## Outline

- Equilibrium Condition
- Equilibrium Constant
- Reaction Quotient
- Equilibrium Problems
- Le Chatelier's Principle


## Equilibrium Condition

All reactions proceed in both directions...

$$
\mathrm{H}_{2}+\mathrm{Cl}_{2} \rightleftarrows 2 \mathrm{HCl}
$$

The rate of the forward and reverse rxns depend on temperature and the concentrations

$$
\begin{aligned}
& \mathrm{R}_{\mathrm{f}}=\mathrm{k}_{\mathrm{f}}\left[\mathrm{H}_{2}\right]\left[\mathrm{Cl}_{2}\right] \\
& \mathrm{R}_{\mathrm{r}}=\mathrm{k}_{\mathrm{r}}[\mathrm{HCl}]^{2}
\end{aligned}
$$

The net direction of the reaction is determined by the rates of the reactions, relative to one another

In a container with $\mathrm{H}_{2}, \mathrm{Cl}_{2}$ and $\mathrm{HCl} .$.

1. If $R_{f}>R_{r}$, then forward spontaneous: $H_{2}+\mathrm{Cl}_{2} \rightarrow 2 \mathrm{HCl}$
2. If $\mathrm{R}_{\mathrm{f}}<\mathrm{R}_{\mathrm{r}}$, then reverse spontaneous: $\quad \mathrm{H}_{2}+\mathrm{Cl}_{2} \leftarrow 2 \mathrm{HCl}$
3. If $R_{f}=R_{r}$, then equilibrium: $\mathrm{H}_{2}+\mathrm{Cl}_{2} \rightleftarrows 2 \mathrm{HCl}$

Chemical equilibrium is the condition when the forward and reverse rates of reaction are equal

Reactions proceed until chemical equilibrium is established!

For a certain temperature,

$$
k_{f}=1.00 \mathrm{sec}^{-1} \mathrm{M}^{-1} \quad \text { and } \quad k_{r}=1.36 \mathrm{sec}^{-1} \mathrm{M}^{-1}
$$

where $\mathrm{R}_{\mathrm{f}}=\mathrm{k}_{\mathrm{f}}\left[\mathrm{H}_{2}\right]\left[\mathrm{Cl}_{2}\right]$ and $\mathrm{R}_{\mathrm{r}}=\mathrm{k}_{\mathrm{r}}[\mathrm{HCl}]^{2}$
In which direction is the rxn spontaneous?

| $\left[\mathrm{H}_{2}\right], \mathrm{M}$ | $\left[\mathrm{Cl}_{2}\right], \mathrm{M}$ | $[\mathrm{HCl}], \mathrm{M}$ | $\mathrm{R}_{\mathrm{f}}, \mathrm{M} / \mathrm{s}$ | $\mathrm{R}_{\mathrm{r}}, \mathrm{M} / \mathrm{s}$ | Direction |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 10 | 10 | 0 | 100 | 0 | forward |
| 9 | 9 | 2 | 81 | 5.4 | forward |
| 8 | 8 | 4 | 64 | 22 | forward |
| 7 | 7 | 6 | 49 | 49 | equilibrium |

## Equilibrium Constant

At equilibrium...

$$
\begin{gathered}
\mathrm{R}_{\mathrm{f}}=\mathrm{R}_{\mathrm{r}} \\
\mathrm{k}_{\mathrm{f}}\left[\mathrm{H}_{2}\right]\left[\mathrm{Cl}_{2}\right]=\mathrm{k}_{\mathrm{r}}[\mathrm{HCl}]^{2} \\
\frac{\mathrm{k}_{\mathrm{f}}}{\mathrm{k}_{\mathrm{r}}}=\frac{[\mathrm{HCl}]^{2}}{\left[\mathrm{H}_{2}\right]\left[\mathrm{Cl}_{2}\right]} \quad \begin{array}{c}
\text { equilibrium constant } \\
\text { expression }
\end{array}
\end{gathered}
$$

$\mathrm{k}_{\mathrm{f}} / \mathrm{k}_{\mathrm{r}}=\mathrm{K}_{\text {eq }}$, the equilibrium constant

Equilibrium constants (K) are...
written without units!
constant only for constant temperature!

Equilibrium constants (K) give measure of how far a reaction goes...

