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CHEM 101B Chapter ~~12~~ Equilibrium – PreEquilibrium and i.c.e. tables

e.g.1 At 700K, $K_c = 5.10$ for the following reaction:

$$K_c = \frac{[CO_2][H_2]}{[CO][H_2O]} = 5.10$$

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

A 1.000-liter flask is charged with 1.000 mole of each species. Calculate the equilibrium concentrations of all species.

$\longrightarrow$

i.c.e.

add

	$CO(g)$ +	$H_2O(g)$ $\rightleftharpoons$	$CO_2(g)$ +	$H_2(g)$
Initial	1.000	1.000	1.000	1.000
Change	$-x$	$-x$	$+x$	$+x$
Equilibrium	$1.000 - x$ $1.000 - .387$	$1.000 - x$	$1.000 + x$ $1.000 + .387$	$1.000 + x$
	$= 0.613M$	$0.613M$	$1.387M$	$1.387M$

$$Q = \frac{(1.000)(1.000)}{(1.000)(1.000)} = 1.000 < K$$

x = change (absolute)

$$\pm\sqrt{5.10} = \sqrt{\frac{(1.000+x)^2}{(1.000-x)^2}}$$

Check

$$K = \frac{(1.387)^2}{(.613)^2} = 5.12 \checkmark$$

$$2.26 = \frac{1.000 + x}{1.000 - x}$$

3SF

$$2.26 - 2.26x = 1 + 1x$$

$$-1 \quad +2.26x \qquad -1 \quad +2.26x$$

$$1.26 = 3.26x$$

$$x = \frac{1.26}{3.26} = 0.387$$

57. At 35°C, $K = 1.6 \times 10^{-5}$ for the reaction

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

$K = \frac{[NO]^2[Cl_2]}{[NOCl]^2}$

Calculate the concentrations of all species at equilibrium for each of the following original mixtures.

5% Rule: Test the assumption that the "change" is less than 5% of the original value:

$$\frac{x}{[orig\ conc]} < 0.05$$

1.0 mole of NOCl and 1.0 mole of NO in a 1.0-L flask

$2NOCl \rightleftharpoons 2NO + Cl_2$

	$NOCl$	NO	Cl_2
I.	1.0M	1.0M	0M
C.	$-2x$	$+2x$	$+x$
E.	$1.0-2x$	$1.0+2x$	x
	1.0M	1.0M	1.6×10^{-5}M

$Q = 0 \longrightarrow$

$2x << 1.0$

v. small

$$1.6 \times 10^{-5} = \frac{(1.0+\cancel{2x})\,x}{1.0-\cancel{2x}}$$

$$1.6 \times 10^{-5} = \frac{x}{1.0}$$

$$.000016 = x$$

$$\begin{array}{r} 1.0 \\ 0.000016 \\ \hline 1.000016 \\ 1.0 \end{array}$$

Check

$$K = \frac{1.6\times10^{-5}(1.0)^2}{1.0} = 1.6\times10^{-5}$$

Check

$$\frac{2(0.000016)}{1.0} < 0.05$$

59. At a particular temperature, $K = 2.0 \times 10^{-6}$ for the reaction

$$2CO_2(g) \rightleftharpoons 2CO(g) + O_2(g)$$

If 2.0 moles of CO_2 is initially placed into a 5.0-L vessel, calculate the equilibrium concentrations of all species.

$$K = \frac{[CO]^2[O_2]}{[CO_2]^2}$$

$$Q = \frac{(0)^2(0)}{(.40)^2} = 0$$

$\xrightarrow{\text{shift}}$

	$2CO_2 \rightleftharpoons$	$2CO\ +$	O_2
I.	.40	0	0
C.	$-2x$	$+2x$	$+x$
e.	$.40-2x$	$2x$	x

Assume $2x \ll .40$

$$2.0 \times 10^{-6} = \frac{(2x)^2(x)}{(.40-\cancel{2x})^2}$$

$$2.0 \times 10^{-6} = \frac{(4x^3)}{(.40)^2}$$

$$2.0 \times 10^{-6} = \frac{4x^3}{.16}$$

$$8.0 \times 10^{-8} = x^3$$

$$x = \sqrt[3]{8.0 \times 10^{-8}}$$

$$x = 0.0043$$

5% check

$$\frac{2(.0043)}{.40} < .05\ ?$$

$$= .02 < .05\ \checkmark$$

$[CO_2]_{eq} = .40 - .0043 \cdot 2 = 0.38\ M$

$[CO]_{eq} = 0.0043 \cdot 2 = 0.0086\ M$

$[O_2]_{eq} = .0043\ M$

61. At 25°C, $K_p = 2.9 \times 10^{-3}$ for the reaction

$$NH_4OCONH_2(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$$

solid

In an experiment carried out at 25°C, a certain amount of NH_4OCONH_2 is placed in an evacuated rigid container and allowed to come to equilibrium. Calculate the total pressure in the container at equilibrium.

$$K_p = P_{NH_3}^2 P_{CO_2}$$

Any species that is not in the equilibrium phase--usually solution or gas phase--is not part of equilibrium expression (i.e. exclude solids)

$$NH_4OCONH_2(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$$

I.	—	0	0
C.	—	$+2x$	$+x$
e.	—	$2x$	x

$$2.9 \times 10^{-3} = (2x)^2(x)$$

$$= 4x^3$$

$$7.25 \times 10^{-4} = x^3$$

$$x = \sqrt[3]{7.25 \times 10^{-4}}$$

$$= 0.0898$$

$$x = 0.090$$

$$P_{NH_3} = 2(.090)$$
$$= 0.18 \text{ atm}$$

$$P_{CO_2} = .090 \text{ atm}$$

$+$

$$P_{tot} = 0.27 \text{ atm}$$