Heat of Formation

THERMODYNAMICS / ELECTROCHEMISTRY

$$q = mc\Delta T$$

$$\Delta S^\circ = \sum S^\circ \text{ products} - \sum S^\circ \text{ reactants}$$

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \sum \Delta G_f^\circ \text{ products} - \sum \Delta G_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$
$$= -RT \ln K$$
$$= -nFE^\circ$$

$$I = \frac{q}{t}$$

$$E_{cell} = E^\circ_{cell} - \frac{RT}{nF}\ln Q$$

q = heat
m = mass
c = specific heat capacity
T = temperature
S° = standard entropy
H° = standard enthalpy
G° = standard Gibbs free energy
n = number of moles
E° = standard reduction potential
I = current (amperes)
q = charge (coulombs)
t = time (seconds)
Q = reaction quotient

Faraday's constant, F = 96,485 coulombs per mole of electrons

$$1 \text{ volt} = \frac{1 \text{ joule}}{1 \text{ coulomb}}$$

Enthalpy of formation

$$2Al_{(s)} + Fe_2O_{3(s)} \rightarrow Al_2O_{3(s)} + 2Fe_{(s)}$$

- Using enthalpies of formation, calculate the standard change in enthalpy for the thermite reaction:
- This reaction occurs when a mixture of powdered aluminum and iron(III) oxide is ignited with a magnesium fuse.

Standard Enthalpy of Formation ΔH_f (kJ/mol)	
$NH_{3(g)}$	-46
$NO_{2\,(g)}$	34
$H_2O_{(l)}$	-286
$Al_2O_{3(s)}$	-1676
$Fe_2O_{3(s)}$	-826
CO_2	-394
$CH_3OH_{(l)}$	-239
$C_8H_{18(l)}$	-269

Enthalpy

Methanol (CH_3OH) is often used as a fuel in high-performance engines in race cars. Using the data in Table, compare the standard enthalpy of combustion per gram of methanol with that per gram of gasoline. Gasoline is actually a mixture of compounds, but assume for this problem that gasoline is pure liquid octane (C_8H_{18}).

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Summary

- When a reaction is reversed, the magnitude of ΔH remains the same, but the sign changes.
- When the balanced equation for a reaction is multiplied by an integer, the value of ΔH for that reaction must be multiplied by the same integer.

Summary II

- The change in enthalpy for a given reaction can be calculated from the enthalpies of formation of the reactants and products:
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$$\Delta H_{rxn}^\circ = \Sigma m\Delta H_f^\circ{}_{(products)} - \Sigma n\Delta H_f^\circ{}_{(reactants)}$$

- Elements in their standard states are not include in the ΔH_{rxn}° calculations. That is, ΔH_f° for an element in its standard state is 0.

Laws of Thermodynamics

Intro

Most natural events involve a decrease in total energy and an increase in disorder.

- The energy that was "lost" was converted to heat.
- An increase in energy/motion decreases the overall order (organization) of the system.
- Energy is never created nor destroyed it simply changes form.

Entropy and heat

- Entropy is a measure of randomness or disorder of a system.
- Entropy gets the symbol S
- Heat energy is the kinetic energy of an object.
- The more motion in an object the more random it becomes.

Thermodynamics

- Thermo – heat; dynamic- change or motion.
- Thermodynamics- conversion of heat energy (into other forms or objects).
- 1^{st} Law of Thermodynamics- the amount of energy in the universe is constant. Law of conservation of energy.
- 2^{nd} Law of Thermodynamics- Spontaneous processes, ones that happen on their own, involve an increase in entropy. Entropy in the universe is always increasing.

Heat

- ~is the total thermal energy of an object.
- Like all energy, heat is measured in joules (J)
- The terms hot, warm, cool and cold are always relative.
- Heat is only noticed when there is a ***transfer*** from one object to another.
- Heat always flows from hot to cold.
- This due to the 2^{nd} law of thermodynamics.