For...

$$
\mathrm{aA}+\mathrm{bB} \rightleftarrows \mathrm{cC}+\mathrm{dD}
$$

We write... $K=\frac{[C]^{c}[D]^{d}}{[A]^{a}[B]^{b}} \quad$ (equilibrium constant expression)

K expression contains substances whose concentrations can change
gases ( g ) and dissolved substances (aq) are included solids (s) and liquids (I) are not included

Find $\mathrm{K}_{\text {eq }}$ for

$$
\mathrm{CO}_{2}(\mathrm{~g})+\mathrm{C}(\mathrm{~s}) \rightleftarrows 2 \mathrm{CO}(\mathrm{~g})
$$

in a $2.0-\mathrm{L}$ flask that contains 6.0 mol of $\mathrm{CO}_{2}$ and 8.0 mol CO at equilibrium

$$
\mathrm{K}_{\mathrm{eq}}=\frac{[\mathrm{CO}]^{2}}{\left[\mathrm{CO}_{2}\right]}=\frac{[4.0 \mathrm{M}]^{2}}{[3.0 \mathrm{M}]}=5.33 \mathrm{M}=5.3
$$

What's [CO] if $\left[\mathrm{CO}_{2}\right]=2.0 \mathrm{M}$

$$
\mathrm{K}_{\mathrm{eq}}=\frac{\left[\mathrm{CO}^{2}\right.}{\left[\mathrm{CO}_{2}\right]} \Rightarrow[\mathrm{CO}]=\sqrt{\left[\mathrm{CO}_{2}\right] \mathrm{K}_{\mathrm{eq}}}=\sqrt{(2.0)(5.3)}=3.25 \mathrm{M}=3.3 \mathrm{M}
$$

For same temperature, what is $\mathrm{K}_{\text {eq }}$ for,

$$
\begin{aligned}
2 \mathrm{CO}_{2}(\mathrm{~g}) & +2 \mathrm{C}(\mathrm{~s}) \rightleftarrows 4 \mathrm{CO}(\mathrm{~g}) \\
\mathrm{K}_{\text {eq }}^{\prime}= & \frac{[\mathrm{CO}]^{4}}{\left[\mathrm{CO}_{2}\right]^{2}}=\left(\frac{[\mathrm{CO}]^{2}}{\left[\mathrm{CO}_{2}\right]}\right)^{2}=\left(\mathrm{K}_{\text {eq }}\right)^{2}=(5.3)^{2}=\underline{28} \\
2 \mathrm{CO}(\mathrm{~g}) & \rightleftarrows \quad \mathrm{CO}_{2}(\mathrm{~g})+\mathrm{C}(\mathrm{~s}) \\
\mathrm{K}_{\text {eq }}^{\prime \prime} & =\frac{\left[\mathrm{CO}_{2}\right]}{[\mathrm{CO}]^{2}}=\left(\frac{1}{\mathrm{~K}_{\text {eq }}}\right)=\left(\frac{1}{5.3}\right)=\underline{0.19}
\end{aligned}
$$

There are two types of $\mathrm{K}_{\mathrm{eq}}$ ' s :

1. $K_{C} \quad$ concentration units $(M)$ are used in the expression
2. $K_{p} \quad$ pressure units (atm) are used in the expression

$$
\mathrm{K}_{\mathrm{C}}=\frac{[\mathrm{HCl}]^{2}}{\left[\mathrm{H}_{2}\right]\left[\mathrm{Cl}_{2}\right]} \quad \mathrm{K}_{\mathrm{p}}=\frac{\mathrm{p}_{\mathrm{HCl}}^{2}}{\mathrm{p}_{\mathrm{H}_{2}} \mathrm{p}_{\mathrm{Cl}_{2}}}
$$

Numerical values for $\mathrm{K}_{\mathrm{p}}$ and $\mathrm{K}_{\mathrm{C}}$ are usually different...

$$
\begin{aligned}
& \mathrm{K}_{\mathrm{P}}=\mathrm{K}_{\mathrm{C}}(\mathrm{RT})^{\Delta \mathrm{n}} \\
& \mathrm{R}=0.08206 \mathrm{~L} \text { atm } / \mathrm{mol} \mathrm{~K} \\
& \Delta \mathrm{n}=\text { moles of products minus moles of reactants (for gases) }
\end{aligned}
$$

The $\mathrm{K}_{\mathrm{C}}$ for the following rxn is 100.0 at $27^{\circ} \mathrm{C}$. Find $\mathrm{K}_{\mathrm{p}}$.

