Energy

Law of Conservation of energy

- Energy can not be created or destroyed ever!
- Energy is stored in the chemical bonds between atoms.
- In a chemical reaction, bonds are broken and new bonds are formed.
- The new bonds will require different amounts of energy than old bonds, so this results in a change in energy.
- Note: Chemical bonds are stable, so it takes energy to break bonds!

Endothermic vs. Exothermic

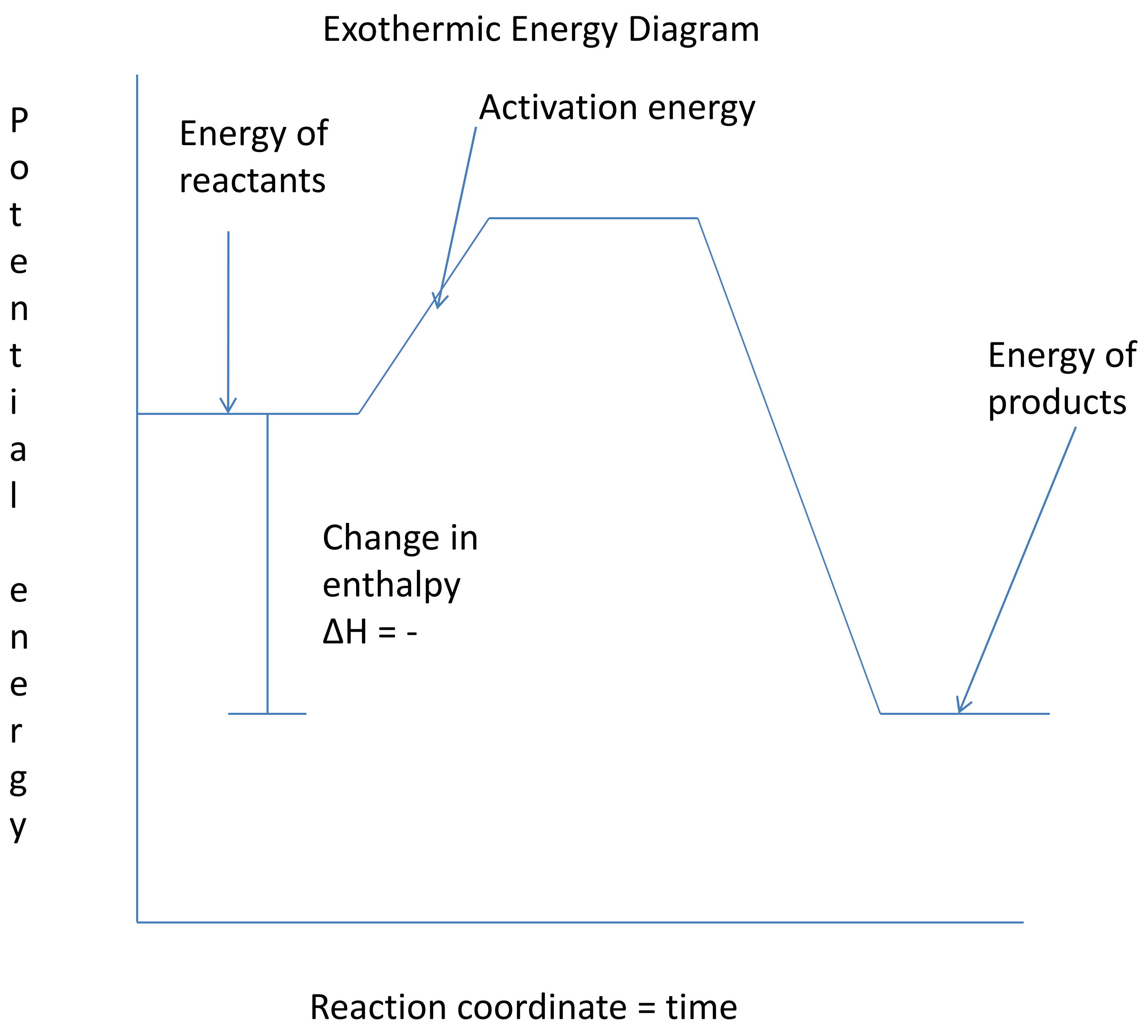
- If the bonds of the products require less energy than the bonds of the reactants, then the reaction will release energy.
- Releasing energy is exothermic (exo means out) and heat will be released.
- IF the bonds of the products require more energy than the bonds of the reactants, then they will need to absorb energy.
- Absorbing energy is endothermic (endo means in)

