Solutions to:
Chemical Equlibrium Homework Problem Set

S.E. Van Bramer 1/9/96

1. Write an expression for each of the equilibria

(a) 3 O_2 (g) <-> 2 O_3 (g)

$$K_p = \frac{\left(P_{O3}\right)^2}{\left(P_{O2}\right)^3}$$

(b) H_2 (g) + I_2 (g) <-> 2 HI (g)

$$K_p = \frac{\left(P_{HI}\right)^2}{\left(P_{H2}\right)\cdot\left(P_{I2}\right)}$$

(c) 2 HI (g) <-> H_2 (g) + I_2 (g)

$$K_p = \frac{\left(P_{H2}\right)\cdot\left(P_{I2}\right)}{\left(P_{HI}\right)^2}$$

(d) 4 NH_3 (g) + 3 O_2 (g) <-> 6 H_2O (g) + 2 N_2 (g)

$$K_p = \frac{\left(P_{H2O}\right)^6\cdot\left(P_{N2}\right)^2}{\left(P_{NH3}\right)^4\cdot\left(P_{O2}\right)^3}$$

(e) 2 H_2S (g) + 3 O_2 (g) <-> 2 H_2O (g) + 2 SO_2 (g)

$$K_p = \frac{\left(P_{H2O}\right)^2\cdot\left(P_{SO2}\right)^2}{\left(P_{H2S}\right)^2\cdot\left(P_{O2}\right)^3}$$

(f) $CaCO_3$ (s) + CO_2 (g) + H_2O (l) <-> Ca^{2+} (aq) + 2 HCO_3^{1-} (aq)

$$K = \frac{\left(C_{CaII}\right)\cdot\left(C_{HCO3}\right)^2}{C_{CO2}}$$

2. A 10 g sample of gaseous PCl_5 is introduced into a 3.0 L flask at 250 C. After the system comes to equlibrium the pressure in the flask is 1.136 x 10 ^{5} Pa.

The reaction is: PCl_5 (g) <-> PCl_3 (g) + Cl_2 (g)

The initial amount of PCl_5 is:

$$Initial\_mass_{PCl5} := 10 \cdot gm$$

Convert this to moles:

$$MW_{PCl5} := ((30.974) + (5) \cdot (35.453)) \cdot \frac{gm}{mole}$$

$$Initial\_mole_{PCl5} := \frac{Initial\_mass_{PCl5}}{MW_{PCl5}}$$

$$Initial\_mole_{PCl5} = 0.04802 \cdot mole$$

From the equlibrium pressure and the ideal gas law determine the moles of gas at equlibrium.

$$P_{total} := 1.136 \cdot 10^5 \cdot Pa$$

$$V := 3 \cdot liter$$

$$T := (273.15 + 250) \cdot K$$

$$R := 8.314 \cdot joule \cdot K^{-1} \cdot mole^{-1}$$

$$n_{total} := \frac{P_{total} \cdot V}{R \cdot T}$$

$$n_{total} = 0.0784 \cdot mole$$

From the balanced equation the amount of each species at equlibrium is expressed as:

$$n_{PCl5} = Initial\_mole_{PCl5} - X$$

$$n_{PCl3} = X$$

$$n_{Cl2} = X$$

So at equlibrium the total number of moles is:

$$n_{total} = Initial\_mole_{PCl5} - X + X + X$$

$$X := n_{total} - Initial\_mole_{PCl5}$$

$X = 0.0303 \cdot mole$

And the amout of each species is:

$n_{PCl5} := Initial\_mole_{PCl5} - X$ $\quad n_{PCl5} = 0.0177 \cdot mole$

$n_{PCl3} := X$ $\quad n_{PCl3} = 0.0303 \cdot mole$

$n_{Cl2} := X$ $\quad n_{Cl2} = 0.0303 \cdot mole$

The concentration of each species is:

$C_{PCl5} := \frac{n_{PCl5}}{V}$ $\quad C_{PCl5} = 0.0059 \cdot mole \cdot liter^{-1}$

$C_{PCl3} := \frac{n_{PCl3}}{V}$ $\quad C_{PCl3} = 0.0101 \cdot mole \cdot liter^{-1}$

$C_{Cl2} := \frac{n_{Cl2}}{V}$ $\quad C_{Cl2} = 0.0101 \cdot mole \cdot liter^{-1}$