$$
\begin{aligned}
& \quad 2 \mathrm{SO}_{2}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g}) \rightleftarrows 2 \mathrm{SO}_{3}(\mathrm{~g}) \\
& \mathrm{K}_{\mathrm{p}}=\mathrm{K}_{\mathrm{C}}(\mathrm{RT})^{\Delta \mathrm{n}} \\
& \Delta \mathrm{n}=2-3=-1 \\
& \mathrm{~K}_{\mathrm{p}}=(100.0)[(0.0821 \mathrm{~L} \mathrm{~atm} / \mathrm{mol} \mathrm{~K})(300 . \mathrm{K})]^{-1} \\
&=4.06 \mathrm{~mol} / \mathrm{L} \mathrm{~atm} \\
&=4.06
\end{aligned}
$$

$\mathrm{K}_{\mathrm{C}}=25$ at $20 .{ }^{\circ} \mathrm{C}$ for the reaction

$$
2 \mathrm{HCl}(\mathrm{~g}) \rightleftarrows \mathrm{H}_{2}(\mathrm{~g})+\mathrm{Cl}_{2}(\mathrm{~g})
$$

Find $K_{p}$.

$$
\begin{aligned}
\mathrm{K}_{\mathrm{p}} & =\mathrm{K}_{\mathrm{C}}(\mathrm{RT})^{\Delta \mathrm{n}} \\
\Delta \mathrm{n} & =2-2=0 \\
\mathrm{~K}_{\mathrm{p}} & =(25)[(0.0821 \mathrm{Latm} / \mathrm{mol} \mathrm{~K})(293 \mathrm{~K})]^{0} \\
& =25
\end{aligned}
$$

## Reaction Quotient

Reaction quotient $(\mathrm{Q})$ is used to predict direction to reach equilibrium...
insert concentrations into equilibrium constant expression and compare value to K
if $\mathrm{Q}<\mathrm{K}_{\text {eq }}$, forward reaction is spontaneous
if $\mathrm{Q}>\mathrm{K}_{\text {eq }}$, reverse reaction is spontaneous
if $\mathrm{Q}=\mathrm{K}_{\text {eq }}$, reaction is at equilibrium

For some temperature, the following equilibrium has $\mathrm{K}_{\mathrm{eq}}=16$ :

$$
2 \mathrm{H}_{2}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g}) \rightleftarrows 2 \mathrm{H}_{2} \mathrm{O}(\mathrm{~g})
$$

In which direction is the rxn spontaneous,

$$
\begin{aligned}
& \text { if }\left[\mathrm{H}_{2}\right]=\left[\mathrm{O}_{2}\right]=\left[\mathrm{H}_{2} \mathrm{O}\right]=1.0 \mathrm{M} \text { ? } \\
& \qquad \mathrm{Q}=\frac{\left[\mathrm{H}_{2} \mathrm{O}\right]^{2}}{\left[\mathrm{H}_{2}\right]^{2}\left[\mathrm{O}_{2}\right]}=\frac{(1.0)^{2}}{(1.0)^{2}(1.0)}=1.0<16=\mathrm{K}_{\text {eq }} \Rightarrow \text { forward } \\
& \text { if }\left[\mathrm{H}_{2}\right]=1.0 \mathrm{M},\left[\mathrm{O}_{2}\right]=2.0 \mathrm{M},\left[\mathrm{H}_{2} \mathrm{O}\right]=6.0 \mathrm{M} \text { ? } \\
& \quad \mathrm{Q}=\frac{\left[\mathrm{H}_{2} \mathrm{O}\right]^{2}}{\left[\mathrm{H}_{2}\right]^{2}\left[\mathrm{O}_{2}\right]}=\frac{(6.0)^{2}}{(1.0)^{2}(2.0)}=18>16=\mathrm{K}_{\text {eq }} \Rightarrow \text { reverse }
\end{aligned}
$$

## Equilibrium Problems

General types:

1. equilibrium conc's $\rightarrow K_{\text {eq }}$
2. $K_{\text {eq }} \rightarrow$ equilibrium conc's
3. initial conc's, change $\rightarrow K_{\text {eq }}$

General steps:

1. initial conc's
2. changes (from coefficients)
3. equilibrium conc's
4. write $\mathrm{K}_{\text {eq }}$ expression
5. solve for " $x$ "

