# AP CHEMISTRY

## TOPIC 6: EQUILIBRIUM, PART E  EXAMPLES ( PART IV )  Day 69:

- A few example problems **NOT USING THE 5% RULE**

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1. At 223 $^0$C, $K = 4.10 \times 10^{-4}$ for the reaction

$$2\ NO_{(g)} \leftrightarrow N_{2\,(g)} + O_{2\,(g)}$$

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

a) 2.0 mol pure NO in a 4.0 liter flask.

***Answers: Not Using the 5% Rule…***

| | 2 [ NO ] | ↔ | [ $N_2$ ] | + | [ $O_2$ ] |
|---|---|---|---|---|---|
| I | 2.0 mol / 4.0 L | | 0 | | 0 |
| C | - 2$x$ | | + $x$ | | + $x$ |
| E | 0.5 - 2$x$ | | $x$ | | $x$ |

$$K = 4.10\times10^{-4} = \frac{\left[\ N_2\ \right]\left[\ O_2\ \right]}{\left[\ NO\ \right]^2} = \frac{(x)(x)}{(0.5-2x)^2} = \frac{(x)^2}{(0.5-2x)^2}$$

$$4.10\times10^{-4} = \frac{x^2}{(0.5\ -2x)^2}$$

$$4.10\times10^{-4} = \frac{x^2}{\left(4x^2\ -2x\ +\ 0.25\right)}$$

$$4.10\times10^{-4} = \frac{x^2}{\left(4x^2\ -2x\ +\ 0.25\right)}$$

$$\left(4.10\times10^{-4}\right)\left(4x^2\ -2x\ +\ 0.25\right) = x^2$$

$$0.00164x^2\ -\ 0.00082x\ +\ 0.0001025\ =\ x^2$$

$$0\ =\ 0.99836x^2\ +\ 0.00082x\ -\ 0.0001025$$

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

$$x = \frac{-0.00082\ \pm\sqrt{\ 0.00082^2 -\ 4(0.99836)(-0.0001025)}}{2(0.99836)} = +\ 0.0097302$$

**IGNORE** the negative value for an answer, we do not use negative concentrations…

***- OR -***

$$K = 4.10\times10^{-4} = \frac{\left[\ N_2\ \right]\left[\ O_2\ \right]}{\left[\ NO\ \right]^2} = \frac{(x)(x)}{(0.5-2x)^2}$$

$$\sqrt{\ 4.10\times10^{-4}} = \sqrt{\frac{(x)^2}{(0.5-2x)^2}}$$

$$0.020248 = \frac{x}{0.5-2x}$$

$$(0.020248)(0.5-2x) = x$$

$$0.010124\ -\ 0.0404969x\ =\ x$$

$$0.010124\ =\ 1.040496913x$$

$$\frac{0.010124}{1.040496913}\ =\ \frac{1.040496913x}{1.040496913}$$

$$0.00973\ =\ x$$

***Note***: Using the 5% rule gave us a value for x = 0.01012. Within our 5% error ☺

$$\left[\ NO\ \right] = 0.5-2x\ =\ 0.5-2(0.0097302)\ =\ 0.4805\ \ ;\ \ \left[\ N_2\ \right] = x = 0.0097302\ ;\ \left[\ O_2\ \right] = x = 0.0097302$$

$$K = \frac{\left[\ N_2\ \right]\left[\ O_2\ \right]}{\left[\ NO\ \right]^2} = \frac{(0.0097302)^2}{(0.4805396)^2} = 4.1\times10^{-4}$$

b) 2.0 mol pure NO, and 1.0 mol pure $N_2$ in a 4.0 liter flask.

***Answers:***

| | 2 [ NO ] | ↔ | [ $N_2$ ] | + | [ $O_2$ ] |
|---|---|---|---|---|---|
| I | 2.0 mol / 4.0 L | | 1.0 mol / 4.0 L | | 0 |
| C | - 2$x$ | | + $x$ | | + $x$ |
| E | 0.5 - 2$x$ | | 0.25 + $x$ | | $x$ |

$$K = 4.10\times10^{-4} = \frac{\left[\ N_2\ \right]\left[\ O_2\ \right]}{\left[\ NO\ \right]^2} = \frac{(0.25\ +\ x)(x)}{(0.5-2x)^2}$$

$$\frac{(0.25\ +\ x)(x)}{(0.5-2x)^2} = \frac{0.25x\ +\ x^2}{4x^2\ -\ 2x\ +\ 0.25} = 4.10\times10^{-4}$$

$$0.25x\ +\ x^2 = \left(4.10\times10^{-4}\right)\left(4x^2\ -\ 2x\ +\ 0.25\right)$$

$$0.25x\ +\ x^2 =\ 0.00164x^2\ -\ 0.00082x\ +\ 0.0001025$$

$$0.99836x^2\ +\ 0.25082x\ -\ 0.0001025\ =\ 0$$

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

$$x = \frac{-0.25082\ \pm\sqrt{\ 0.25082^2 -\ 4(0.99836)(-0.0001025)}}{2(0.99836)} = +\ 0.000407997$$

**IGNORE** the negative value for an answer, we do not use negative concentrations…

$$\left[\ NO\ \right] = 0.5-2x\ =\ 0.5-2(0.000408)\ =\ 0.4992\ \ ;\ \ \left[\ N_2\ \right]\ =\ 0.25-x\ =\ 0.25-0.000408\ =\ 0.24592\ ;$$

$$\left[\ O_2\ \right]\ = x = 0.000408$$

$$K = \frac{\left[\ N_2\ \right]\left[\ O_2\ \right]}{\left[\ NO\ \right]^2} = \frac{(0.24592)(0.000408)}{(0.4992)^2} = 4.1\times10^{-4}$$

***Note***: Using the 5% rule gave us a value for x = 0.000410.
Well within our 5% error ☺

Remember, you can ALWAYS use the "real algebra" to solve these problems if you are not comfortable using the 5% rule. In college, you will need to know how to use the quadratic equation to solve for "$x$". On the AP exam and on all the TESTS and QUIZZES, the 5% rule will apply. Remember this, it never hurts to know too much!