The partial pressure of each species is:

$P_{PCl5} := \frac{n_{PCl5} \cdot R \cdot T}{V}$ $\quad P_{PCl5} = 2.5646 \cdot 10^{4} \cdot Pa$

$P_{PCl3} := \frac{n_{PCl3} \cdot R \cdot T}{V}$ $\quad P_{PCl3} = 4.3977 \cdot 10^{4} \cdot Pa$

$P_{Cl2} := \frac{n_{Cl2} \cdot R \cdot T}{V}$ $\quad P_{Cl2} = 4.3977 \cdot 10^{4} \cdot Pa$

What is K_c for this system?

$K_c := \frac{C_{PCl3} \cdot C_{Cl2}}{C_{PCl5}}$ $\quad K_c = 0.0173 \cdot mole \cdot liter^{-1}$

What is K_p for this system?

$K_p := \frac{P_{PCl3} \cdot P_{Cl2}}{P_{PCl5}}$ $\quad K_p = 7.541 \cdot 10^{4} \cdot Pa$

3. Using the equlibrium constant for PCl_5 from the previous problem, calculate the equlibrium pressure of each species under the following conditions:

a. 5 grams of PCl_5 is added to a 3.0 liter flask at 250 °C.

$$V := 3.00 \cdot \text{liter}$$

$$T = 523.15 \cdot K$$

$$Mass_{PCl5} := 5 \cdot gm$$

$$MW_{PCl5} = 208.239 \cdot gm \cdot mole^{-1}$$

$$n_{initial} := \frac{Mass_{PCl5}}{MW_{PCl5}} \qquad n_{initial} = 0.024 \cdot mole$$

$$P_{initial} := \frac{n_{initial} \cdot R \cdot T}{V} \qquad P_{initial} = 3.4812 \cdot 10^{4} \cdot Pa$$

From the equlibrium expression with final pressures of:

$$P_{PCl5} = P_{initial} - X$$

$$P_{PCl3} = X$$

$$P_{Cl2} = X$$

$$K_p = \frac{X \cdot X}{P_{initial} - X}$$

Rearange to solve using the quadratic equation:

$$X^2 + K_p \cdot X - K_p \cdot P_{initial} = 0$$

Include values

$$X^2 + \left(7.541 \cdot 10^4 \cdot X\right) - \left(7.541 \cdot 10^4 \cdot 3.4812 \cdot 10^4\right) = 0$$

$$X^2 + \left(7.541 \cdot 10^4 \cdot X\right) - (2625172920.) = 0$$

$$X = \begin{pmatrix} 25909.77772499091268 \\ -101319.77772499091268 \end{pmatrix}$$

Two roots from solving the quadratic equation, only the first is "real"

$$X := 25909.8 \cdot Pa$$

Gives equlibrium pressures of:

$$P_{PCl5} := P_{initial} - X \qquad P_{PCl5} = 8.9017 \cdot 10^{3} \cdot Pa$$

$$P_{PCl3} := X \qquad P_{PCl3} = 2.591 \cdot 10^{4} \cdot Pa$$

$$P_{Cl2} := X \qquad P_{Cl2} = 2.591 \cdot 10^{4} \cdot Pa$$

b. 25 grams of PCl_5 is added to a 6.0 liter flask at 250 ^oC.

$$V := 6.00 \cdot liter$$

$$Mass_{PCl5} := 25 \cdot gm$$

$$n_{initial} := \frac{Mass_{PCl5}}{MW_{PCl5}} \qquad n_{initial} = 0.1201 \cdot mole$$

$$P_{initial} := \frac{n_{initial} \cdot R \cdot T}{V} \qquad P_{initial} = 8.7029 \cdot 10^4 \cdot Pa$$

From the equlibrium expression with final pressures of:

$$P_{PCl5} = P_{initial} - X$$

$$P_{PCl3} = X$$

$$P_{Cl2} = X$$

$$K_p = \frac{X \cdot X}{P_{initial} - X}$$

Rearange to solve using the quadratic equation:

$$X^2 + K_p \cdot X - K_p \cdot P_{initial} = 0$$

Include values

$$X^2 + \left(7.541 \cdot 10^4 \cdot X\right) - \left(7.541 \cdot 10^4 \cdot 8.7029 \cdot 10^4\right) = 0$$

$$X^2 + \left(7.541 \cdot 10^4 \cdot X\right) - (6562856890.) = 0$$

$$X = \begin{pmatrix} 51651.163273721639799 \\ -127061.1632737216398 \end{pmatrix}$$