Kinetic Energy

- All atoms/molecules in any object are moving.
- The faster they are moving the more kinetic energy an object has.
- The heat energy or thermal energy is the total (sum of) kinetic energy of all particles in an object.

Temperature

- Temperature is a measure of the **intensity** of the heat energy present.
- This is measured by the average kinetic energy of all atoms/molecules present.
- In other words, it's the average amount of heat energy that will transfer.
- Temperature is measured in Fahrenheit, Celsius or Kelvin.

Units of Temperature

- Here are some common temperatures in the different scales

COMMON TEMPERATURES	F	C	K
freezing point of water	32	0	273
room temperature (comfortable)	68	20	293
human body temperature	98.6	37	310
Boiling point of water	212	100	373

Converting between temperature units

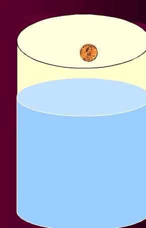
- Kelvin = 273 + Celsius
- (9/5 Celsius) + 32 = Fahrenheit
- Convert 65° F to C and K
- 18° C, 291 K
- Convert 301 K to C and F
- 28° C, 82° F

Two objects

- When two objects of different temperatures are next to each other heat will transfer from the higher temperature to the lower temperature object.
- By the 2nd law of thermodynamics
- This is not necessarily the object with more energy.
- Consider a hot penny dropped into a large cup of room temperature water.

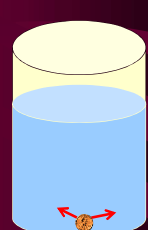
Penny and water

- Here is a hot penny about to be dropped in a large cup of water.
- The penny will have a higher temperature, intensity of heat energy, but the water will have to have more thermal energy due to the amount of water present.



Penny and water

- When dropped in, the penny sizzles, and the heat flows from the penny into the water.
- This is obvious, since you can now touch the penny.
- Even though the water had more total energy than the penny.
- This increases entropy.



The Zeroth Law of Thermodynamics

- If two different systems or objects are at thermal equilibrium with the same object, then they must be at thermal equilibrium with each other.
- Another way to state this is they must all be at the same temperature and therefore no transfer of heat will take place.

Zeroth Law of thermodynamics

- So back to the penny in the cup of water.
- They are now at thermal equilibrium.
- If a spoon is introduced to the cup of water it will also reach a thermal equilibrium with the water.
- By this law, if the spoon and penny are removed, they are at thermal equilibrium, or the same temperature.

Matter without heat energy

- Solids have the lowest amount of kinetic energy, however their particles still vibrate.
- If you cool it until molecules no longer vibrate...
- it is theorized this occurs at -273.15^{o} C or - 459^{o} F or 0 K
- This is called ***absolute zero***. It is when all motion stops.
- Scientists have made it to 0.000 000 02 K

Third Law of Thermodynamics

- As the temperature of a body approaches absolute zero, all processes cease and the entropy approaches a minimum value.
- This minimum value is almost zero, but not quite.
- The law continues that…
- It is impossible for any procedure, no matter how idealized, to reduce any system to absolute zero in a finite number of steps.
- Laws explain what, not why.

Problems with forcing extremes

- Whenever you are heating something, heat is escaping somewhere.
- Why can't you melt steel on your stove?
- Natural gas flames are in the range of 1800-2000^{o} C
- Steel melts around 1400^{o}C, depending on the alloy.
- As it gets hotter more heat escapes to the surrounding area.
- You eventually reach a point where the amount of heat escaping the surrounding area equals the amount going into the substance.
- So it isn't getting heated anymore.

Cont.

- Now of course you can correct this problem by getting a hotter flame, or by better insulating the area around the steel.
- However, you would run into this same problem again at a higher temperature.
- Further corrections would be needed.

Reverse the problem

- Whenever you are cooling something, (removing heat, there is NO cold energy) heat is always entering from somewhere.
- This is why there is such difficulty getting to absolute zero.
- How do you stop any heat from being able to enter a substance?
- No one knows.
- Which leads us right back to the Third Law of Thermodynamics. "It can't be done" as a summary of all attempts so far.