A tank is filled with 0.20 atm of $\mathrm{H}_{2}$ and 0.20 atm of $\mathrm{I}_{2}$. Find the equilibrium pressure of HI given

$$
\begin{aligned}
& \mathrm{H}_{2}(\mathrm{~g})+\mathrm{I}_{2}(\mathrm{~g}) \rightleftarrows 2 \mathrm{HI}(\mathrm{~g}) \quad \mathrm{K}_{\mathrm{p}}=36.0 \\
& \begin{array}{llll}
\text { I } & 0.20 & 0.20 & 0
\end{array} \\
& \begin{array}{llll}
C & -x & -x & 2 x
\end{array} \\
& \text { E } 0.20-x 0.20-x \quad 2 x \\
& \mathrm{~K}_{\mathrm{P}}=\frac{\mathrm{p}_{\mathrm{HI}}^{2}}{\mathrm{p}_{\mathrm{H}_{2}} \mathrm{p}_{\mathrm{I}_{2}}}=\frac{[2 \mathrm{x}]^{2}}{[0.20-\mathrm{x}]^{2}}=36.0 \Rightarrow \frac{2 \mathrm{x}}{0.20-\mathrm{x}}=6.00 \Rightarrow \underline{x=0.15} \\
& p_{H I(e q)}=2(0.15 \mathrm{~atm})=\underline{0.30 \mathrm{~atm}}
\end{aligned}
$$

0.10 mol of HCl gas is placed in a 2.0 L flask. What is the concentration of HCl at equilibrium?

$$
[\mathrm{HCl}]_{\mathrm{eq}}=0.050 \mathrm{M}-2(0.0047 \mathrm{M})=\underline{0.041 \mathrm{M}}
$$

$$
\begin{aligned}
& \mathrm{H}_{2}(\mathrm{~g})+\mathrm{Cl}_{2}(\mathrm{~g}) \rightleftarrows 2 \mathrm{HCl}(\mathrm{~g}) \quad \mathrm{K}_{\mathrm{C}}=75 \\
& \begin{array}{llll}
\mathrm{I} & 0 & 0 & 0.050
\end{array} \\
& \begin{array}{lll}
\mathrm{C} & \mathrm{x} & -2 x
\end{array} \\
& \text { E } x \quad x \quad 0.050-2 x \\
& \mathrm{~K}_{\text {eq }}=\frac{[\mathrm{HCl}]^{2}}{\left[\mathrm{H}_{2}\right]\left[\mathrm{Cl}_{2}\right]}=\frac{[0.050-2 \mathrm{x}]^{2}}{[\mathrm{x}]^{2}}=75 \Rightarrow \frac{0.050-2 \mathrm{x}}{\mathrm{x}}=8.7 \Rightarrow x=0.0047 \mathrm{M}
\end{aligned}
$$

Percent dissociation measures extent of reaction

$$
\% \text { diss. }=\frac{\text { amount dissociated }}{\text { original amount }}(100 \%)
$$

What is the percent dissociation of HCl ?
$\%$ diss. $=\frac{2 x}{0.050}(100 \%)=\frac{2(0.0047)}{0.050}(100 \%)=19 \%$
$2.0 \mathrm{~mol} \mathrm{NH}_{3}$ gas are placed in a 1.0 L container and at equilibrium 1.0 mol remains. Find $\mathrm{K}_{\mathrm{C}}$.

$$
\begin{aligned}
& 2 \mathrm{NH}_{3}(\mathrm{~g}) \rightleftarrows \mathrm{N}_{2}(\mathrm{~g})+3 \mathrm{H}_{2}(\mathrm{~g}) \\
& \begin{array}{llll}
\text { I } & 2.0 & 0 & 0
\end{array} \\
& \text { C }-2 x \quad x \quad 3 x \\
& \text { E 2.0-2x } \quad x \quad 3 x \\
& {\left[\mathrm{NH}_{3}\right]_{\text {eq }}=1.0 \mathrm{M}=2.0-2 \mathrm{x} \Rightarrow \mathrm{x}=0.50 \mathrm{M}} \\
& {\left[\mathrm{~N}_{2}\right]_{\text {eq }}=\mathrm{x}=0.50 \mathrm{M}} \\
& {\left[\mathrm{H}_{2}\right]_{\mathrm{eq}}=3 \mathrm{x}=1.5 \mathrm{M}} \\
& \mathrm{~K}_{\mathrm{C}}=\frac{\left[\mathrm{N}_{2}\right]\left[\mathrm{H}_{2}\right]^{3}}{\left[\mathrm{NH}_{3}\right]^{2}}=\frac{(0.50)(1.5)^{3}}{(1.0)^{2}}=\underline{1.7}
\end{aligned}
$$

