From last time: (Exercise 16.5)

$$C_6H_{10}I_2 \rightleftharpoons C_6H_{10} + I_2$$

	$C_6H_{10}I_2$	C_6H_{10}	I_2
I	0.050 m	0	0
C	-0.035	+0.035	+0.035
Equil	0.015	0.035	0.035 m

$$K = \frac{[I_2][C_6H_{10}]}{[C_6H_{10}I_2]} = \frac{(0.035)(0.035)}{0.0015}$$

$$K = 0.082$$

Good first example Know K, find conc. at equilibrium

Other extreme : small values of K.

$N_2 + O_2 \rightleftharpoons 2NO$

$K = 1 \times 10^{-5}$ at 1500K

Initially, $[N_2] = 0.8$ m (air, under pressure, at high T) compression of ~ 4.5

$[O_2] = 0.2$ m what is [NO] at equilibrium?

	N_2	+ O_2	$\rightleftharpoons$ $2NO$
I	0.8	0.2	0
C	$-x$	$-x$	$+2x$
E	$0.8-x$	$0.2-x$	$2x$

$$K = \frac{[NO]^2}{[N_2][O_2]} = \frac{(2x)^2}{(0.8-x)(0.2-x)} = 1 \times 10^{-5}$$

K is small → look at expression →

this means that $(2x)^2$ is small

so x is small and

$0.8 - x \simeq 0.8$

$0.2 - x \simeq 0.2$ ... try it.

$$\frac{(2x)^2}{(0.8)(0.2)} = 10^{-5}$$

$4x^2 = 1.6 \times 10^{-6}$

$x^2 = 4 \times 10^{-7}$

$x = 6.3 \times 10^{-4}$, so $[NO] = 2x = 1.26 \times 10^{-3}$ M

Check answer! (in full expression)

$$\frac{[2(6.3 \times 10^{-4})]^2}{(0.8 - 6.3 \times 10^{-4})(0.2 - 6.3 \times 10^{-4})} = 1.0 \times 10^{-5} \checkmark$$

also, note that $0.2 - x$ really is very close to 0.2 (good approx.)

What to include and not include in K :

$$S_{(s)} + O_{2(g)} \rightleftharpoons SO_{2(g)}$$

→ don't include solid reactants or products!
(Conc = density (for a solid) → unchanged by rxn)

$$K = \frac{[SO_2]}{[O_2]}$$

→ in aqueous solution, don't include H_2O if it a reactant or product (as $[H_2O]$ doesn't ~~really~~ change much at all) → $[H_2O] \approx 55\,M$

$$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

$$K = \frac{[NH_4^+][OH^-]}{[NH_3]}$$

Math with equilibrium constants

① $2\,H_2(g) + O_2(g) \rightleftharpoons 2\,H_2O(g)$ $\quad K = K_1$

② $2\,H_2O_2(g) \rightleftharpoons 2\,H_2O(g) + O_2(g)$ $\quad K = K_2$

Want: to know K for

$H_2(g) + O_2(g) \rightleftharpoons H_2O_2(g)$

Write reverse of rxn ②:

③: $2\,H_2O(g) + O_2(g) \rightleftharpoons 2\,H_2O_2(g)$ $\quad K = \frac{1}{K_2}$

(reverse reaction, so $K \rightarrow 1/K$)

Add reaction ① and ③ to get

$2\,H_2(g) + 2\,O_2(g) \rightleftharpoons 2\,H_2O_2(g)$ $\quad K = K_1\left(\frac{1}{K_2}\right) = \frac{K_1}{K_2}$

(add reactions, so multiply K)

This is the correct reaction, but coefficients are not in lowest terms

$H_2(g) + O_2(g) \rightleftharpoons H_2O_2(g)$ $\quad K = \sqrt{\frac{K_1}{K_2}}$

divide coefficients by two → take square root of K

(ie, multiply coefficients by 1/2, so raise K to the 1/2 power).

→ gases: so far we've used K_p ← pressures.

~~$H_2(g) + I_2(g) \rightleftharpoons$~~

$$2\,NO_2(g) \rightleftharpoons N_2O_4(g)$$

$$K_p = \frac{P_{N_2O_4}}{(P_{NO_2})^2}$$

~~This is~~ ~~Ro~~

Use K_p for $\Delta G_{rxn} = -RT \ln K_p$

Could use concentrations for gases (as for solutions)

$$PV = nRT$$

$$\frac{n}{V} = \frac{P}{RT} \qquad \text{conc} \propto P$$

conc

$$\text{conc} = \frac{P}{RT} \qquad P = RT \cdot \text{conc.}$$

From above,

$$K_p = \frac{P_{N_2O_4}}{(P_{NO_2})^2} = \frac{[N_2O_4]\,RT}{[NO_2]^2\,(RT)^2} = \frac{[N_2O_4]}{[NO_2]^2}\,\frac{1}{RT}$$

$$= K_c\,\frac{1}{RT}$$

In general, $K_p = K_c\,(RT)^{\Delta n}$

where Δn = moles of gas products − moles of gas reactants

($\Delta n = 1 - 2 = -1$ here).

use R in ℓ atm/mol K, as P is in atm.

Note: text uses K for K_c, even for gases