed{1.11 \text{ M}}$$

b)

	$\text{CO(g)} + \text{H}_2\text{O(g)}$	\longleftrightarrow	$\text{CO}_2\text{(g)} + \text{H}_2\text{(g)}$
I	2M		1M
C	-X		-X
E	2-X		1-X

$$K_{eq} = \frac{[\text{CO}_2][\text{H}_2]}{[\text{CO}][\text{H}_2\text{O}]}$$

$$1.56 = \frac{x^2}{(2-x)(1-x)}$$

$$1.56 = \frac{x^2}{2-3x+x^2}$$

$$3.12 - 4.68x + 1.56x^2 = x^2$$

$$3.12 - 4.68x + 0.56x^2 = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$x = \frac{4.68 \pm \sqrt{4.68^2 - 4(0.56)(3.12)}}{2(0.56)}$$

$$x = 7.63 \text{ OR } x = 0.731$$

$$[\text{CO}]/[\text{H}_2\text{O}] = 2 - 0.731 \text{ OR } 2 - 7$$

$$= \boxed{1.269}^M = -5.$$

$$[\text{H}_2\text{O}] = 0.269 \text{ M.}$$

$$[\text{CO}_2][\text{H}_2] = \boxed{0.731}$$

#6

R	$N_2(g)$	$+ O_2(g)$	$\leftrightarrow 2NO(g)$
I	0.2M	0.15M	\emptyset
C	-X	-X	+2x
E	0.2-x	0.15-x	

$$C = \frac{n}{V} = \frac{0.2 \text{ mol}}{1L} = 0.2M$$

$$= \frac{0.15 \text{ mol}}{1L} = 0.15M$$

$$4.1 \times 10^{-4} = \frac{(2x)^2}{(0.2-x)(0.15-x)}$$

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

$$4.1 \times 10^{-4} = \frac{4x^2}{0.03 - 0.35x + x^2}$$

$$1.23 \times 10^{-5} - 1.435 \times 10^{-4}x + 4.1 \times 10^{-4}x^2 = 4x^2$$

$$0 = 3.9996x^2 + 1.435 \times 10^{-4}x - 1.23 \times 10^{-5}$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$x = \frac{-1.435 \times 10^{-4} \pm \sqrt{(1.435 \times 10^{-4})^2 - 4(3.9996)(-1.23 \times 10^{-5})}}{2(3.9996)}$$

$$x = \frac{-1.435 \times 10^{-4} + 0.014}{2(3.9996)}$$

$$x = 0.001736$$

$$x = \frac{-1.435 \times 10^{-4} - 0.014}{2(3.9996)}$$

$$x = -0.001768 \text{ not possible}$$

ANSWER: $[N_2]: 0.2 - 0.0017 = 0.198$

$[O_2]: 0.15 - 0.0017 = 0.148$

$[NO]: 2(0.0017) = 0.0034$