Two roots from solving the quadratic equation, only the first is "real"

$$X := 51651 \cdot Pa$$

Gives equlibrium pressures of:

$$P_{PCl5} := P_{initial} - X \qquad P_{PCl5} = 3.5378 \cdot 10^4 \cdot Pa$$

$$P_{PCl3} := X \qquad P_{PCl3} = 5.1651 \cdot 10^4 \cdot Pa$$

$$P_{Cl2} := X \qquad P_{Cl2} = 5.1651 \cdot 10^4 \cdot Pa$$

c. 5 grams of PCl_3 and 5 grams of Cl_2 is added to a 3.0 liter flask at 250 ^oC.

$$V := 3.0 \cdot liter$$

Initial PCl3:

$$Mass_{PCl3} := 5 \cdot gm$$

$$MW_{PCl3} := (30.9738 + 3 \cdot 35.4527) \cdot gm \cdot mole^{-1}$$

$$n_{PCl3} := \frac{Mass_{PCl3}}{MW_{PCl3}} \qquad n_{PCl3} = 0.0364 \cdot mole$$

$$P_{PCl3\_initial} := \frac{n_{PCl3} \cdot R \cdot T}{V} \qquad P_{PCl3\_initial} = 5.2785 \cdot 10^4 \cdot Pa$$

Initial Cl2:

$$Mass_{Cl2} := 5 \cdot gm$$

$$MW_{Cl2} := (2 \cdot 35.4527) \cdot gm \cdot mole^{-1}$$

$$n_{Cl2} := \frac{Mass_{Cl2}}{MW_{Cl2}} \qquad n_{Cl2} = 0.0705 \cdot mole$$

$$P_{Cl2\_initial} := \frac{n_{Cl2} \cdot R \cdot T}{V} \qquad P_{Cl2\_initial} = 1.0224 \cdot 10^5 \cdot Pa$$

The Equlibrium Pressure of each species is:

$$P_{PCl5} = X$$

$$P_{PCl3} = P_{PCl3\_initial} - X$$

$$P_{Cl2} = P_{Cl2\_initial} - X$$

So the equlibrium expression is:

$$K_p = \frac{(P_{PCl3\_initial} - X) \cdot (P_{Cl2\_initial} - X)}{X}$$

Substitute known values:

$$7.541 \cdot 10^4 = \frac{(5.2785 \cdot 10^4 - X) \cdot (1.0224 \cdot 10^5 - X)}{X}$$

Expand the expression:

$$7.541 \cdot 10^4 = \frac{\left(5396738400.0 - 155025.0 \cdot X + X^2\right)}{X}$$

Rearange and set equal to zero:

$$7.541 \cdot 10^4 \cdot X = \left(5396738400.0 - 155025.0 \cdot X + X^2\right)$$

$$5396738400.0 - 155025.0 \cdot X + X^2 - 7.541 \cdot 10^4 \cdot X = 0$$

$$5396738400. - 230435. \cdot X + X^2 = 0$$

$$X = \begin{pmatrix} 203977.47919248291487 \\ 26457.520807517085132 \end{pmatrix}$$

Solve using the quadratic equation, only the second root is meaningful. The first root is too large and would result in a negative pressure of the products.

$$X := 26457 \cdot Pa$$

This gives equlibrium pressures of:

$$P_{PCl5} := X \qquad P_{PCl5} = 2.6457 \cdot 10^4 \cdot Pa$$

$$P_{PCl3} := P_{PCl3\_initial} - X \qquad P_{PCl3} = 2.6328 \cdot 10^4 \cdot Pa$$

$$P_{Cl2} := P_{Cl2\_initial} - X \qquad P_{Cl2} = 7.5779 \cdot 10^4 \cdot Pa$$

Check the solution:

$$\frac{P_{PCl3} \cdot P_{Cl2}}{P_{PCl5}} = 7.5411 \cdot 10^4 \cdot Pa \qquad K_p = 7.541 \cdot 10^4 \cdot Pa$$

