20.1 Spontaneous Reactions and Speed: Thermodynamics vs. Kinetics

- Product favored reaction (spontaneous)
- Reactant favored reaction (non-spontaneous)
- Thermodynamics
- Kinetics
- Review terms
  - System
  - Surroundings
  - Exothermic
  - Endothermic
  - 1st Law of Thermodynamics
  - Enthalpy change
  - State function
  - Standard conditions
  - Enthalpy of formation

20.2 Direction of Reactions: Entropy

- Dispersal of Energy and Matter
- Entropy: A Measure of Matter Dispersal or Disorder (Exercises 20.1 and 20.2)
  - GASES >>> LIQUIDS >>> SOLIDS *(SCATTER KIDS ON A PLAYGROUND)*
  - COMPLEX >>> SIMPLE *(CAR VS. BICYCLE)*
  - AS BONDS WEAKEN *(MORE MOVEMENT)* (+)
  - DISORDER *(SOLUTIONS)* (+)
  - GAS ESCAPES (+)
- Entropy and the Second Law of Thermodynamics *(Total entropy of the universe is continually increasing)*
  - $\Delta S_{universe} > 0$ (positive)
  - Calculating the Entropy Change for a System (Example 20.1 and Exercise 20.3)
    - $\Delta S^\circ_{system} = \sum \Delta S^\circ(\text{products}) - \Delta S^\circ(\text{reactants})$
  - Calculating the Entropy Change in the Surroundings
    - $\Delta S^\circ_{surroundings} = \frac{q_{surroundings}}{T} = -\frac{\Delta H_{system}}{T}$
- Calculating the Total Change for System and Surroundings (Table 20.2) (Exercises 20.4 and 20.5)

ΔH_{system}		ΔS_{system}		Product Favored?
-, negative	Exothermic	+, positive	Less order	YES
-, negative	Exothermic	-, negative	More order	Generally Yes (Lower T)
+, positive	Endothermic	+, positive	Less order	Generally Yes (Higher T)
+, positive	Endothermic	-, negative	More order	NO

20.3 Gibbs Free Energy

Gibbs Free Energy Equation, $\Delta G^{\circ}_{system} = \Delta H^{\circ}_{system} - T\Delta S^{\circ}_{system}$

What happens when both ΔH°_{rxn} and ΔS°_{rxn} have the SAME SIGN?

ΔH_{system}		ΔS_{system}		$\Delta G^{\circ}_{system}$
-, negative	Exothermic	+, positive	Less order	-, negative, PRODUCT FAVORED
SAME		SAME		Look at T, ΔH_{system} and ΔS_{system}
+, positive	Endothermic	-, negative	More order	+, positive, REACTANT FAVORED

- Calculating ΔG°_{rxn}, the Free Energy Change for a Reaction (Exercise 20.6)
- Standard Free Energy of Formation, ΔG°_{f} (Example 20.3, and Exercises 20.7 and 20.8)
  - $\Delta G^{\circ}_{reaction} = \sum \Delta G^{\circ}_{f}(\text{products}) - \Delta G^{\circ}_{f}(\text{reactants})$
- Product-favored or Reactant-favored? (Exercise 20.9)
  - Enthalpy driven
  - Entropy driven
- Free Energy and Temperature (Exercise 20.10)

20.4 Thermodynamics and the Equilibrium ($\Delta G = 0$) Constant (Examples 20.4, 20.5 and 20.6; Exercises 20.11 and 20.12)

Thermodynamic equilibrium ($\Delta G = 0$) constant, $\Delta G^{\circ} = -RT \ln K$

ΔG°	K	Product formation
$\Delta G^{\circ} < 0$ (Negative)	K > 1 (Positive)	Product favored
$\Delta G^{\circ} = 0$	K = 1	Equilibrium
$\Delta G^{\circ} > 0$ (Positive)	K < 1(Negative)	Reactant favored

20.5 Thermodynamics and Time (Examples 20.4, 20.5 and 20.6; Exercises 20.11 and 20.12)

1. The total energy of the universe is a constant (YOU CAN'T WIN!)
2. The total entropy of the universe is always increasing (YOU CAN'T BREAK EVEN EITHER! or THINGS ALWAYS TEND TO GO WRONG)
3. The entropy of a pure, perfectly formed crystalline substance at absolute zero is zero.

SUMMARY

ΔH°_{rxn}		ΔS°_{rxn}		ΔG°_{rxn}	K	Reaction outcome
-, negative	Exothermic	+, positive	Less order	-, negative	>1, positive	PRODUCTS
-, negative	Exothermic	-, negative	More order	- or +	Depends on T	Generally products at *lower* T
+, positive	Endothermic	+, positive	Less order	+ or -	Depends on T	Generally products at *higher* T
+, positive	Endothermic	-, negative	More order	+	<1, negative	REACTANTS