$0.84 \mathrm{~mol} \mathrm{PCl}_{5}$ and $0.18 \mathrm{~mol}_{\mathrm{PCl}_{3}}$ are placed in a 1.0 L flask. At equilibrium $0.72 \mathrm{~mol} \mathrm{PCl}_{5}$ remains. Find $\mathrm{K}_{\mathrm{C}}$ for

$$
\begin{aligned}
& \mathrm{PCl}_{5}(\mathrm{~g}) \rightleftarrows \mathrm{PCl}_{3}(\mathrm{~g})+\mathrm{Cl}_{2}(\mathrm{~g}) \\
& \begin{array}{llll}
\mathrm{I} & 0.84 & 0.18 & 0
\end{array} \\
& \text { C -x } x \quad x \\
& \text { E } 0.84-x \quad 0.18+x x \\
& {\left[\mathrm{PCl}_{5}\right]_{\text {eq }}=0.72 \mathrm{M}=0.84-\mathrm{x} \Rightarrow \mathrm{x}=0.12 \mathrm{M}} \\
& {\left[\mathrm{PCl}_{3}\right]_{\text {eq }}=0.18+x=0.30 \mathrm{M}} \\
& {\left[\mathrm{Cl}_{2}\right]_{\text {eq }}=x=0.12 \mathrm{M}} \\
& \mathrm{~K}_{\mathrm{C}}=\frac{\left[\mathrm{PCl}_{3}\right]\left[\mathrm{Cl}_{2}\right]}{\left[\mathrm{PCl}_{5}\right]}=\frac{(0.30)(0.12)}{(0.72)}=0.050
\end{aligned}
$$

## Le Chatelier's Principle

Le Chatelier's Principle
If an external stress is applied to a system at equilibrium, the equilibrium position will change to counteract the stress

$$
\mathrm{H}_{2}(\mathrm{~g})+\mathrm{I}_{2}(\mathrm{~g}) \rightleftarrows 2 \mathrm{HI}(\mathrm{~g})
$$

If $\mathrm{H}_{2}$ is added...
equilibrium shifts right (more products are formed)
$\mathrm{K}_{\text {eq }}$ stays the same

Change in Enthalpy $(\Delta \mathrm{H})$ : The energy change during a chemical reaction
$\Delta \mathrm{H}$ positive...
$\Delta \mathrm{H}$ negative...

E absorbed endothermic
E released exothermic

When this reaction occurs, energy is released...

$$
\begin{gathered}
\mathrm{H}_{2}(\mathrm{~g})+\mathrm{I}_{2}(\mathrm{~g}) \rightleftarrows 2 \mathrm{HI}(\mathrm{~g})+\text { energy } \\
\Delta \mathrm{H}_{298} \text { for reaction }=-10.2 \mathrm{~kJ} \text { (exothermic!) }
\end{gathered}
$$

If T increases... equilibrium shifts left (more reactants are formed) $\mathrm{K}_{\text {eq }}$ decreases

If T decreases...
equilibrium shifts right
$\mathrm{K}_{\text {eq }}$ increases
$4 \mathrm{HCl}(\mathrm{g})+\mathrm{O}_{2}(\mathrm{~g}) \rightleftarrows 2 \mathrm{Cl}_{2}(\mathrm{~g})+2 \mathrm{H}_{2} \mathrm{O}(\mathrm{I}) \quad \Delta \mathrm{H}=+3.1 \mathrm{~kJ} / \mathrm{mol} \mathrm{O}_{2}$
If T increases...
equilibrium shifts right $\quad \mathrm{K}_{\text {eq }}$ increases
If $\mathrm{Cl}_{2}$ removed...
equilibrium shifts right $\quad \mathrm{K}_{\text {eq }}$ stays the same
If $\mathrm{H}_{2} \mathrm{O}$ added...
no change; not in $\mathrm{K}_{\text {eq }}$ expression!
If $P$ increases...
equilibrium shifts right $\quad \mathrm{K}_{\text {eq }}$ stays the same (pressure affects gases, less gas on right)

$$
\mathrm{CO}(\mathrm{~g})+\mathrm{H}_{2} \mathrm{O}(\mathrm{I}) \rightleftarrows \mathrm{CO}_{2}(\mathrm{~g})+\mathrm{H}_{2}(\mathrm{~g}) \quad \Delta \mathrm{H}=+4.1 \mathrm{~kJ}
$$

| Stress | Shift | $\Delta\left[\mathrm{CO}_{2}\right]$ |
| :--- | :--- | :--- |
| add CO | right | incr |
| add $\mathrm{H}_{2} \mathrm{O}$ | none | no |
| add $\mathrm{H}_{2}$ | left | decr |
| add $\mathrm{CO}_{2}$ | left | incr |
| incr T | right | incr |
| decr T | left | decr |
| incr P | left | decr |
| decr P | right | incr |

