AP CHEMISTRY

TOPIC 6: EQUILIBRIUM, PART E

Day 69:

- Solving Equilibrium Problems

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1. At 35 ^{0}C, K = 1.6 x 10 $^{-5}$ for the reaction

$$2\ NOCl_{(g)} \rightleftharpoons 2\ NO_{(g)} + Cl_{2\,(g)}$$

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

a) 2.0 mol pure NOCl in a 2.0 liter flask.

Answers:

	2 [NOCl]	$\rightleftharpoons$	2 [NO]	+	[Cl_2]
I	2.0 mol / 2.0 L		0		0
C	- 2x		+ 2x		+ x
E	1.0 - 2x		2x		x

$$K = 1.6\times10^{-5} = \frac{\left[\ NO\ \right]^2\left[\ Cl_2\ \right]}{\left[\ NOCl\ \right]^2} = \frac{(2x)^2\ (x)}{(1.0-2x)^2} = \frac{(2x)^2\ (x)}{(1.0)^2}$$

$$1.6\times10^{-5} = \frac{4x^3}{(\ 1.0\ )^2}, \quad \frac{1.6\times10^{-5}}{4} = \frac{4x^3}{4}$$

$$4.0\times10^{-6} = x^3 \ ; \ \sqrt[3]{\ 4.0\times10^{-6}} = \ x\ = 0.016$$

$$\left[\ NO\ \right] = 2x = (2)(0.016) = 0.032\ M\ ; \quad \left[\ Cl_2\ \right] = \ \text{x}\ = 0.016\ M\ ; \ \left[\ NOCl\ \right] \approx 1.0\ M$$

b) 1.0 mol NOCl and 1.0 mol NO in a 1.0 liter flask.

Answers:

	2 [NOCl]	⇌	2 [NO]	+	[Cl_2]
I	1.0 mol / 1.0 L		1.0 mol / 1.0 L		0
C	- 2*x*		+ 2*x*		+ *x*
E	1.0 - 2*x*		1.0 + 2*x*		*x*

$$K = 1.6\times10^{-5} = \frac{\left[\ NO\ \right]^2\left[\ Cl_2\ \right]}{\left[\ NOCl\ \right]^2} = \frac{(1.0\ +\ 2x)^2\ (x)}{(1.0\ -\ 2x)^2} = \frac{(1.0)^2\ (x)}{(1.0)^2}$$

$$x = 1.6 \text{ x } 10^{-5}$$

$$\left[\ NOCl\ \right] \approx \left[\ NO\ \right] \approx 1.0\ M\ ; \quad \left[\ Cl_2\ \right] = x = 1.6\times10^{-5}\ M$$

c) 2.0 mol NOCl and 1.0 mol Cl_2 in a 1.0 liter flask

Answers:

	2 [NOCl]	⇌	2 [NO]	+	[Cl_2]
I	2.0 mol / 1.0 L		0		1.0 mol / 1.0 L
C	- 2*x*		+ 2*x*		+ *x*
E	2.0 - 2*x*		2*x*		1.0 + *x*

$$K = 1.6\times10^{-5} = \frac{\left[\ NO\ \right]^2\left[\ Cl_2\ \right]}{\left[\ NOCl\ \right]^2} = \frac{(2x)^2\ (1.0+x)}{(2.0-2x)^2} = \frac{(2x)^2\ (1.0)}{(2.0)^2} = \frac{4x^2}{4.0}$$

$$1.6\times10^{-5} = \frac{4x^2}{4.0}\ ;\ 1.6\times10^{-5} = x^2$$

$$\sqrt{1.6\times10^{-5}} = x\ = 4.0\times10^{-3}$$

$$\left[\ NOCl\ \right] = 2.0\ M$$

$$\left[\ NO\ \right] = 2(4.0 \text{ x } 10^{-3}) = 8.0 \text{ x } 10^{-3}\ M$$

$$\left[\ Cl_2\ \right] = 1.0\ M$$

2. At a particular temperature, $K = 4.0 \times 10^{-7}$ for the reaction

$$N_2O_{4\,(g)} \rightleftharpoons 2\,NO_{2\,(g)}$$

In an experiment, 1.0 mol N_2O_4 is placed in a 10.0 liter vessel. Calculate the concentrations of N_2O_4 and NO_2 when this reaction reaches equilibrium.

Answers:

	[N_2O_4]	$\rightleftharpoons$	2 [NO_2]
I	1.0 mol / 10.0 L		0
C	- x		+ 2x
E	0.1 - x		2x

$$K = 4.0\times10^{-7} = \frac{\left[\ NO_2\ \right]^2}{\left[\ N_2O_4\ \right]} = \frac{(2x)^2}{(0.1-x)} = \frac{(2x)^2}{(0.1)} = \frac{4x^2}{0.1}$$

$$4.0\times10^{-7} = \frac{4x^2}{0.1}$$

$$4.0\times10^{-8} = 4x^2$$

$$1.0\times10^{-4} = x$$

$$\left[\ N_2O_4\ \right] \approx 0.1\ M\ ; \quad \left[\ NO_2\ \right] = 2x = 2\ (1.0 \times 10^{-4}) = 2.0 \times 10^{-4}$$

3. At a particular temperature, $K_p = 6.8 \times 10^{-9}$ for the reaction

$$COCl_{2\,(g)} \rightleftharpoons CO_{(g)} + Cl_{2\,(g)}$$

If pure $COCl_2$ at an initial concentration of 1.0 atm decomposes, calculate the equilibrium pressures of all species.

Answers:

	[$COCl_2$]	$\rightleftharpoons$	[CO]	+	[Cl_2]
I	1.0		0		0
C	- x		+ x		+ x
E	1.0 - x		x		x

$$6.8\times10^{-9} = \frac{\left(P_{CO}\right)\left(P_{Cl_2}\right)}{\left(P_{COCl_2}\right)} = \frac{x^2}{(1.0-x)} = \frac{x^2}{(1.0)}$$

$$\sqrt{6.8\times10^{-9}} = x = 8.2\times10^{-5}\,atm$$

$$P_{COCl_2} = 1.0 \text{ atm}, \quad P_{CO} = P_{Cl_2} = 8.2 \text{ x } 10^{-5} \text{ atm}$$

4. At 25 ^{0}C, K_p = 2.9 x 10 $^{-3}$ for the reaction

$$NH_4OCONH_{2\,(s)} \rightleftharpoons 2\,NH_{3\,(g)} + CO_{2\,(g)}$$

In an experiment carried out at 25 ^{0}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.

Answers:

	[NH_4OCONH_2]	$\rightleftharpoons$	2 [NH_3]	+	[CO_2]
I	-		0		0
C	-		+ 2x		+ x
E	-		2x		x

$$K_p = 2.9\times10^{-3} = \left(P_{NH_3}{}^2\right)\left(P_{CO_2}\right)$$

$$2.9\times10^{-3} = \left(\,2x\,\right)^2\left(\,x\,\right) = 4x^3$$

$$2.9\times10^{-3} = 4x^3$$

$$\frac{2.9\times10^{-3}}{4} = \frac{4x^3}{4} \quad ; \quad 7.25\times10^{-4} = x^3$$

$$\sqrt[3]{7.25\times10^{-4}} = x = 8.98\times10^{-2}$$

$$P_T = P_{NH_3} + P_{CO_2} = 2x + x$$

$$P_T = P_{NH_3} + P_{CO_2} = 2\left(8.98\times10^{-2}atm\right) + \left(8.98\times10^{-2}atm\right) = 0.27\ atm$$