4. For the reaction SO_2 (g) + NO_2 (g) <-> SO_3 (g) + NO (g) at 973 K the equilibrium constant, K_c, is 9.00. Calculate the equlibrium concentrations of all the species present when:

(a). 1.00 mol of SO_2 and 1.00 mol of NO_2 are injected into a 1.00 L container at 973 K:

The container volume is:

$$volume := 1.00 \cdot liter$$

The initial concentration (I_M) for each species is:

$$I\_M_{SO2} := \frac{1.00 \cdot mole}{volume} \qquad I\_M_{SO2} = 1 \cdot \frac{mole}{liter}$$

$$I\_M_{NO2} := \frac{1.00 \cdot mole}{volume} \qquad I\_M_{NO2} = 1 \cdot \frac{mole}{liter}$$

$$I\_M_{SO3} := \frac{0.00 \cdot mole}{volume} \qquad I\_M_{SO3} = 0 \cdot \frac{mole}{liter}$$

$$I\_M_{NO} := \frac{0.00 \cdot mole}{volume} \qquad I\_M_{NO} = 0 \cdot \frac{mole}{liter}$$

The Equlibrium concentration (E_M) for each species, where X is the moles that react:

$$E\_M_{SO2} = I\_M_{SO2} - X \qquad E\_M_{SO3} = I\_M_{SO3} + X$$

$$E\_M_{NO2} = I\_M_{NO2} - X \qquad E\_M_{NO} = I\_M_{NO} + X$$

The expression for K_c is:

$$K_C = \frac{(E\_M_{SO3}) \cdot (E\_M_{NO})}{(E\_M_{SO2}) \cdot (E\_M_{NO2})}$$

Then substitute the expressions for the initial concentrations into the expression to yield:

$$K_C = \frac{(I\_M_{SO3} + X) \cdot (I\_M_{NO} + X)}{(I\_M_{SO2} - X) \cdot (I\_M_{NO2} - X)}$$

Now let's put in the numbers from above (ignoring units):

$$9.00 = \frac{(0.0 + X)\cdot(0.0 + X)}{(1.0 - X)\cdot(1.0 - X)}$$

Then expand and rearrange the equations:

$$9.00 = \frac{X^2}{\left(1.0 - 2.0\cdot X + X^2\right)}$$

And set equal to zero:

$$9.00\cdot\left(1.0 - 2.0\cdot X + X^2\right) - X^2 = 0$$

Multiply out to form for using the quadratic equation:

$$9. - 18.\cdot X + 8.\cdot X^2 = 0$$

Solves for two possible values of X: $\begin{pmatrix} 1.5 \\ .75 \end{pmatrix}$

These solutions for X may be found using the quadratic equation where:

For the equation $9. - 18.\cdot X + 8.\cdot X^2 = 0$

$$X = \frac{-b + \sqrt{b^2 - 4\cdot a\cdot c}}{2\cdot a} \qquad \text{And} \qquad X = \frac{-b - \sqrt{b^2 - 4\cdot a\cdot c}}{2\cdot a}$$

Where

$a := 8$ $\qquad b := -18$ $\qquad c := 9$

This gives two possible values for X from the above equations.

First

$$X := \frac{-b + \sqrt{b^2 - 4\cdot a\cdot c}}{2\cdot a}$$

$X = 1.5$

Second

$$X := \frac{-b - \sqrt{b^2 - 4\cdot a\cdot c}}{2\cdot a}$$

$X = 0.75$

Finally, Recall the initial conditions:

$I\_M_{SO2} = 1 \cdot \frac{mole}{liter}$ $\qquad I\_M_{NO} = 0 \cdot \frac{mole}{liter}$

$I\_M_{NO2} = 1 \cdot \frac{mole}{liter}$ $\qquad I\_M_{SO3} = 0 \cdot \frac{mole}{liter}$

