

## AP Chemistry – Thermochemistry and Thermodynamics

### Heat (q)

Heat is defined as the amount of energy exchanged between two systems.  
Generally losing heat means q is negative and gaining heat means q is positive

Units of heat are commonly Joules (J) or calories (cal) 4.18 J = 1 cal

### Temperature

proportional to the average KE of the molecules (think Boltzmann distribution) as long as temp is in Kelvin!

**\*\* Remember:**  
Temperature is NOT a measure of energy. It is only a reflection of the motion of the particles!

**Heat'em up...**

**Speed'em up**

### Enthalpy (ΔH)

Enthalpy is a molar heat value (multiply enthalpy by moles to get energy).

Units are typically  $\frac{\text{kJ}}{\text{mole}}$

**Most common types of enthalpy you should be familiar with:**

Enthalpy of reaction ( $\Delta H_{\text{rxn}}$ ), enthalpy of combustion ( $\Delta H_{\text{comb}}$ ), enthalpy of fusion ( $\Delta H_{\text{fus}}$ ), enthalpy of vaporization ( $\Delta H_{\text{vap}}$ )

Enthalpy of formation ( $\Delta H_f$ ) – heat absorbed or released when 1 MOLE of compound is formed (be able to write formation reactions!!!)

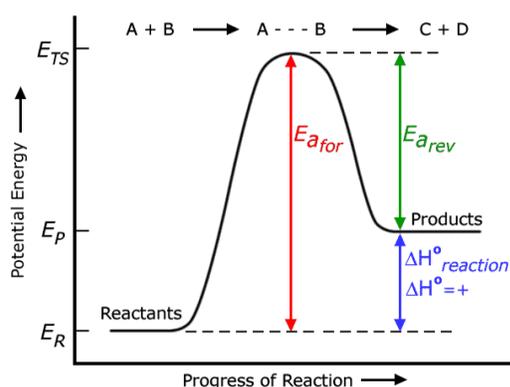
### Internal E change

$$\Delta E = q - P\Delta V$$

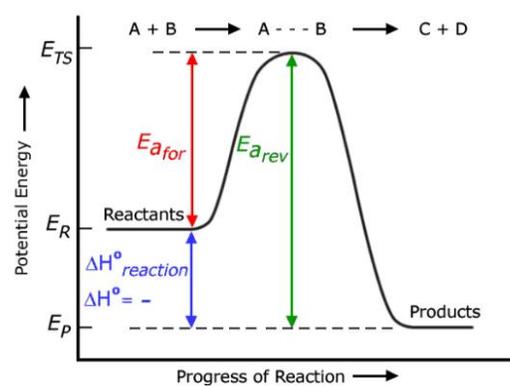
Changes in volume require work

(most of our reactions are done under constant volume conditions so  $\Delta E = q$ )

### Endothermic Energy Diagram



### Exothermic Energy Diagram



### Calorimetry (q = mcΔT)

Used to calculate the energy change associated with changing the temp of a specific mass of substance

Specific heat capacity (c) – heat required to raise the temp of 1 gram 1 degree Celsius (smaller c = change is faster)

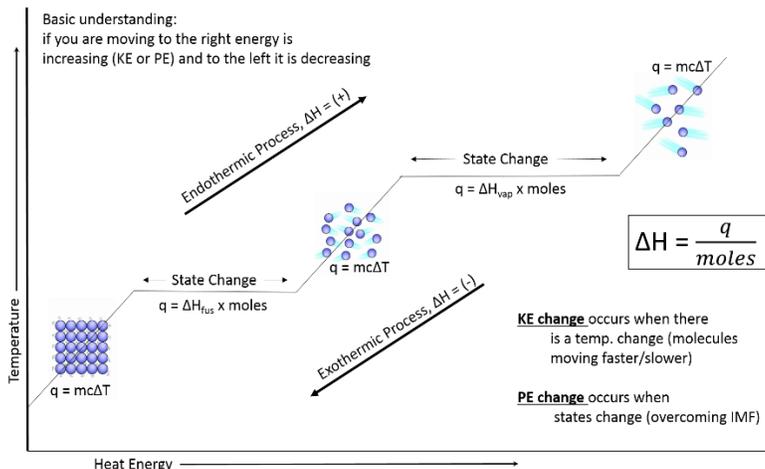
### Calculating ΔH<sub>rxn</sub> using ΔH<sub>f</sub>

$$\Delta H_{\text{rxn}} = \sum \Delta H_f (\text{products}) - \sum \Delta H_f (\text{reactants})$$

Don't forget to multiply by coefficients before summing!

