Petroleum II- Notes

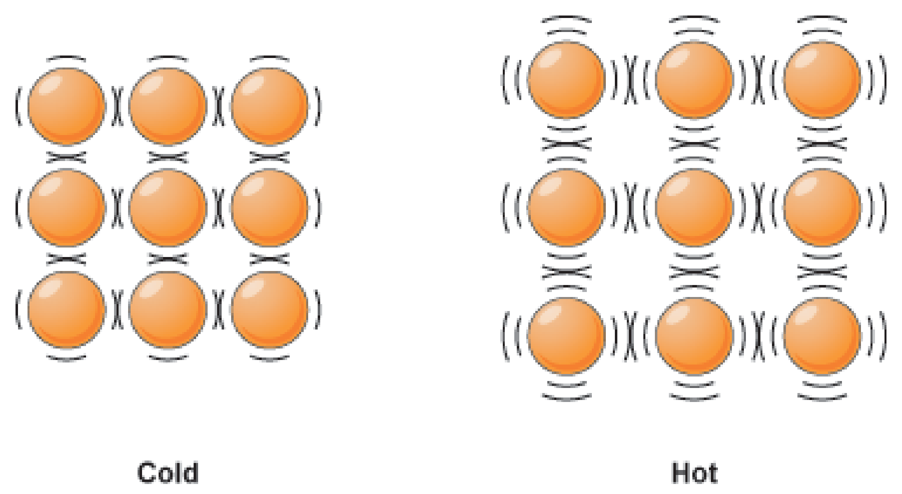
Unit 12, Chemistry Themed

Law of conservation of energy

- Conservation of Energy: Energy can neither be created nor destroyed
- You can’t “make” energy, you can only convert it
- When I burn something, don’t I “make” energy?
  - NO! You convert energy from chemical energy to thermal
  - Energy undergoes conversions all the time, but no new energy is ever made
- What is Energy efficiency?
  - The percentage of energy used for the intended purpose
  - Some energy if “wasted”, usually useless waste heat is generated
  - Cars are about 25% efficient and so are modern LED light bulbs
    - Most of the energy consumed by cars goes into waste heat rather than moving the car forward
    - Same for LED bulbs, but this about 6x more efficient that the older incandescent bulbs

Heat vs. Temperature

- Are heat and temperature are the same?
- Temperature is a measure of the average kinetic energy of an object
  - Kinetic energy is energy of motion – high temperature gases consist of fast-moving molecules; high temperature solids have fast-vibrating atoms
  - Below illustrates a fast-vibrating solid (one with a high temperature)
- Heat = flow of energy from high temperature object to cold ones



Specific Heat Capacity

- The ability to hold a lot of heat energy is called "Heat Capacity"
- If 1 g of H_2O absorbs 4.184 Joules of energy, it's temperature increases by 1° C
- Heat capacity is given the symbol C
- For water, C = 4.184 J/g/°C (you need to memorize this)

Calorimetry Equation

- Q is the symbol for heat
- The energy that flows into a cold object (and out of a warm one) is heat
- The amount of energy flow depends on three things
  - How massive an object is – big objects can absorb or release more heat energy
  - Heat capacity – objects with big specific heats can absorb or release more heat energy
  - Temperature change – lots of heat energy will increase an object's temperature
- These relationships are summarized by an equation:

$Q = mC\Delta T$

- The ability to hold a lot of heat energy is called "Heat Capacity"
  - Example: If 28 grams of water is warmed so that it's temperature rises from 14.1°C to 33.7°C
    - ΔT is the temperature change of an object. then $\Delta T = 33.7 - 14.1 = \underline{19.6°C}$
    - C = 4.184 J/g/°C (since the example is water, this would be different for a different material)
    - m = 28 grams
    - Q = the value of heat that flowed into the water. This energy came from some place since energy cannot be created or destroyed.

$Q = 28\text{ g} \times (4.184\text{ J/g/°C}) \times 19.6°C = \underline{2{,}300\text{ J}}$

Calorimetry Lab Example

- A hot cube of a mystery metal cube whose mass is 72.8 g is removed from hot 97.8° water and placed into a container of water. The water volume is 48.50 mL and prior to insertion of the metal cube, the water's initial temperature is 36.5°C. The metal and water reach a temperature of 45.3°C. What is the specific heat capacity of the mystery metal?

Solution:

- The heat gain by the water = heat lost by cube, or $Q_w = Q_m$
- $Q_w = mC\Delta T = 48.50\text{ g} \times 4.184\text{ J/g/°C} \times (45.3 - 36.5)\text{°C} = 1{,}790\text{ J}$ absorbed
  - Note: you know water's density = 1 g/mL, so 48.50 mL of water has a mass of 48.50 g
- $Q_m = mC\Delta T \rightarrow -1{,}790 = 72.8\text{ g} \times C_m \times (45.3 - 97.8)\text{°C}$
  - Note: negative is used since the metal LOSES heat (same amt. as water gained)
- $-1{,}790 = -3820\ C_m \rightarrow C_m =$ **0.468 J/g/°C**

Why does petroleum release energy?

