Part 2: predict the direction of eqm

1. $H_2(g) + I_2(g) \rightleftharpoons 2HI_{(g)}$

$K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$, $Q = \frac{[HI]^2}{[H_2][I_2]} = \frac{(0.950)^2}{(0.150)(0.175)} = 34.4$

Q < Keq therefore, the reaction will shift towards products.

2. $COCl_2(g) \rightleftharpoons CO_{(g)} + Cl_2(g)$ $K_{eq} = 2.19 \times 10^{-10}$

$K_{eq} = \frac{[CO][Cl_2]}{[COCl_2]}$

a) $Q = \frac{(3.31 \times 10^{-2} M)(3.31 \times 10^{-2} M)}{(5.00 \times 10^{-2} M)} = 2.19 \times 10^{-2}$ Q 2.19×10^{-2} > Keq 2.19×10^{-10} shifts left

b) $Q = \frac{(1.11 \times 10^{-5} M)(3.25 \times 10^{-4} M)}{3.50 \times 10^{-3} M} = 1.03 \times 10^{-8}$ Q 1.03×10^{-8} > Keq 2.19×10^{-10} shifts left

c) $Q = \frac{(1.56 \times 10^{-6} M)(1.56 \times 10^{-6} M)}{1.45 M} = 1.68 \times 10^{-12}$ Q < Keq shifts right

3. $CaCO_3(s) \rightleftharpoons CaO_{(s)} + CO_2(g)$ $K_{eq} = 0.0108$

$K_{eq} = [CO_2]$

a) $15.0g\ CO_2 \cdot \frac{mol}{44.0g\ CO_2} \cdot \frac{1}{10.0L} = 0.034 M$ Q > Keq mass increases.

b) $4.75g\ CO_2 \cdot \frac{mol}{44.0g\ CO_2} \cdot \frac{1}{10.0L} = 0.0108 M$ Q = Keq no change

c) $2.50g\ CO_2 \cdot \frac{mol}{44.0g\ CO_2} \cdot \frac{1}{10.0L} = 5.68 \times 10^{-3} M$ Q < Keq mass decreases

4. $2HF_{(g)} \rightleftharpoons H_2(g) + F_2(g)$ $K_{eq} = 4$

$K_{eq} = \frac{[H_2][F_2]}{[HF]^2}$

a) $[H_2] = \frac{2.0 mol}{5.0 L} = 0.40 M$

$[F_2] = \frac{4.0 mol}{5.0 L} = 0.80 M$

$[HF] = \frac{3.0 mol}{5.0 L} = 0.60 M$

$Q = \frac{(0.40)(0.80)}{(0.60)^2} = 0.89$

Q < Keq

RIGHT

b) $[H_2] = 0.10M$

$[F_2] = 0.12M$

$[HF] = 0.04M$

$Q = \frac{(0.10)(0.12)}{(0.04)^2} = 7.5$

Q > Keq

LEFT

c) $[H_2] = 0.36M$

$[F_2] = 0.04M$

$[HF] = 0.06M$

$Q = \frac{(0.36)(0.04)}{(0.06)^2} = 4$

NO SHIFT

5. $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ $K_{eq} = 125$

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

$[HI] = \frac{0.15 \text{ mol}}{10.0 \text{ L}} = 0.015M$

$[H_2] = \frac{0.034 \text{ mol}}{10.0 \text{ L}} = 0.0034M$

$[I_2] = \frac{0.096 \text{ mol}}{10.0 \text{ L}} = 0.0096M$

$$Q = \frac{[HI]^2}{[H_2][I_2]} = \frac{(0.015)^2}{(0.0034)(0.0096)} = 6.89$$

$Q < K_{eq}$ shifts RIGHT

Calculating Equilibrium Constants

1.

	$PCl_5(g)$ + 92.5 kJ	⇌	$PCl_3(g)$	+ $Cl_2(g)$
R				
I	0.40 M		0	0
C	− 0.25 M		+ 0.25 M	+ 0.25 M
E	0.15 M		0.25 M	0.25 M

a) $[PCl_5] = 0.15M$

$[PCl_3] = 0.25M$

$[Cl_2] = 0.25M$

b) $K_{eq} = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{(0.25)(0.25)}{0.15} = 0.42$

2.