### Heating Curve and Energy Changes

(cooling curves would be opposite)



Things to know:

1. State changes are physical changes
2. Calculating energy when temp goes up/down use...  $q = mc\Delta T$
3. Calculating energy associated with state changes...  $q = \Delta H \times \text{moles}$
4. If temperature change KE energy changes
5. Energy required to change states is PE b/c overcoming IMFs (stronger IMFs require more energy)
6. Equilibrium exists during state changes

### Calculating $\Delta H_{rxn}$ using Bond Energies

Energy is required to break bonds (endothermic) and released (exothermic) when bonds form

Just total up bond energies (watch your signs here!) for the whole reaction

### Calculating $\Delta H_{rxn}$ using Stoichiometry

$$\Delta H \left( \frac{\text{kJ}}{\text{mole}} \right) \times \text{moles} = \text{Actual Energy value}$$

Trick alert: Watch for molar ratios not equal to 1!!!!

### Entropy ( $\Delta S$ )

In simple terms entropy is a measure of disorder of a system. The higher the disorder the higher the entropy.

All entropy values are positive (nothing will have a zero entropy value!) Entropy increases from solid  $\rightarrow$  liquid  $\rightarrow$  gas

Trick alert: Units of entropy are:  $\frac{\text{J}}{\text{K mole}}$

soo.... Make sure you convert before using with  $\Delta G$  or  $\Delta H$ !

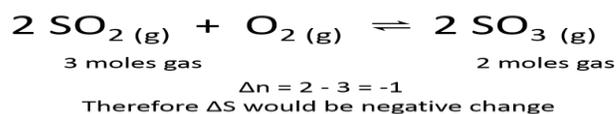
### Calculating $\Delta S_{rxn}$ using $\Delta S_f$

$$\Delta S_{rxn} = \sum \Delta S_f (\text{products}) - \sum \Delta S_f (\text{reactants})$$

Don't forget to multiply by coefficients before summing!

### Predicting Sign of Entropy

- Total moles of gas for each side of reaction (P/R)
- If moles of gas ( $\Delta n$ ) go up  $\Delta S = (+)$



### Gibbs Free Energy ( $\Delta G$ )

Free energy is what ultimately determines is a reaction is thermodynamically favorable. If a reaction is thermodynamically favorable it will happen (it won't if it is not favorable)

Units are typically  $\frac{\text{kJ}}{\text{mole}}$

**(-)  $\Delta G$   
Thermo  
Favorable**

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

Trick alert: be sure convert units of  $\Delta S$  AND at equilibrium  $\Delta G = 0$

### Calculating $\Delta G_{rxn}$ using $\Delta G_f$

$$\Delta G_{rxn} = \sum \Delta G_f (\text{products}) - \sum \Delta G_f (\text{reactants})$$

Don't forget to multiply by coefficients before summing!

### Law of Summation (adding reactions)

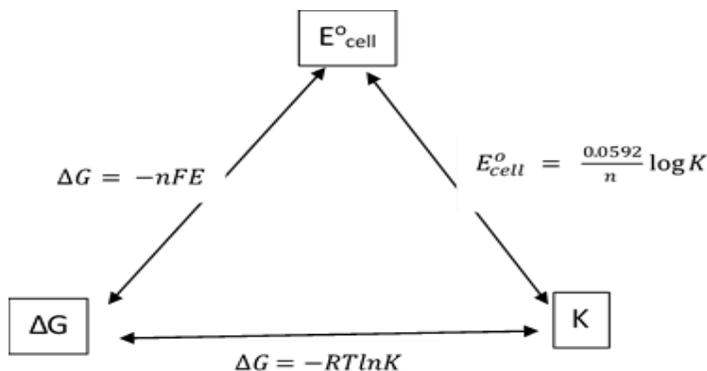
- For  $\Delta G$ ,  $\Delta H$ , and  $\Delta S$  we can add reactions to get overall



You would have to flip second reaction...



**DON'T FORGET TO CHANGE THERMO VALUES IF YOU CHANGE RXNS**



### 4 SCENARIOS TO KNOW FOR G

$\Delta H$	$\Delta S$	Effect on $\Delta G$
Neg	Pos	$-\Delta G$ , favorable at all temps
Pos	Pos	$-\Delta G$ , favorable at HIGH temps
Neg	Neg	$-\Delta G$ , favorable at LOW temps
Pos	Neg	$+\Delta G$ , NEVER favorable

### Relationships between $\Delta G$ , K and $E_{cell}$

$\Delta G$	K	E
0	At equilibrium, $K=1$	0
Negative	$K > 1$ , products favored	Positive
Positive	$K < 1$ , reactants favored	Negative