

## Thermochemistry Notes #2

“Spontaneous” A process that occurs without any ongoing outside intervention

Examples: Dropping an egg, burning methane (natural gas)

**Entropy:** “Disorder”

- A measure of the randomness or disorder of a system.
- The more disordered, the greater the entropy.
- My office desk has a lot of clutter. (Large amount of entropy)
- Symbol for Entropy is S
- Entropy units are Joules/Kelvin
- $S_{\text{solid}} < S_{\text{liquid}} \ll S_{\text{gas}}$

As before, we are interested in the change in entropy,  $\Delta S$

$$\Delta S = S_{\text{final}} - S_{\text{initial}}$$

If  $\Delta S > 0$ , the system is becoming more disordered

If  $\Delta S < 0$ , the system is becoming less disordered (or more ordered)

Generally, an increase in entropy occurs when:

1. Liquids or solutions are formed from solids.
2. Gases are formed from solids or liquids.
3. The number of gas molecules increases during a reaction.

Predict whether  $\Delta S$  will be positive or negative for each reaction below:



Things to Notice About Standard Molar Entropies:

- Standard molar entropies (as in per mole) of elements at 298 K are not 0 (unlike  $\Delta H_f^\circ$ )
- Standard molar entropies of gases are greater than those of liquids.
- Standard molar entropies generally increase as the atoms and/or molecules get larger.
- Units are J/(mole · K)

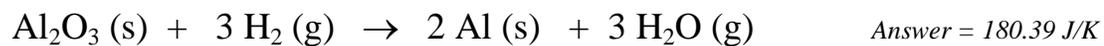
Entropy Changes in Chemical Reactions:

Key Formula:  $\Delta S^\circ_{\text{rxn}} = \Sigma S^\circ (\text{Products}) - \Sigma S^\circ (\text{Reactants})$

Calculate the  $\Delta S^\circ_{\text{rxn}}$  for the synthesis of ammonia from  $\text{N}_2 (\text{g})$  and  $\text{H}_2 (\text{g})$  at 298 K.



Calculate the  $\Delta S^\circ_{\text{rxn}}$  for the following reaction at 298 K.



## Gibbs Free Energy

Key Formula:  $\Delta G^\circ = \sum G_f^\circ (\text{Products}) - \sum G_f^\circ (\text{Reactants})$

$\Delta G^\circ < 0$ , then the forward reaction is spontaneous

$\Delta G^\circ = 0$ , then the reaction is at equilibrium

$\Delta G^\circ > 0$ , then the forward reaction is not spontaneous (the reverse reaction is spontaneous)

$$\Delta G = \Delta H - T\Delta S$$

where T = Temp in Kelvin

Connection to Chemical Equilibrium Constant

$$\Delta G = -RT \ln K$$

where R = 8.314 J/(mol·K)

Units for  $\Delta G$  must be Joules, not kiloJoules (like on colored sheet)

<b>K</b>	<b>ln K</b>	<b><math>\Delta G</math></b>	<b>Equilibrium Characteristics</b>
>1	+	-	Products favored
=1	0	0	Products & Reactants Equally Favored
<1	-	+	Reactants favored