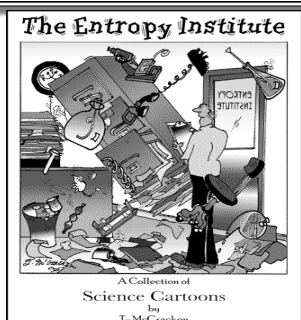


Entropy



Spontaneity

- _____ process – a process that occurs without intervention
 - can be fast or slow

Entropy

- _____(s) – the measure of molecular randomness or disorder
 - Think of entropy as the amount of chaos

Entropy

- Predict which has the highest entropy
 1. CO_2 (s) or CO_2 (g)
 2. 1 mol of N_2 at 1 atm or 1 mol of N_2 at 0.001 atm

Entropy

- Predict the sign of the entropy change for the following...
1. Sugar is added to water to form a solution
 2. Iodine vapor condenses on a cold surface to produce a liquid

2nd Law of Thermodynamics

- 2nd Law of Thermodynamics – In any spontaneous process there is always an increase in entropy of the universe
 - Energy is conserved...entropy is NOT conserved!

3rd Law of Thermodynamics

- The entropy of a perfect crystal at 0K is zero

Free Energy

- _____(G) – a thermodynamic function equal to the enthalpy minus the product of the entropy and the Kelvin temperature
- $\Delta G = \Delta H - T\Delta S$
- A process is only spontaneous in the direction where ΔG is _____

Example

- At what temperatures is the following process spontaneous at 1 atm?
 - $\text{Br}_2(\text{l}) \rightarrow \text{Br}_2(\text{g})$
 - $\Delta H = 31.0 \text{ KJ/mol} \rightarrow 31000 \text{ J/mol}$
 - $\Delta S = 93.0 \text{ J/ K mol}$

Dependence of H & S on Spontaneity

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

ΔH	ΔS	Result
-	+	
+	+	
-	-	
+	-	

What is the sign for ΔS ?

- $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$

- $4\text{NH}_3 + 5\text{O}_2 \rightarrow 4\text{NO} + 6\text{H}_2\text{O}$

Calculating ΔS

- Calculating ΔS is just like calculating ΔH
- Simply use the Appendix...just look at the column for S instead of H
- ΔS° of any element or diatomic molecule is NOT zero.
- You must look these up!

Example

- Calculate ΔS for the following reaction:
- $2\text{NiS}(s) + 3\text{O}_2(g) \rightarrow 2\text{SO}_2(g) + 2\text{NiO}(s)$

Example

- Calculate ΔS for the following reaction:
- $\text{Al}_2\text{O}_3(s) + 3\text{H}_2(g) \rightarrow 2\text{Al}(s) + 3\text{H}_2\text{O}(g)$

Gibbs Free Energy & Chemical Reactions

- You can calculate ΔG in 3 ways...
- 1. Like Hess's Law
- 2. Like ΔH°
- 3. With the equation $\Delta G = \Delta H - T \Delta S$

Example

- Calculate ΔH , ΔS , & ΔG at 25°C using the following data...
- $2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{SO}_3$

Substance	ΔH (KJ/mol)	ΔS (J/K mol)
SO_2	-297	248
SO_3	-396	257
O_2	0	205

Calculate ΔG

- Using the following data at 25°C
- $C_{diamond} + O_2(g) \rightarrow CO_2(g) \quad \Delta G = -397KJ$
- $C_{graphite} + O_2(g) \rightarrow CO_2(g) \quad \Delta G = -394KJ$
- Calculate ΔG for the reaction:
- $C_{diamond} \rightarrow C_{graphite}$

Calculating ΔG

- Methanol is a high octane fuel used in high performance racing engines. Calculate ΔG for the following reaction
- $2 CH_3OH(g) + 3 O_2(g) \rightarrow 2 CO_2(g) + 4 H_2O(g)$
- Given the following free energies of formation:

Substance	ΔG° (KJ/mol)
$CH_3OH(g)$	-163
$O_2(g)$	0
$CO_2(g)$	-394
$H_2O(g)$	-229

ΔG

- Several ways to get ΔG
- $\Delta G = \Delta H - T \Delta S$
- $\Delta G^\circ = nF\epsilon$
- $\Delta G^\circ = -RT \ln K$
- $\Delta G = \Delta G^\circ + RT \ln Q$
- R on these is 8.31J/molK

Example

- $N_2 + 3H_2 \rightarrow 2NH_3$
- $\Delta G^\circ = -33.3 KJ/mol$ of N_2 consumed at 25 °C. Calculate the value for the equilibrium constant

Example

- Calculate ΔG° at 389 K at equilibrium where $[\text{NH}_3] = 2.0\text{M}$, $[\text{H}_2] = 1.25\text{ M}$, & $[\text{N}_2] = 3.01\text{ M}$
- $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$

AP Like Questions

- $\text{C(s)} + \text{CO}_2(\text{g}) \leftrightarrow 2\text{CO(g)}$
- All 3 of the gases above form an equilibrium mixture by the equation above
- a. Predict the sign of ΔS of the reaction & justify your prediction

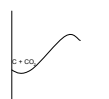
AP Like Questions

- b. In the table below are data that show the % CO in the equilibrium mixture at 2 different temperatures. Predict the sign of ΔH & justify

<u>Temp</u>	<u>%CO</u>
700K	60%
900K	94%

AP Like Questions

- Appropriately complete the energy diagram for the reaction by finishing the graph below. Also clearly label ΔH for the reaction...



AP Like Questions

- d. If the initial amount of C were doubled, what would be the effect of CO? Justify

AP Like Questions

- Will the following be endo or exo?
- Boil H₂O
- Dissolve NH₄Cl (gets colder)
- Dissolving CaCl₂ (gets hot)
- Melting ice

AP Like Questions

- NO & CO are air pollutants generated by automobiles. It has been proposed that under suitable conditions these 2 gases could react to form N₂ & CO₂ which are components of unpolluted air.
- a. Write the balanced equation for the reaction described above. Indicate whether C in CO is oxidized or reduced...justify.

AP Like Questions

- b. Write the K_p expression

AP Like Questions

- c. Consider the following thermodynamic data...
- ΔG° (KJ/mol) NO = +86.55, CO = -137.15, & CO₂ = -394.36
- Calculate the ΔG° of the reaction
- $2\text{NO} + 2\text{CO} \rightarrow \text{N}_2 + 2\text{CO}_2$

AP Like Questions

- d. Given that the ΔH at 298 K is -746 KJ/mol of N₂ formed, calculate ΔS (include units).

AP Like Questions

- e. For the reaction at 298K $K_p = 3.33 \times 10^{120}$. In an urban area the typical pressures of the gases are $P_{\text{NO}} = 5.0 \times 10^{-7}$ atm, $P_{\text{CO}} = 5.0 \times 10^{-7}$ atm, $P_{\text{N}_2} = 0.781$ atm, & $P_{\text{CO}_2} = 3.1 \times 10^{-4}$ atm.
- Calculate the value of ΔG at 298 K with the partial pressures given above.

AP Like Questions

- f. In which direction (Right of left) will the reaction be spontaneous at 298 K with these pressures? Justify