From the initial conditions, one solution for X is not Physically reasonable and we pick:

$$X := 0.75 \cdot \frac{mole}{liter}$$

The expressions for the equlibrium concentrations is:

$$E\_M_{SO2} := I\_M_{SO2} - X \qquad E\_M_{SO3} := I\_M_{SO3} + X$$

$$E\_M_{NO2} := I\_M_{NO2} - X \qquad E\_M_{NO} := I\_M_{NO} + X$$

And this gives equlibrium concentrations of:

$$E\_M_{SO2} = 0.25 \cdot \frac{mole}{liter} \qquad E\_M_{SO3} = 0.75 \cdot \frac{mole}{liter}$$

$$E\_M_{NO2} = 0.25 \cdot \frac{mole}{liter} \qquad E\_M_{NO} = 0.75 \cdot \frac{mole}{liter}$$

(b). 1.00 mol of SO_2 and 1.00 mol of NO_2 are injected into a 2.00 L container at 973 K (some steps will be skipped here, but solve the same as a:

The container volume is:

$$volume := 2.00 \cdot liter$$

The initial concentration (I_M) for each species is:

$$I\_M_{SO2} := \frac{1.00 \cdot mole}{volume} \qquad I\_M_{SO2} = 0.5 \cdot \frac{mole}{liter}$$

$$I\_M_{NO2} := \frac{1.00 \cdot mole}{volume} \qquad I\_M_{NO2} = 0.5 \cdot \frac{mole}{liter}$$

$$I\_M_{SO3} := \frac{0.00 \cdot mole}{volume} \qquad I\_M_{SO3} = 0 \cdot \frac{mole}{liter}$$

$$I\_M_{NO} := \frac{0.00 \cdot mole}{volume} \qquad I\_M_{NO} = 0 \cdot \frac{mole}{liter}$$

The expression for K_c is:

$$K_C = \frac{\left(I\_M_{SO3} + X\right) \cdot \left(I\_M_{NO} + X\right)}{\left(I\_M_{SO2} - X\right) \cdot \left(I\_M_{NO2} - X\right)}$$

Now let's put in the numbers from above (ignoring units):

$$9.00 = \frac{(0.0 + X) \cdot (0.0 + X)}{(0.5 - X) \cdot (0.5 - X)}$$

Then expand, rearrange, and set equal to zero:

$$2.25 - 9. \cdot X + 8. \cdot X^2 = 0$$

Solves for two possible values of X: $\begin{pmatrix} .75 \\ .375 \end{pmatrix}$

These solutions for X may be found using the quadratic equation where:

Where $a := 8$ $b := -9$ $c := 2.25$

This gives two possible values for X from the above equations.

First

$$X := \frac{-b + \sqrt{b^2 - 4 \cdot a \cdot c}}{2 \cdot a} \qquad X = 0.75$$

Second

$$X := \frac{-b - \sqrt{b^2 - 4 \cdot a \cdot c}}{2 \cdot a} \qquad X = 0.375$$

Finally, Recall the initial conditions:

$$I\_M_{SO2} = 0.5 \cdot \frac{mole}{liter} \qquad I\_M_{NO} = 0 \cdot \frac{mole}{liter}$$

$$I\_M_{NO2} = 0.5 \cdot \frac{mole}{liter} \qquad I\_M_{SO3} = 0 \cdot \frac{mole}{liter}$$

From the initial conditions, one solution for X is not Physically reasonable and we pick:

$$X := 0.375 \cdot \frac{mole}{liter}$$

The expressions for the equlibrium concentrations is:

$$E\_M_{SO2} := I\_M_{SO2} - X \qquad E\_M_{SO3} := I\_M_{SO3} + X$$

$$E\_M_{NO2} := I\_M_{NO2} - X \qquad E\_M_{NO} := I\_M_{NO} + X$$

And this gives equlibrium concentrations of:

$$E\_M_{SO2} = 0.125 \cdot \frac{mole}{liter} \qquad E\_M_{SO3} = 0.375 \cdot \frac{mole}{liter}$$

$$E\_M_{NO2} = 0.125 \cdot \frac{mole}{liter} \qquad E\_M_{NO} = 0.375 \cdot \frac{mole}{liter}$$

(c). 1.00 mol of SO_3 and 1.00 mol of NO are injected into a 1.00 L container at 973 K. (Notice in this example the products are given for the initial conditions. (some steps will be skipped here, but solve the same as a:

The container volume is:

$$volume := 1.00 \cdot liter$$

The initial concentration (I_M) for each species is:

$$I\_M_{SO2} := \frac{0.0 \cdot mole}{volume} \qquad I\_M_{SO2} = 0 \cdot \frac{mole}{liter}$$

$$I\_M_{NO2} := \frac{0.0 \cdot mole}{volume} \qquad I\_M_{NO2} = 0 \cdot \frac{mole}{liter}$$

$$I\_M_{SO3} := \frac{1.0 \cdot mole}{volume} \qquad I\_M_{SO3} = 1 \cdot \frac{mole}{liter}$$

$$I\_M_{NO} := \frac{1.0 \cdot mole}{volume} \qquad I\_M_{NO} = 1 \cdot \frac{mole}{liter}$$

The expression for K_c is:

$$K_C = \frac{(I\_M_{SO3} + X) \cdot (I\_M_{NO} + X)}{(I\_M_{SO2} - X) \cdot (I\_M_{NO2} - X)}$$

Now let's put in the numbers from above (ignoring units):

$$9.00 = \frac{(1.0 + X) \cdot (1.0 + X)}{(0.0 - X) \cdot (0.0 - X)}$$

Then expand and rearrange:

$$9.00 = \frac{(1.0 + 2.0 \cdot X + X^2)}{X^2}$$

Set this expression equal to zero for the quadratic:

$$8. \cdot X^2 - 1. - 2. \cdot X = 0$$

Solves for two possible values of X: $\begin{pmatrix} .5 \\ -.25 \end{pmatrix}$

These solutions for X may be found using the quadratic equation where:

Where $a := 8$ $b := -2$ $c := -1$

This gives two possible values for X from the above equations.

First $X := \frac{-b + \sqrt{b^2 - 4 \cdot a \cdot c}}{2 \cdot a}$ $X = 0.5$

Second $X := \frac{-b - \sqrt{b^2 - 4 \cdot a \cdot c}}{2 \cdot a}$ $X = -0.25$

Finally, Recall the initial conditions:

$I\_M_{SO2} = 0 \cdot \frac{mole}{liter}$ $I\_M_{NO} = 1 \cdot \frac{mole}{liter}$

$I\_M_{NO2} = 0 \cdot \frac{mole}{liter}$ $I\_M_{SO3} = 1 \cdot \frac{mole}{liter}$

From the initial conditions, one solution for X is not Physically reasonable and we pick:

$X := -0.25 \cdot \frac{mole}{liter}$

The expressions for the equlibrium concentrations is:

$E\_M_{SO2} := I\_M_{SO2} - X$ $E\_M_{SO3} := I\_M_{SO3} + X$

$E\_M_{NO2} := I\_M_{NO2} - X$ $E\_M_{NO} := I\_M_{NO} + X$

And this gives equlibrium concentrations of:

$E\_M_{SO2} = 0.25 \cdot \frac{mole}{liter}$ $E\_M_{SO3} = 0.75 \cdot \frac{mole}{liter}$

$E\_M_{NO2} = 0.25 \cdot \frac{mole}{liter}$ $E\_M_{NO} = 0.75 \cdot \frac{mole}{liter}$

Notice: these are the same equlibrium values as for part a. Does this make sense?

Solution to Chapter 16, question 73 from: Kotz & Treichel, *Chemistry & Chemical Reactivity*, 3rd ed. 1996, Saunders, page 793.

Nitrosyl bromide, NOBr, is prepared by the direct reaction of NO and BR2.

2 NO (g) + Br2 (g) --> 2 NOBr (g)

But the compound dissociates readily at room temperature.

NOBr (g) <--> NO(g) + 1/2 Br2 (g)

(a) If you mix 3.50 g of NO and 9.67 g of Br2, how many grams of NOBr can be prepared?

Amounts given (initial)

$$Mass_{NO} := 3.50 \cdot gm$$

$$Mass_{Br2} := 9.67 \cdot gm$$

$$MW_{NO} := (14.00674 + 15.9994) \cdot gm \cdot mole^{-1}$$

$$MW_{Br2} := (2 \cdot 79.904) \cdot gm \cdot mole^{-1}$$

$$n_{NO} := \frac{Mass_{NO}}{MW_{NO}} \qquad n_{NO} = 0.1166 \cdot mole$$

$$n_{Br2} := \frac{Mass_{Br2}}{MW_{Br2}} \qquad n_{Br2} = 0.0605 \cdot mole$$

Determine the limiting reagent

If all NO reacts

$$n_{Br2\_required} := \frac{1}{2} \cdot n_{NO}$$

$$n_{Br2\_required} = 0.0583 \cdot mole$$

Since sufficient Br2 is available for all the NO to react, NO is the limiting reagent.

