Energy: the capacity to perform work.

-There are two main categories of energy:
1. Kinetic energy: energy of an object due to its motion.

2. Potential energy: Energy stored in matter.

Examples:
Flow of water and movement of a car are examples of kinetic energy.
- Ball at the top of a hill is storing potential energy.
- In the food, bonds between atoms have energy, but what kind of energy it is?
With respect to us it is potential energy. While for the atoms themselves it is kinetic! Because in these atoms, there are electrons **moving** all the time.

Why do reactions occur?
The reactants react to become more stable.
Products are more stable than reactants because they have **less** potential energy than reactants.

Stability is a common state for both reactants and products. True or false?
True, both reactants and products are stable but the reaction will occur to reach more stability.
 Since reactants are "stable", how would they react!!!
For this to occur, reactants should be converted to unstable state, after that they may:
1. React and restore their original state. Or,
2. Convert to new products that are more stable.

Here,
1. The **energy** required to convert stable reactants into unstable state is called: **Activation energy.**
This energy is necessary for all reactions to occur.
2. Reactants should be converted to unstable state called: **The Transition State.**

-Bond dissociation energy:
The energy needed to break down the bond between two atoms.
Its value is determined by the **type** and **number** of bonds involved.

Cl_2 (clack) is a single bond with bond dissociation energy =58 Kcal/mol.
N_2 (N≡N) is a triple bond with bond dissociation energy =226 Kcal/mol.

- **Notice that:** the greater is the number of bonds, the larger the amount of energy needed to break down these bonds.
-Importance of Bond dissociation energy:
For the calculations of energy value in our food

-In biochemistry there are two Theories that depend on energy were developed:

1. Thermodynamic theory.   2. Kinetic theory

Thermodynamics:

The study of energy transformations that occur in a collection of matter.
Therefore it is based on prediction (you predict how things will occur).

Differences between thermodynamics and kinetics:
Thermodynamics studies potential energy and energy transformation of any matter, it is NOT related to the mechanism, rate or pathway of a reaction.
However, kinetic theory explains things according to the motion .And it deals with mechanisms, pathways and rates of reactions.

Bioenergetics:
Studying thermodynamics (energy) in living organisms.

Laws of Thermodynamics:
-First law:
Energy cannot be created or destroyed but can be converted from one form to another.
(Energy of the universe is conserved.)

Importance of the first law:
If you are going in a reaction in a certain way and need certain amount of energy to convert reactants to products, you will get the same amount of energy by converting products to reactants.

-Second law:
All energy transformations are inefficient, which means that there is no reaction works with 100% efficiency.
Some energy is lost from the system (not from universe). This loss of energy could be in two forms:
1. Heat: some energy is used to perform work, while the excess will be lost as heat.
2. Entropy (disorder): spontaneous reactions are tending to increase in entropy.
(Entropy increases by converting the material from the solid state to the liquid or gaseous state in other words by making the bonds weaker and increasing the freedom of movement.)
So, some of the lost energy is used to reorganize this disorder of atoms.
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Free energy change:

$\Delta G = \Delta H - T\Delta S$
ΔG: the total energy change between reactants and products (free energy change).
 Enthalpy: ΔH
ΔS: entropy.
T:Absolute temperature (in Kelvin).

-Free energy change: the total energy change in a system with respect to its temperature.**-**
-Enthalpy (ΔH): A measure of the amount of energy associated with substances involved in a reaction. (Heat)
-entropy (ΔS): The amount of disorder in a system.

-Terms related to ΔH:

Exothermic: reactions release heat.
Endothermic: reactions absorb heat.

-Terms related to ΔG:
Endergonic: need (absorbs) energy.
Exergonic: release energy.

Note: ΔG and ΔH are both expressing the same thing (bond energies inside the matter) but the difference is that ΔG is concerned about the order of atoms while ΔH isn't. This is illustrated by the part "TΔS" of the equation above.

ΔG **ALWAYS** determine the spontaneity of the reaction, that is:
1: spontaneous reactions are **always** exergonic and favorable.
2: non-spontaneous reactions are **always** Endergonic and unfavorable.

Value of ΔG could be:
(+): Endergonic (non-spontaneous – unfavorable).
(-): Exergonic (spontaneous – favorable).

-does ΔH also determine the spontaneity? In other words, is there a relation between exergonic, exothermic and endergonic, endothermic?!
To answer this, let's return to the equation:
$\Delta G = \Delta H - T\Delta S$
Notice that ΔG, which determines the spontaneity, depends on both enthalpy and entropy. If ΔS increases, the effect of the second part of the equation will increase. Which means that ΔG may be negative (-). >> Spontaneous! **SO**: ΔH doesn't determine the spontaneity. (It is determined with respect to ΔH AND ΔS.)

Example:
When ice is melting, it cools the surrounding air, so we expect it is **Endothermic** reaction that absorbs heat from the surrounding environment. However, we also knew that melting of ice is a **spontaneous** reaction, which is at the end **Exergonic.** (The entropy increased by converting the ice into water).

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ΔG is the free energy difference in any system at any condition.
Another term is ΔG^0 or $\Delta G^{0`}$: is the free energy difference in any system at standard conditions (25^0, 1 M concentration, 7 PH)
ΔG is the term which determine whether the reaction is spontaneous (favorable) or not, NOT the **ΔG⁰**.
Why? Because ΔG^0 has certain value and it is standard (known for any reaction), and to determine the spontaneity we should deal with variable conditions not standard.
(To know if the reaction is favorable or not you have to calculate ΔG in the given conditions although you know ΔG^0)
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ΔG depends only on initial state and final state of biochemical pathways.
It is not affected by the mechanism or rate of the reaction.

Example :

If you have a reaction of 10 steps and you want to know if it will occur or not, what you are supposed to do?
You should calculate the ΔG between the reactant 1 and the final product (10)
(If you calculate ΔG in each step, then the summation of these small ΔGs is equal to total ΔG).
This prove that ΔG is not affected by the pathway.

How do reactions occur?

-There must be collisions between atoms or molecules to produce a reaction, also, these collisions have to be successful (in the correct direction that provides enough energy for activation). By this, atoms will reach activation energy then the transition state and the reaction occur.

-At room temperature there is collisions but not all of them produce reactions because the atoms may not collide in correct way to reach activation energy.

The rate of the reaction is affected by many factors:

1. Temperature: once you are increasing temperature. You are giving more kinetic energy, increasing the movement and increasing the chance to have successful collisions.

2. Concentration: increasing concentration also increases the chance to collide.

3. Presence of a catalyst (enzyme): doesn't affect ΔG value but it decreases the time needed for the reaction to occur by reducing the activation energy.