

# Notes #58 Entropy, Free E, and K

ENTROPY - The second driving force 1. What is ENTROPY? It is represented by the symbol S.

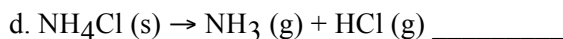
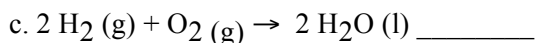
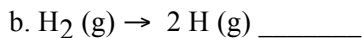
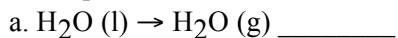
It is the measure of the \_\_\_\_\_ or \_\_\_\_\_ of a system. All matter has some disorder in it so all matter has a \_\_\_\_\_ S value except when matter is: \_\_\_\_\_ and \_\_\_\_\_.

How do you calculate  $\Delta S^\circ_{\text{rxn}}$  (the change in entropy during a certain process)?

$$\Delta S^\circ_{\text{rxn}} = \sum n S^\circ_{\text{products}} - \sum n S^\circ_{\text{reactants}}$$

$+\Delta S =$  \_\_\_\_\_ in disorder;  $-\Delta S =$  \_\_\_\_\_ in disorder

Make predictions about whether a process would have a  $+\Delta S$  or a  $-\Delta S$ .



**Second Law of Thermodynamics** - The entropy of the universe must INCREASE in a spontaneous process and remain UNCHANGED in a process in equilibrium. Both a \_\_\_\_\_  $\Delta H$  and \_\_\_\_\_  $\Delta S$  can contribute to a increase in the entropy of the universe.

**Gibb's Free Energy ( $\Delta G$ )** - a result of the 2nd law of Thermodynamics.

1. What is it? It refers to energy that is "free" or \_\_\_\_\_.  $\Delta G^\circ$  is a measure of the OVERALL spontaneity or favorability of a process.  $\Delta G$  is proportional to  $\Delta S_{\text{universe}}$ .

2.  $\Delta G$  takes into account  $\Delta H$ , T, and  $\Delta S$ ....  $\Delta G = \Delta H - T\Delta S$  or, under STANDARD conditions

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

$\Delta G$  is (-) Energy is RELEASED (available to do work). Entropy of the universe (surroundings) \_\_\_\_\_  
Process is \_\_\_\_\_ in the forward reaction.

$\Delta G$  is (+) Energy is REQUIRED. Entropy of the universe (surroundings) \_\_\_\_\_  
Process is \_\_\_\_\_ in the forward reaction, but it is favorable in the \_\_\_\_\_ reaction

$\Delta G = 0$  The process is in \_\_\_\_\_. No net change in  $\Delta G$ .

4. TWO ways of calculating  $\Delta G^\circ_{\text{rxn}}$ . a. We can calculate the  $\Delta G^\circ_{\text{rxn}}$  the same way we would calculate  $\Delta H^\circ_{\text{rxn}}$ .

$$\Delta G^\circ_{\text{rxn}} = \sum n G^\circ_{\text{products}} - \sum n G^\circ_{\text{reactants}}$$

\*\*  $\Delta G^\circ_{\text{f}}$  = standard free energy of formation = the free-energy change that occurs when \_\_\_\_\_ of the compound is synthesized from its elements in their standard state.

\*\* Just like with  $\Delta H^\circ_{\text{f}}$ , the  $\Delta G^\circ_{\text{f}}$  for elements in their most stable form is \_\_\_\_\_. We can also calculate the

$\Delta G^\circ_{\text{rxn}}$  using  $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

5. Predicting the sign of  $\Delta G^\circ$  in the equation,  $\Delta G^\circ = \Delta H^\circ - T\Delta S$ . There are FOUR possible outcomes of this equation.

$\Delta H^\circ$	$\Delta S^\circ$	$\Delta G^\circ$	Comment
------------------	------------------	------------------	---------

Example

(-)

(+)

(+) (-)

(-) (-)

(+) (+)

\*\* For the situations at which  $\Delta G^\circ$  is dependent on temperature, you can predict the exact temperature that  $\Delta G^\circ$  is going to change signs by setting  $\Delta G^\circ$  equal to zero, plugging in  $\Delta H^\circ$  and  $\Delta S^\circ$  and solving for T.....

EX 2: If  $\Delta H^\circ$  for a reaction is 10.5 kJ/mol and  $\Delta S^\circ$  is 30 J/molK....will this process be spontaneous at 25°C? At what temperature WILL this process become spontaneous?

- What errors are we actually bringing into the temperature determination calculation?

EX3: 1997 #7

Free Energy and Chemical Equilibria:

1. When we carry out a reaction, we may start off at standard conditions, but soon after, we WILL NOT be in standard conditions anymore. Under conditions that are NOT standard, we use  $\Delta G$  instead of  $\Delta G^\circ$ .

\*  $\Delta G$  varies as the reaction proceeds, where as  $\Delta G^\circ$  is a constant for a reaction under standard conditions.

2. The relationship between  $\Delta G^\circ$  and  $\Delta G$  is as follows:

$$\Delta G = \Delta G^\circ + RT \ln Q$$

3. We can illustrate the difference between  $\Delta G^\circ$  and  $\Delta G$ .

$R = 8.314 \text{ J/K}\cdot\text{mol}$

$Q = \text{reaction quotient}$

$T = \text{temperature in Kelvin}$



3. When the system DOES reach equilibrium, how will the equation above change?

$\Delta G = \text{_____} @ \text{Eq}$

$\Delta G = \Delta G^\circ + RT \ln Q$

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

OR,

$Q = K_{eq} @ \text{Eq}$

$0 = \Delta G^\circ + RT \ln K$

$-\Delta G^\circ / RT = \ln K$

$K = e^{-\Delta G^\circ / RT}$

- Notice, that the LARGER K is, the \_\_\_\_\_  $\Delta G^\circ$ . Does this make sense to us?

EX 4: Use the  $\Delta G^\circ$  in your appendix, to determine  $K_p$  for the following rxn at 25°C:  $2 \text{O}_3 (\text{g}) \rightarrow 2 \text{O}_2 (\text{g})$

EX 5:  $K_p = 4.40$  at 2000. K for the following reaction:  $\text{H}_2 (\text{g}) + \text{CO}_2 (\text{g}) \rightleftharpoons \text{H}_2\text{O} (\text{g}) + \text{CO} (\text{g})$

(a) Determine  $\Delta G^\circ$ .

(b) Determine  $\Delta G$  when the partial pressures are  $P_{\text{H}_2} = 0.25 \text{ atm}$ ,  $P_{\text{CO}_2} = 0.78 \text{ atm}$ ,  $P_{\text{H}_2\text{O}} = 0.66 \text{ atm}$ ,  $P_{\text{CO}} = 1.20 \text{ atm}$