R	$CO(g)$ +	$H_2O(g)$ ⇌	$CO_2(g)$ +	$H_2(g)$
I	0.750 M	1.075 M	0	0
C	−0.250 M	− 0.250 M	+ 0.250 M	+ 0.250 M
E	0.500 M	0.825 M	0.250 M	0.250 M

$K_{eq} = \frac{[CO_2][H_2]}{[CO][H_2O]} = \frac{(0.250)(0.250)}{(0.500)(0.825)} = 5.0$

3.

R	$SO_2(g)$ +	$NO_2(g)$ ⇌	$SO_3(g)$ +	$NO(g)$
I	1.2 M	0.5 M	0.2 M	0
C	−0.4 M	−0.4 M	+ 0.4 M	+ 0.4 M
E	0.8 M	0.1 M	0.6 M	0.4 M

$K_{eq} = \frac{[SO_3][NO]}{[SO_2][NO_2]} = \frac{(0.6)(0.4)}{(0.8)(0.1)} = 3.0$

4.

R	$N_2(g)$ +	$3H_2(g)$ ⇌	$2NH_3(g)$
I	0.60 M	0.40 M	0
C	−0.010 M	−0.030 M	+ 0.020 M
E	0.59 M	0.37 M	0.020 M

a) $K_{eq} = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(0.020)^2}{(0.59)(0.37)^3} = 0.013$

b) If 6.0 mol NH_3 was left, it's concentration would be 1.2 M. Keq would be undefined, too much product left, reaction goes to completion.

5.

R	$H_2(g)$ +	$Br_2(g)$ ⇌	$2HBr(g)$
I	0.3435 M	0.22.. M	0
C	−0.202 M	−0.202 M	+0.404 M
E	0.1415 M	0.018.. M	0.404 M

$$K_{eq} = \frac{[HBr]^2}{[H_2][Br_2]} = \frac{(0.404)^2}{(0.1415)(0.018)} = 64$$

$$1.374\,g\ H_2 \cdot \frac{mol}{2.0\,g} \cdot \frac{1}{2.00\,L} = 0.3435\ M$$

$$70.31\,g\ Br_2 \cdot \frac{mol}{159.8\,g} \cdot \frac{1}{2.00\,L} = 0.2199937422\,M$$

$$0.566\,g\ H_2 \cdot \frac{mol}{2.0\,g} \cdot \frac{1}{2.00\,L} = 0.1415\,M$$

Part 4

1.

R	$2H_2(g)$ +	$S_2(g)$ ⇌	$2H_2S(g)$
I	0	0	0.049 M
C	+0.036 M	+0.018 M	−0.036 M
E	0.036 M	0.018 M	0.013 M

$$K_{eq} = \frac{[H_2S]^2}{[H_2]^2[S_2]} = 7.5$$

$$7.5 = \frac{[H_2S]^2}{(0.036)^2(0.018)}$$

$$[H_2S]^2 = 1.7496 \times 10^{-4}\,M$$

$$[H_2S] = 0.013..\,M$$

$$\text{Moles } H_2S = \frac{0.049\ mol}{L} \cdot 2.0\,L = 0.098\,mol$$

2.

R	$H_2(g)$ +	$I_2(g)$ ⇌	$2HI(g)$
I	0.025 M	0.025 M	0
C	−x	−x	+2x
E	0.025 − x	0.025 − x	2x

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = 49.5$$

$$49.5 = \frac{[2x]^2}{(0.025-x)^2}$$

$$7.03 = \frac{2x}{0.025-x}$$

$$7.03(0.025-x) = 2x$$

$$0.176 - 7.03x = 2x$$

$$9.04x = 0.176$$

$$x = 0.01946634765$$

$$[H_2] = [I_2] = 0.025 - 0.019 = 5.53 \times 10^{-3}\,M$$

$$[HI] = 2(0.019) = 0.0389\,M$$

3\.