The equilibrium concentrations of $0.30 \mathrm{M} \mathrm{HCl}, 0.20 \mathrm{M} \mathrm{H}_{2}$, and $0.10 \mathrm{M} \mathrm{Cl}_{2}$ are all in a 1.0 L flask. Then $0.10 \mathrm{~mol} \mathrm{Cl}_{2}$ is added. Find the new equilibrium concentration of HCl .

|  | $2 \mathrm{HCl}(\mathrm{g})$ | $\rightleftarrows$ | $\mathrm{H}_{2}(\mathrm{~g})+\mathrm{Cl}_{2}(\mathrm{~g})$ |  |
| :---: | :---: | :---: | :---: | :---: |
| E | 0.30 |  | 0.20 | 0.10 |
| I | 0.30 |  | 0.20 | 0.20 |
| C | +2 x |  | -x | -x |
| E | $0.30+2 \mathrm{x}$ | $0.20-\mathrm{x}$ | $0.20-\mathrm{x}$ |  |

Find $\mathrm{K}_{\mathrm{C}}$ from initial eq. conc.'s:
$\mathrm{K}_{\mathrm{C}}=\frac{\left[\mathrm{H}_{2}\right]\left[\mathrm{Cl}_{2}\right]}{[\mathrm{HCl}]^{2}}=\frac{[0.20 \mathrm{M}][0.10 \mathrm{M}]}{[0.30 \mathrm{M}]^{2}}=0.22$

The equilibrium concentrations of $0.30 \mathrm{M} \mathrm{HCl}, 0.20 \mathrm{M} \mathrm{H}_{2}$, and $0.10 \mathrm{M} \mathrm{Cl}_{2}$ are all in a 1.0 L flask. Then $0.10 \mathrm{~mol} \mathrm{Cl}_{2}$ is added. Find the new equilibrium concentration of HCl .

Find new eq. conc.'s:
$0.22=\frac{[0.20-x]^{2}}{[0.30+2 x]^{2}} \Rightarrow 0.47=\frac{0.20-x}{0.30+2 x} \Rightarrow x=0.030 M$
$[\mathrm{HCl}]=0.30+2 x=\underline{0.36 \mathrm{M}}$

A flask is filled with the equilibrium pressures 0.25 atm $\mathrm{N}_{2}, 0.25$ atm $\mathrm{O}_{2}$, and 0.40 atm NO . Then 0.10 atm of NO is added. What are the new equilibrium pressures.

|  | $\mathrm{N}_{2}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g})$ |  | $\rightleftarrows$ | $2 \mathrm{NO}(\mathrm{g})$ |
| :---: | :---: | :---: | :---: | :---: |
| E | 0.25 | 0.25 | 0.40 |  |
| I | 0.25 | 0.25 | 0.50 |  |
| C | x | x | -2 x |  |
| E | $0.25+\mathrm{x} 0.25+\mathrm{x}$ | $0.50-2 \mathrm{x}$ |  |  |

Find $K_{p}$ from initial eq. prs.'s:
$\mathrm{K}_{\mathrm{P}}=\frac{\mathrm{p}_{\mathrm{NO}}{ }^{2}}{\mathrm{p}_{\mathrm{N}_{2}} \mathrm{p}_{\mathrm{O}_{2}}}=\frac{[0.40 \mathrm{~atm}]^{2}}{[0.25 \mathrm{~atm}]^{2}}=2.56$

A flask is filled with the equilibrium pressures 0.25 atm $\mathrm{N}_{2}, 0.25$ atm $\mathrm{O}_{2}$, and 0.40 atm NO . Then 0.10 atm of NO is added. What are the new equilibrium pressures.

Find new eq. prs.'s:
$2.56=\frac{[0.50-2 x]^{2}}{[0.25+x]^{2}} \Rightarrow 1.6=\frac{0.50-2 x}{0.25+x} \Rightarrow x=0.028 \mathrm{~atm}$
$\left[N_{2}\right]=0.25+x=0.28 \mathrm{~atm}$
$\left[\mathrm{O}_{2}\right]=0.25+x=\underline{0.28 \mathrm{~atm}}$
$[\mathrm{NO}]=0.50-2 x=\underline{0.44 \mathrm{~atm}}$