Energy Diagrams

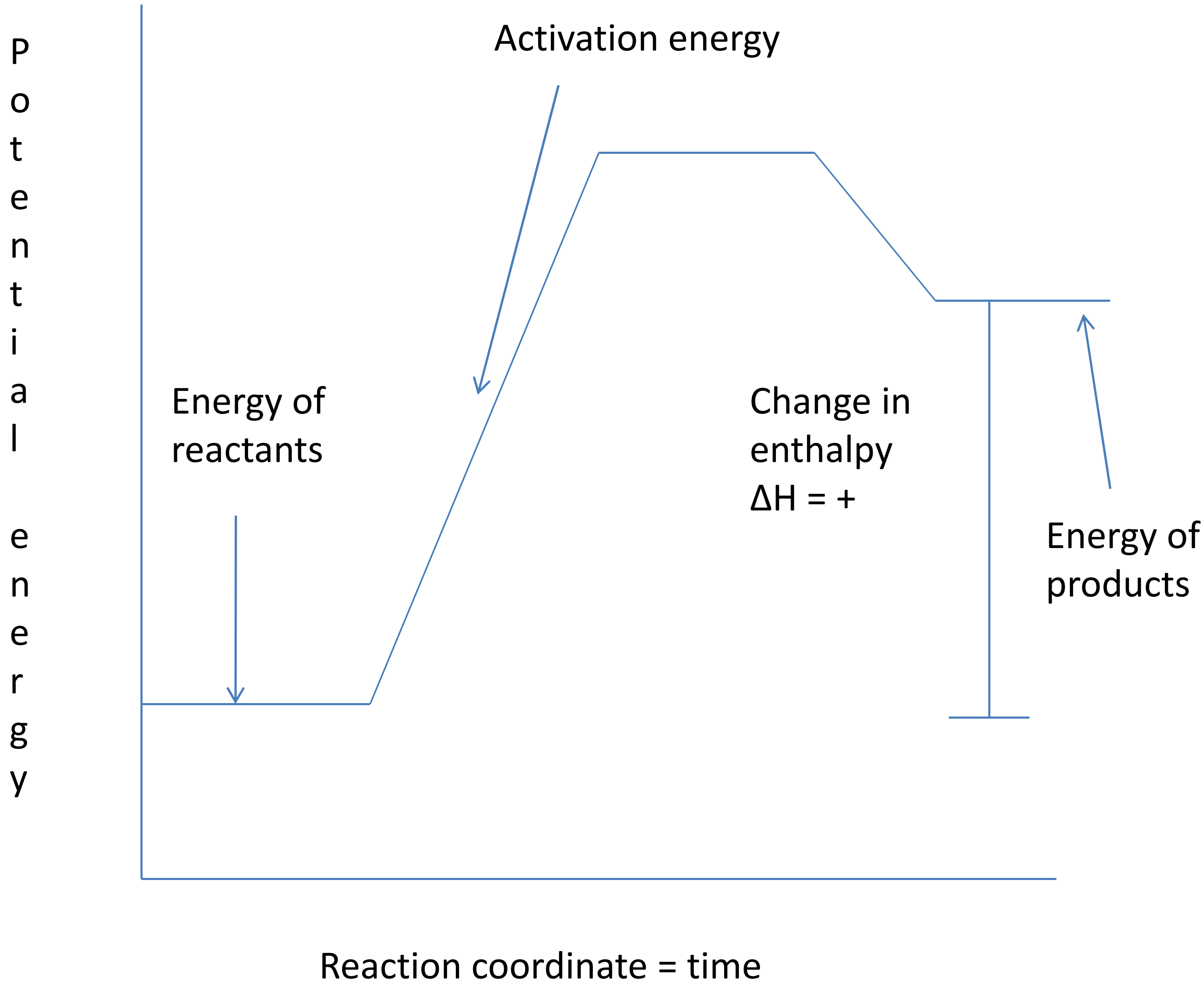
- All reactions have a starting potential energy value from their chemical bonds.
- They must gain energy to break the bond to be free to make new bonds. This energy gained is called the <u>activation energy</u>.
- After the reaction, the products will have a new potential energy value from the energy stored in the bonds.
- The difference between where the starting and final potential energies are is called the change in enthalpy or ΔH.