Amount of NOBr prepared

$$n_{NOBr} := n_{NO}$$

$$MW_{NOBr} := (14.00674 + 15.9994 + 79.904) \cdot gm \cdot mole^{-1}$$

$$Mass_{NOBr} := n_{NOBr} \cdot MW_{NOBr}$$

$$Mass_{NOBr} = 12.8202 \cdot gm$$

(b) If N is the central atom of nitrosyl bromide, draw the electron dot structure for the molecule.

O=N-Br

You have to add non-bonding electrons to fill the valence for each atom.

(c) What is the electron pair geometry of NOBr?

O - trigonal planar
N - trigonal planar
Br - tetrahedral

What is the molecular geometry?

N - bent

Is the molecule polar?

Yes, look at the geometry and the electronegativities.

(d) Some NOBr is placed in a flask at 25 C and allowed to dissociated. The total pressure at equilibrium is 190 mm Hg, and the compound is found to be 34% dissocated. What is the value of Kp?

Start by setting up an equlibrium table. There are lots of blanks, but it will help you see where to start. The question states that "some" NOBr is placed in a flask. You do not know what the initial amount is or the size of the flask, so use "X" for the initial pressure of NOBr in the flask. The other piece of information that is relevant at this point is that 34% of the NOBr dissociates. This gives us an expression for the amount of change (34% of X).

	NOBr (g)	<-->	NO(g)	+	1/2 Br2 (g)
Initial	X		0		0
Change	$-34\%\cdot X$		$+34\%\cdot X$		$+\frac{1}{2}\cdot(34\%\cdot X)$
Final	$X-0.34\cdot X$		$0.34\cdot X$		$0.17\cdot X$

Now, from the relationships that are found in the equlibrium table we can write an equlibrium expression.

$$K_p = \frac{P_{NO}\cdot P_{Br2}^{\frac{1}{2}}}{P_{NOBr}}$$

Substitute in the appropriate equations from the equlibrium table to get:

$$K_p = \frac{(0.34\cdot X)\cdot(0.17\cdot X)^{\frac{1}{2}}}{(X-0.34\cdot X)}$$

Notice how many variables there are in this expression.

Now we have a single equation, but it contains two variables. So there is no "solution" to this equation. To solve for two variables (Kp and X), we need two equations. So look back at the original problem to see what other information is provided.

The question states that the "total pressure at equlibrium is 190 mmHg". Is there any way to relate that to what is happening and the variables that we are using?

Recall that we have expressions for the equlibrium pressure of each species. Based upon the concept of "partial pressure", the total pressure is the sum of the pressure for each species present. So that:

$$P_{total} = P_{NOBr} + P_{NO} + P_{Br}$$

Now substitute in the above expressions:

$$P_{total} = (X - 0.34 \cdot X) + (0.34 \cdot X) + (0.17 \cdot X)$$

This is another equation with two variables, but we know what P_{total} is at equlibrium. So we can write:

$$190 \cdot torr = (X - 0.34 \cdot X) + (0.34 \cdot X) + (0.17 \cdot X)$$

Since torr=mmHg, and Mathcad uses torr for pressure units.

Which solves as:

$$190 \cdot torr = (.66 \cdot X) + (0.34 \cdot X) + (0.17 \cdot X)$$

$$190 \cdot torr = 1.17 \cdot X$$

$$X := \frac{190 \cdot torr}{1.17}$$

$$X = 162.3932 \cdot torr$$

Now we have a value for X, so it is possible to solve for Kp:

$$K_p := \frac{(0.34 \cdot X) \cdot (0.17 \cdot X)^{\frac{1}{2}}}{(X - 0.34 \cdot X)}$$

$$K_p = 2.7067 \cdot torr^{\frac{1}{2}}$$

$$K_p = 0.0982 \cdot atm^{\frac{1}{2}}$$

Normally 1 atmosphere is used as the "standard state", so Kp is given with all pressures in atmospheres. Just be certain that you indicated the units YOU use to solve the problem.

Take a careful look at the problem solving techniques used to answer this question. It is a great example.