spontaneous – product favored
nonspontaneous – reactant favored

combustion of propane — spontaneous and exothermic

$NaOH_{(aq)}$ + $HCl_{(aq)}$ — spontaneous and exothermic

$H_2O_{(l)} \rightarrow H_{2\,(g)} + \frac{1}{2} O_{2\,(g)}$ — non-spontaneous

$H_{2\,(g)} + \frac{1}{2} O_{2\,(g)} \rightarrow H_2O_{(l)}$ — spontaneous and exothermic

Many spontaneous reactions are exothermic. But that's not all there is to it.

2 factors that favor spontaneity
- a) heat is released (exothermic)
- b) increase in disorder

2nd law of thermodynamics – in spontaneous changes, universe tends toward state of greater disorder

entropy (S) – a measure of the disorder of the system

analogies: hair spray comes out of can, dorm room gets messy during finals

the more ways an event can happen, the more probable that event is

$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings} > 0$

ex. some physical changes which increase entropy (disorder)

1) mixing of pure substances (Fig. 15-12)

2) some phase changes (ex. from s $\rightarrow$ l or l$\rightarrow$g)

3) increase in temperature (kin. E of gas)

4) increase in volume

$$Ba(OH)_2{\bullet}8H_2O\ (s) + 2NH_4SCN\ (s) \rightarrow Ba(SCN)_2\ (aq) + 2NH_3\ (l) + 10H_2O\ (l)$$

This is an acid/base reaction (NH_4^+ is the acid)

It is endothermic (heat consumed) but spontaneous. Why does it happen?

Entropy of system must increase

solids	$\rightarrow$	liquids and solutions
3 mole reactants	$\rightarrow$	14 mole products

ex. some chemical changes which increase entropy

1) # particles (moles) increase (demo)

2) # moles of gas increase

$$C_8H_{18}\ (g) + 5O_2\ (g) \rightarrow 9H_2O\ (l) + 8CO_2\ (g)$$

6 moles gas	$\rightarrow$	8 moles gas

$C_3H_8\,(g) \quad + \quad 5O_2\,(g) \quad \rightarrow \quad 4H_2O\,(l) \quad + \quad 3CO_2\,(g)$

6 moles gas $\rightarrow$ 3 moles gas

spontaneous reactions can

1) be exothermic

   or

2) cause increase in entropy of system

   or

3) both #1 & #2

ΔS_{system} affects ΔE_{system}

Can we quantify entropy (like we quantified heat earlier in this chapter)?

<u>absolute standard molar entropy</u> – (appendix K) quantifies disorder in a substance at 298 K. + #

<u>3rd law of thermodynamics</u> – A perfect, pure crystalline material (ordered) at 0 K has absolute S = 0.

Note –H and E we don't have an absolute scale (we measure Δ). S does.

$$\Delta S^o_{rxn} = \Sigma n S^o_{prod} - \Sigma n S^o_{react}$$

<u>Gibbs free energy</u> (G) – amount of E available for system to do *useful* work (at constant T, <u>P</u>)

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

Quiz #1

Write name, SID #, and Quiz # on paper – everyone has their own
Work in groups – turn your papers in together

For each of the following processes, tell whether the entropy of the system increases, decreases, or stays the same:

1) freezing one mole of water to ice at 0ºC
2) a building collapses
3) silver sulfate [Ag_2SO_4] precipitates from a solution containing silver ions and sulfate ions.
4) 35 pennies are taken out of bag and placed on table, heads up.