Change in Enthalpy

- If the change in enthalpy is positive ($\Delta H = +$), then the reaction gained energy.
- This is endothermic because the products have more energy than the reactants.
- If the change in enthalpy is negative ($\Delta H = -$), then the reaction lost energy.
- This is exothermic because the reactants had more energy than the products.


Exothermic Energy Diagram
Potential energy
Energy of reactants
Activation energy
Energy of products
Change in enthalpy ΔH = -
Reaction coordinate = time

Endothermic Energy Diagram



Things to notice in diagrams

- Activation energies are usually smaller for exothermic than endothermic reactions.
- Endothermic reactions require a constant supply of energy to continue, where exothermic reactions can reuse some of the energy that they produce to activate another reaction.
- Positive ΔH means more potential energy at the end of the reaction than the beginning, negative means the opposite.
- ΔH is only the difference between starting and ending energies and it does not matter how much activation energy is added in the middle.

Transfer of energy

- There is no way for us to measure the amount of energy released through a reaction directly.
- We can look at what happens to other substances though to figure it out.
- Substances around the reaction will absorb or lose energy depending on what the reaction does.
- When substances gain or lose energy, it effects the motion of the particles.
- Give the particles more energy and they move (or vibrate) faster, take energy away and they move (or vibrate) slower.

Temperature

- The energy of motion gets changed then as heat is added.
- This energy of motion is called kinetic energy
- We measure the average kinetic energy of a sample of molecules as the temperature.
- If energy is absorbed, then the temperature will go up because the molecules move faster.
- If temperature goes down, then energy was released because the molecules are moving slower.

Specific Heat Capacity

- Every substance has a resistance to temperature change meaning that it takes difference amounts of heat to change the temperature of different substances.
- This is the Specific Heat Capacity.
- Things that change temperature quickly have low specific heat capacities, things that change slowly have high specific heat capacities.
- Water has a specific heat of 4.184J/g ^{o}C
- This is actually high, so water resists temperature changes.

Temperature and Energy Relationship

- The effect that heat has on the temperature is determined by 2 factors.
  - how much the mass is
  - What the specific heat is
- This can be explained in equation form as follows:
- $\Delta H = m x C x \Delta T$
- ΔH you already know is the change in enthalpy (heat) in Joules.
- m is the mass in grams.
- C is the specific heat in J/g ^{o}C.
- And ΔT is the change in temperature in ^{o}C.

Calorimetry

- There are always two places you can be during a chemical reaction, a part of it, or around it.
- The part of it is only the things involved in the reaction itself. (balanced equation)
- The stuff around it is everything else. (the universe or surroundings)
- $\Delta H_{rxn} = - \Delta H_{surr}$
- The sign tells you which way the energy is moving.
- If the reaction is absorbing energy, that energy must be removed from the surroundings.
- If the reaction is losing energy then the surroundings are taking it in.

Calorimetry

- The determine what a reaction is doing, it is easier for us to measure what the surroundings are doing.
- We usually surround a reaction with water (or have the reaction take place in a solution) and then we measure the temperature change of the water.
- The ΔT of the water can be used to calculate the ΔH of the water ($\Delta H = mc\ \Delta T$)
- Then $\Delta H_{water} = - \Delta H_{rxn}$
- And if we know how many moles we reacted, we can get the J/mole.

Energy in Equations

- Two ways to write an exothermic reaction:
  - $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O \quad \Delta H = -2043kJ$
  - $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O + 2043kJ$
- Two ways to write an endothermic reaction:
  - $2NO_{2(g)} \rightarrow 2NO_{(g)} + O_{2(g)} \quad \Delta H = +112$ kJ/mol
  - $2NO_{2(g)} + 112kJ \rightarrow 2NO_{(g)} + O_{2(g)}$
- Notice if it is exothermic heat gets added to the right (it's a product of the reaction!)
- If it is endothermic then heat is added to the left (it's a reactant, or needed for the reaction to occur.)

Energy and Stoichiometry

- Once we know the J/mole, then we can look at the balanced equation and determine a molar relationship between energy and the moles of substances in the equation.
- This means stoichiometry can be done from moles of a substance to Joules.
- Ex. $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O \quad \Delta H = -2043\text{kj}$

Given 9.000g of water, how much heat is released?

$$9.000\text{g} \times \frac{1 \text{ mole}}{18\text{g}} \times \frac{-2043 \text{ kJ}}{4 \text{ mole } H_2O} = -255.4 \text{ kJ}$$

or 255kJ is released