R	$N_2(g)$ +	$3H_2(g)$ ⇌	$2NH_3(g)$
I	0	0	3.25 M
C	+0.50 M	+1.50 M	−1.0 M
E	1.50 M	1.50 M	2.25 M

$$K_{eq} = \frac{[NH_3]^2}{[N_2][H_2]^3} = 3.0$$

$$[NH_3] = \sqrt{K_{eq} \cdot [N_2] \cdot [H_2]^3}$$
$$= \sqrt{3.0 \cdot 0.50 \cdot (1.50)^3}$$
$$= 2.25\ M$$

$$\frac{3.25\ mol\ NH_3}{L} \cdot 5.0\ L = 16\ mol\ NH_3$$

4\.

R	$N_2O_2(g)$ +	$H_2(g)$ ⇌	$N_2O(g)$ +	$H_2O(g)$
I	0	0	0.150 M	0.250 M
C	$+x$	$+x$	$-x$	$-x$
E	x	x	$0.150M - x$	$0.250M - x$

$$K_{eq} = \frac{[N_2O][H_2O]}{[N_2O_2][H_2]} = 1.00$$

$$K_{eq} = \frac{[N_2O][H_2O]}{[N_2O_2][H_2]}$$

$$1.00 = \frac{(0.150-x)(0.250-x)}{x^2}$$

$$1.00 = \frac{0.0375 - 0.40x + x^2}{x^2}$$

$$1.00x^2 = 0.0375 - 0.40x + x^2$$

$$0.40x = 0.0375$$

$$x = 0.09375$$

0.09375 M ⟶ 0.0938 M N_2O_2 was present at equilibrium

$256x^5$

$x \cdot (4x)^4$

5\.

R	$CH_4(g)$ +	$2H_2S(g)$ ⇌	$CS_2(g)$ +	$4H_2(g)$
I	$0.10M + x$	$0.30M + 2x$	0	0
C	$-x$	$-2x$	$+x$	$+4x$
E	0.10 M	0.30 M	x	$4x$

$$K_{eq} = \frac{[CS_2][H_2]^4}{[CH_4][H_2S]^2} = 100$$

$$100 = \frac{256x^5}{(0.10)(0.30)^2}$$

$$100 = \frac{256x^5}{9.0 \times 10^{-3}}$$

$$256x^5 = 0.90$$

$$x = \sqrt[5]{\frac{0.90}{256}} = 0.32 M$$

$[CS_2]$ at equilibrium was 0.32 M

6\.

R	$2SO_2(g)$ +	$O_2(g)$ ⇌	$2SO_3(g)$
I	0	0	x
C	+0.30 M	+0.15 M	−0.30 M
E	0.30 M	0.15 M	$x - 0.30M$

$$K_{eq} = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = 5.0$$

$$5.0 = \frac{(x-0.30)^2}{(0.30)^2(0.15)}$$

$$5.0 = \frac{(x-0.30)^2}{0.0135}$$

$$0.26.. = x - 0.30$$

$$x = 0.56\ M$$

$[SO_3]$ = 0.56 M

7. $K_{eq} = \frac{[Br]^2}{[Br_2]} = 1.04 \times 10^{-3}$

$$1.04 \times 10^{-3} = \frac{[Br]^2}{7.67 \times 10^{-3}}$$

$$[Br] = \sqrt{(1.04 \times 10^{-3})(7.67 \times 10^{-3})}$$

$$= 2.82 \times 10^{-3} M$$

$$[Br_2] = 0.245g\ Br_2 \cdot \frac{mol}{159.8g} \cdot \frac{1}{0.200L} = 7.67 \times 10^{-3} M$$

$$g\ Br_2 = \frac{2.82 \times 10^{-3} mol}{L} \cdot \frac{79.9g}{mol} \cdot 0.200L = 0.045g$$

0.045g Br present in vessel

8. $K_{eq} = [NH_3][H_2S] = 1.2 \times 10^{-4}$

$$[NH_3] = [H_2S] = \sqrt{1.2 \times 10^{-4}} = 0.011 M$$