Entropy HW

18.1) A spontaneas process is a process in which the entropy of the universe increases, $\Delta S_{universe} > 0$. Two examples of spontaneous processes are the melting of ice at 50°C and the fall of water down a waterfall. Two examples of non-spontaneas processes are the condensation of water at 1 atm and 200°C and the conversion of graphite to diamond. No outside work or influence is needed to start a spontaneous process.

18.2) (a) Salt **spontaneously** dissolves in hot soup.

(b) **no** one **spontaneously** climbs Mt. Everest.

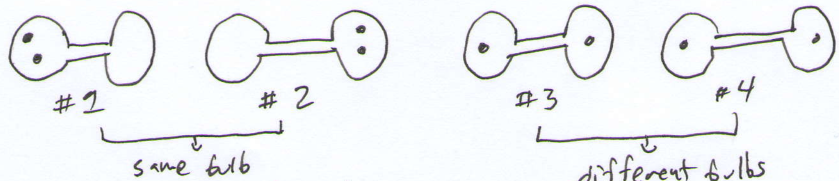
(c) perfume **spontaneously** fills a room.

(d) separation gas mixtures is **non-spontaneous**.

18.4) Entropy is a measure of disorder in a system, entropy increases as disorder increases. The typical units of entropy are J/mol K.

18.5)
(a) $\Delta S_{melt} \overset{?}{>} 0$
(b) $\Delta S_{freeze} \overset{?}{<} 0$
(c) $\Delta S_{boil} > 0$
(d) $\Delta S_{dep.} < 0$
(e) $\Delta S_{condense} < 0$
(f) $\Delta S_{sub} > 0$
(g) $\Delta S_{dissolve} > 0$

18.6) (a) If there are two molecules in the bulbs, there are only two ways in which all the molecules end up in the same bulb:



Since the molecules are in the same bulb 2/4 times, the probability is 1/2.

(b) There are still only two ways in which all the molecules end up in the same bulb, but now there are 2^{100} possible configurations of molecules in the bulb (we call these "microstates"). So the probability of all molecules being in the same bulb is $2/2^{100} = 2^{-99} \approx 1.6\times10^{-30}$.

(c) Now the probability is $2/2^{6\times10^{23}} = 2^{-(6\times10^{23}-1)} \approx 0$.

As we can see, the probability of all molecules being in the same bulb is given by $p(N) = 2^{1-N}$, where N = # of molecules. As $N \to$ large numbers, such as moles in macroscopic systems, $p(N) \to 0$.

18.7) The Second Law of Thermodynamics states that the entropy of the universe increases for all spontaneous processes: $\Delta S_{universe} > 0$.

18.9) (a) $Li_{(l)}$; solid Li metal is highly ordered as a crystal, whereas the liquid form is much less ordered

(b) $CH_3OCH_{3(l)}$; since C_2H_5OH participates in hydrogen bonding, its molecules are less free to move and participate in random, disordered motion

(c) $Xe_{(g)}$; since Xe has more electrons than Ar, its electrons occupy more energy levels and are more disordered

(d) $CO_{2(g)}$; carbon dioxide can execute more vibrations and has more electrons than the more ordered carbon monoxide

(e) $O_{3(g)}$; see explanation for CO_2

(f) N_2O_4; see explanation for CO_2

18.12) (a) $H_{2(g)} + CuO_{(s)} \rightarrow Cu_{(s)} + H_2O_{(g)}$

$\Delta S^\circ_{rxn} = \sum S^\circ(\text{products}) - \sum S^\circ(\text{reactants})$

$= [S^\circ(Cu_{(s)}) + S^\circ(H_2O_{(g)})] - [S^\circ(H_{2(g)}) + S^\circ(CuO_{(s)})]$

$= [33.3\ J/mol\,K + 188.7\ J/mol\,K] - [131.0\ J/mol\,K + 43.5\ J/mol\,K]$

$\Delta S^\circ_{rxn} = 47.5\ J/mol\,K$

(b) $2Al_{(s)} + 3ZnO_{(s)} \rightarrow Al_2O_{3(s)} + 3Zn_{(s)}$

$\Delta S^\circ_{rxn} = [S^\circ(Al_2O_{3(s)}) + 3S^\circ(Zn_{(s)})] - [3S^\circ(ZnO_{(s)}) + 2S^\circ(Al_{(s)})]$

$= [50.99 + 3(41.6)] - [3(43.9) + 2(28.3)]$

$\Delta S^\circ_{rxn} = -12.51\ J/mol\,K$

(c) $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$

$\Delta S^\circ_{rxn} = [213.6 + 2(69.9)] - [186.2 + 2(205.0)]$

$\Delta S^\circ_{rxn} = -242.8\ J/mol\,K$

18.13) (a) $2KClO_4(s) \rightarrow 2KClO_3(s) + O_2(g)$

2 mol solid   2 mol solid   1 mol g

$S(gas) \gg S(solid) \Rightarrow S(products) > S(reactants) \Rightarrow \Delta S_{rxn} > 0$

(b) $H_2O(g) \rightarrow H_2O(l)$

$S(gas) > S(liquid) \Rightarrow S(products) < S(reactants) \Rightarrow \Delta S_{rxn} < 0$

(c) $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

2 mol solid   2 mol liquid   2 mol aqueas   1 mol gas

$S(gas) > S(liquid)$

$S(gas) > S(solid)$ $\Rightarrow S(products) > S(reactants) \Rightarrow \Delta S_{rxn} > 0$

$S(aqueas) \overset{usually}{>} S(pure\ liquid)$

$S(aqueas) \overset{usually}{>} S(solid)$