- All of the energy available in petroleum is stored in high energy bonds
- When petroleum combusts, the high energy bonds break apart and are replaced with lower energy bonds in CO_2 and H_2O
- The extra energy available when low energy bonds are made is released (heat)
- Why/how were these high energy bonds made in the first place?
  - Millions of years ago (around the time of dinosaurs) ancient plants used photosynthesis to create energy stores (carbohydrates) from the sun's energy
  - Pressure, decay and many years turned these carbohydrates into hydrocarbons
  - When we burn petroleum, we're using energy stored from sunlight millions of years past

Endothermic vs. Exothermic

- Exothermic means energy is released
- Combustion is exothermic
- Endothermic means energy is absorbed
  - A cold pack is endothermic
  - If a reaction is endothermic, it feel cold; the products have higher energy bonds than the reactants (it feel cold, because it gets warmth from you when you touch it)

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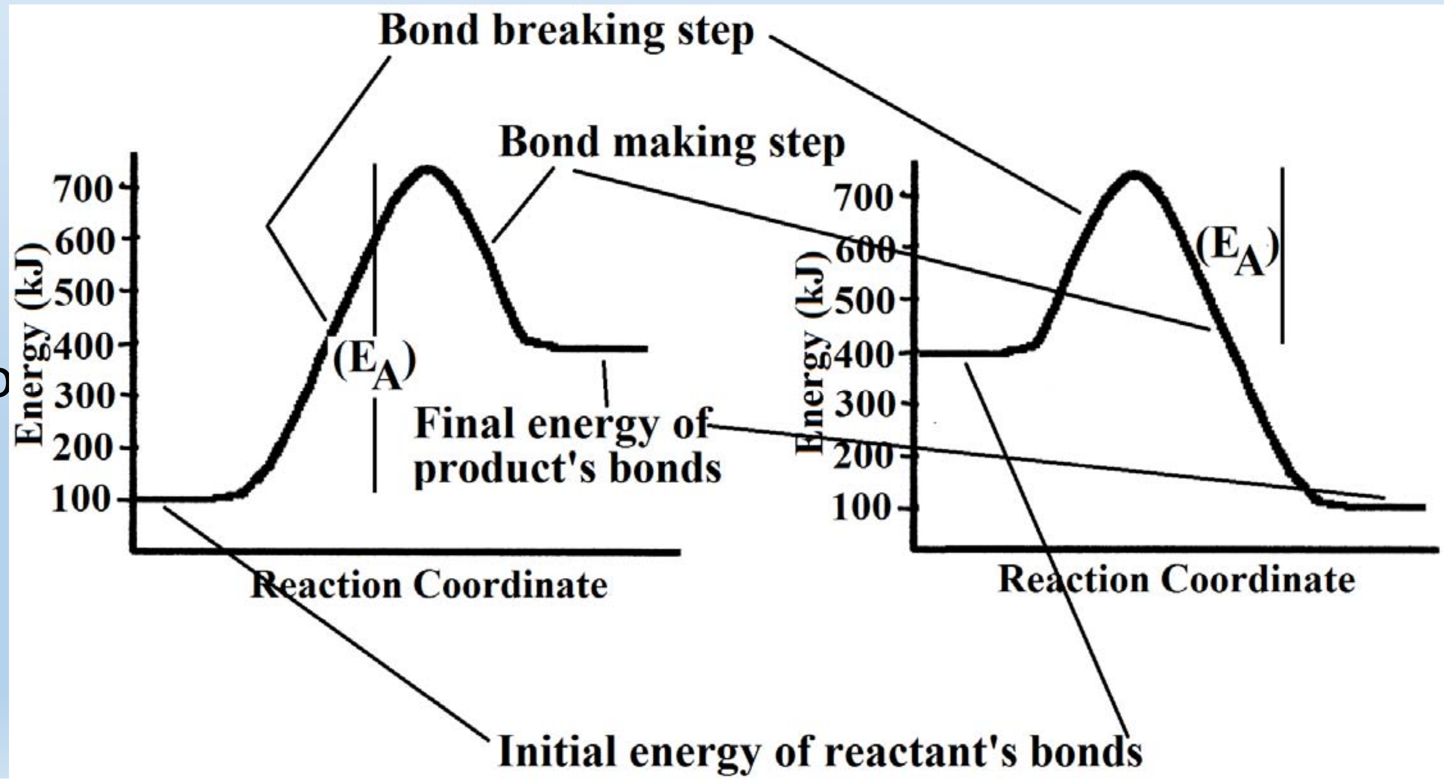
Understanding Energy Diagrams

- Left endothermic, right is exothermic
  - If the final energy is less than initial energy, then heat is released (like combustion)
- Bond breaking is endothermic step; bond breaking is exothermic
- Activation energy E_A is energy to get reaction started (why you need to light a candle….got to get it started)



Heats of combustion

- Two terms: Heat of combustion (kJ/g) and molar heat of combustion (kJ/mol).
- When balancing an equation, use molar heat of combustion, examples:
- $CH_4 + O_2 \rightarrow CO_2 + 2\ H_2O + 890\ kJ$
- $2\ C_2H_6 + 7\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O + 3120\ kJ$
- Note: Ethane BALANCE with a 2
- With two moles of ethane, energy balances with 2 x 1,560 kJ (see table)

Heats of Combustion

Hydrocarbon	Formula	Heat of Combustion (kJ/g)	Molar Heat of Combustion (kJ/mol)
Methane	CH_4	55.6	890
Ethane	C_2H_6	52.0	1560
Propane	C_3H_8	50.0	2200
Butane	C_4H_{10}	49.3	2859
Pentane	C_5H_{12}	48.8	3510
Hexane	C_6H_{14}	48.2	4141
Heptane	C_7H_{16}	48.2	4817
Octane	C_8H_{18}	47.8	5450

Heats of combustion
More examples

- How much energy is released by complete combustion of 12 g of propane? (6.0×10^2 kJ)
  - Start with given of 12 g; use table as conversion factor; final answer has two significant figures, like given does.

- How many moles of octane must be combusted to produce 250,000 kJ? (46 moles)
  - Start with given; use table as conversion factor; final answer has two significant figures, like given does.

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