## Lecture Notes M: Chemical Equilibrium V

Consider the reaction:

$$
2 \mathrm{H}_{2} \mathrm{~S}_{(\mathrm{g})}+\mathrm{O}_{2(\mathrm{~g})} \quad \leftrightarrow \quad 2 \mathrm{~S}_{(\mathrm{s})}+2 \mathrm{H}_{2} \mathrm{O}_{(\mathrm{g})} \quad \Delta \mathrm{H}=-221.19 \mathrm{~kJ} / \mathrm{mol}
$$

## Concept

If $\mathrm{O}_{2(\mathrm{~g})}$ is added to the reaction vessel, what happens to the amount of $\mathrm{S}_{(\mathrm{s})}$ ?
a) It increases
b) It decreases
c) Nothing

If the volume of the vessel is cut in half, what happens to the ratio of $\mathrm{P}_{\mathrm{H} 2 \mathrm{O}} / \mathrm{P}_{\mathrm{H} 2 \mathrm{~s}}$ ?
a) It increases
b) It decreases
c) Nothing

If the temperature is increased, what happens to the equilibrium constant K ?
a) It increases
b) It decreases
c) Nothing

If $\mathrm{S}_{(\mathrm{s})}$ is added to the reaction, what happens to $\mathrm{P}_{\mathrm{H} 2 \mathrm{O}}$ ?
a) It increases
b) It decreases
c) Nothing

## Concept

Consider a mixture of $\mathrm{Cl}_{2(\mathrm{~g})}$ and $\mathrm{I}_{2(\mathrm{~g})}$ in a sealed vessel at $750^{\circ} \mathrm{C}$. The following reaction is in equilibrium:

$$
\mathrm{Cl}_{2(\mathrm{~g})}+\mathrm{I}_{2(\mathrm{~g})} \leftrightarrow 2 \mathrm{ICl}_{(\mathrm{g})}
$$

What happens to the ratio of $\mathrm{P}_{\mathrm{Ic}} / \mathrm{P}_{\mathrm{Cl} 2}$ when the volume of the vessel is decreased?
a) It increases
b) It decreases
c) Nothing

## Concept

If the density of graphite is about $2 \mathrm{~g} / \mathrm{mL}$ and that of buckyball is about $1.5 \mathrm{~g} / \mathrm{mL}$, in which direction would the application of high pressure drive the equilibrium?
A) toward formation of graphite
B) toward formation of buckyball
C) neither would be formed preferentially

## Concept

Consider the gaseous equilibrium:

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

The sketches below show the pressures, P , of these three gases as a function of time during an experiment. Only one is real, i.e. is consistent with Le Chatelier's principle. Which one is it?


## Concept

Consider the following two systems:

## System 1




Assume the following reaction is at equilibrium:

$$
\mathrm{CH}_{4}(\mathrm{~g})+\mathrm{H}_{2} \mathrm{O}(\mathrm{~g}) \leftrightarrow \mathrm{CO}(\mathrm{~g})+3 \mathrm{H}_{2}(\mathrm{~g})
$$

A relatively large amount of Ne is introduced into both systems, keeping the temperature constant.
For system 1:
a) Introduction of the Ne forces the equilibrium to the left.
b) Introduction of the Ne forces the equilibrium to the right.
c) Introduction of the Ne has no effect on the position of the equilibrium.
d) Can't tell from the available information.

For system 2:
a) Introduction of the Ne forces the equilibrium to the left.
b) Introduction of the Ne forces the equilibrium to the right.
c) Introduction of the Ne has no effect on the position of the equilibrium.
d) Can't tell from the available information.

## Concept



Consider the system shown at the left.
Assume the following reaction is at equilibrium:

$$
\mathrm{CH}_{4}(\mathrm{~g})+\mathrm{H}_{2} \mathrm{O}(\mathrm{~g}) \leftrightarrow \mathrm{CO}(\mathrm{~g})+3 \mathrm{H}_{2}(\mathrm{~g})+\text { heat }
$$

When the bunsen burner is used to heat up the system,
a) the equilibrium will shift to the left
b) the equilibrium will shift to the right
c) there will be no effect on the position of the equilibrium
d) can't tell from the available information

## 1) Van't Hoff equation

## 2) Deriving the equilibrium condition from thermodynamics

Dependence of $\Delta \mathrm{G}$ on the pressure of a gas

Dependence of $\Delta \mathbf{G}$ on the concentration of a solution

## $\Delta G$ for a gas reaction

$$
\Delta \mathrm{G}=\Delta \mathrm{G}^{\mathrm{o}}+\mathrm{RT} \ln \left[\left(\frac{1 \mathrm{~atm}}{\mathrm{P}_{\mathrm{A}}}\right)^{\mathrm{a}}\right]+\mathrm{RT} \ln \left[\left(\frac{1 \mathrm{~atm}}{\mathrm{P}_{\mathrm{b}}}\right)^{\mathrm{b}}\right]+\mathrm{RT} \ln \left[\left(\frac{\mathrm{P}_{\mathrm{C}}}{1 \mathrm{~atm}}\right)^{\mathrm{c}}\right]+\mathrm{RT} \ln \left[\left(\frac{\mathrm{P}_{\mathrm{D}}}{1 \mathrm{~atm}}\right)^{\mathrm{d}}\right]
$$

$$
\Delta \mathrm{G}=\Delta \mathrm{G}^{\mathrm{o}}+\mathrm{RT} \ln \left(\left(\frac{1 \mathrm{~atm}}{\mathrm{P}_{\mathrm{A}}}\right)^{\mathrm{a}}\left(\frac{1 \mathrm{~atm}}{\mathrm{P}_{\mathrm{B}}}\right)^{\mathrm{b}}\left(\frac{\mathrm{P}_{\mathrm{C}}}{1 \mathrm{~atm}}\right)^{\mathrm{c}}\left(\frac{\mathrm{P}_{\mathrm{D}}}{1 \mathrm{~atm}}\right)^{\mathrm{d}}\right)=\Delta \mathrm{G}^{\mathrm{o}}+\mathrm{RT} \ln \left(\frac{\mathrm{P}_{\mathrm{C}}{ }^{\mathrm{c}} \mathrm{P}_{\mathrm{D}}{ }^{\mathrm{d}}}{\mathrm{P}_{\mathrm{A}}{ }^{\mathrm{a}} \mathrm{P}_{\mathrm{B}}{ }^{\mathrm{b}}}\right)=\Delta \mathrm{G}^{\mathrm{o}}+\mathrm{RT} \ln \mathrm{Q}
$$

$$
\begin{aligned}
& a \mathrm{~A}_{(\mathrm{g})}+\mathrm{bB} \mathrm{~B}_{(\mathrm{g})} \leftrightarrow \mathrm{c} \mathrm{C}_{(\mathrm{g})}+\mathrm{d} \mathrm{D}_{(\mathrm{g})}
\end{aligned}
$$

$$
\begin{aligned}
& \Delta \mathrm{G}=\Delta \mathrm{G}^{\mathrm{o}}+\mathrm{aRT} \ln \left(\frac{1 \mathrm{~atm}}{\mathrm{P}_{\mathrm{A}}}\right)+\mathrm{bRT} \ln \left(\frac{1 \mathrm{~atm}}{\mathrm{P}_{\mathrm{b}}}\right)+\mathrm{cRT} \ln \left(\frac{\mathrm{P}_{\mathrm{C}}}{1 \mathrm{~atm}}\right)+\mathrm{dRT} \ln \left(\frac{\mathrm{P}_{\mathrm{D}}}{1 \mathrm{~atm}}\right)
\end{aligned}
$$

