

Concept of Free Energy (Unit-II)

- * Living cell constantly perform work. They require energy for maintaining their highly organized structure, synthesizing cellular components, generating electric current and many other processes.
- * All chemical reactions in cell involve energy transformation for eg green plants transform radiant energy into chemical energy.
- * Thermodynamics is the study of energy transformation that occur in a collection of matter. It is concerned with the storage, transformation & dissipation of energy.
- * All the chemical, physical and biological processes are ultimately enabled and regulated by the laws of thermodynamics.
- * Cell need energy to do all their work.

Biological energy needs

To generate and maintain structure	To generate all kinds of movements	To generate concentration & electrical gradients across cell membrane	To maintain body temperature	To generate light in some animals
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* Bioenergetics is the quantitative study of energy relationships and energy conversions in biological systems. Biological energy transformations obey the laws of thermodynamics.

* The thermodynamic free energy is a concept useful in the thermodynamics of chemical or thermal processes and science.

* The free energy is a thermodynamic state function like the internal energy, enthalpy and entropy.

* The combination of entropy, temperature and enthalpy explain whether a reaction is going to be spontaneous or not.

* Free energy is discovered by J. Willard Gibbs in 1870, it is also called the Gibbs Free Energy. The symbol ΔG is used to define free energy.

* Free energy refers to the amount of energy available during chemical reaction to do cellular work.

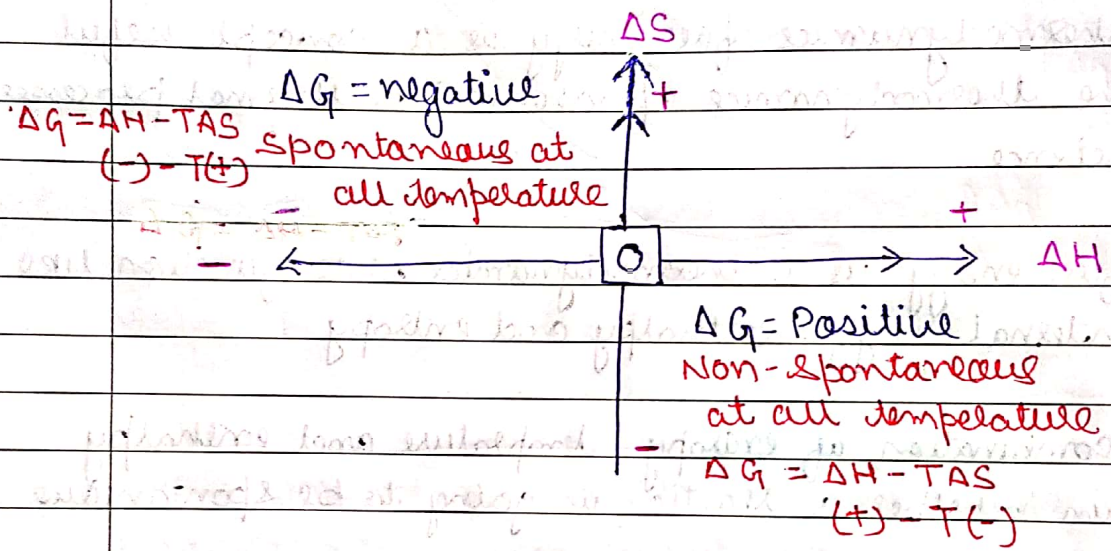
* The free energy equation is

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

where H = is the enthalpy
 T = is the temperature
 S = is the entropy

When ΔG is negative, it indicates that a reaction is spontaneous. A positive ΔG is a non-spontaneous reaction.

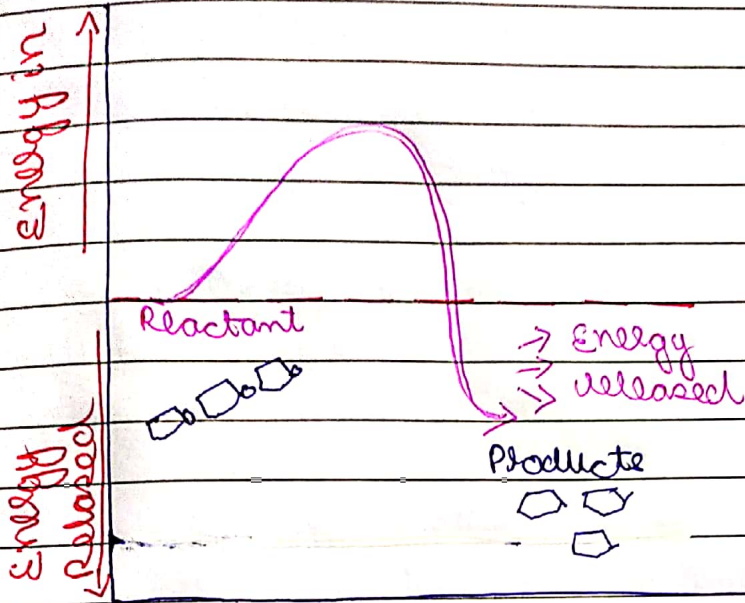
$$\Delta G = \Delta H - T\Delta S$$



* Spontaneous meaning that it will proceed without an input of energy. It is also known as exergonic meaning energy yielding.

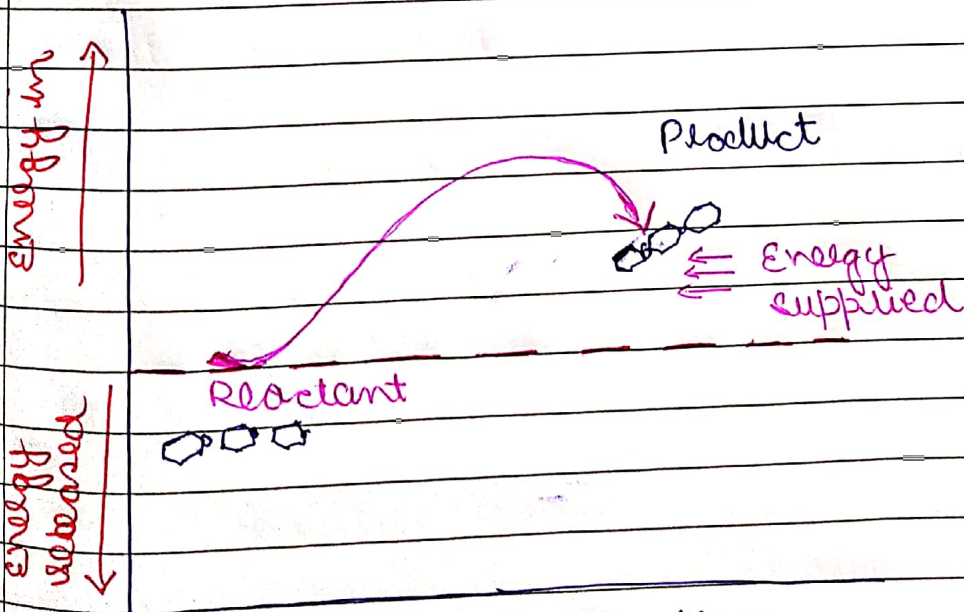
* Non-spontaneous meaning that an input of energy is required for reaction. It is also known as endergonic meaning energy consuming.

* The magnitude of free energy changes is very much a function of a particular set of conditions for that reaction.



Exergonic Reaction

Products have less energy than reactants
Energy released, spontaneous Entropy increases



Endergonic Reaction

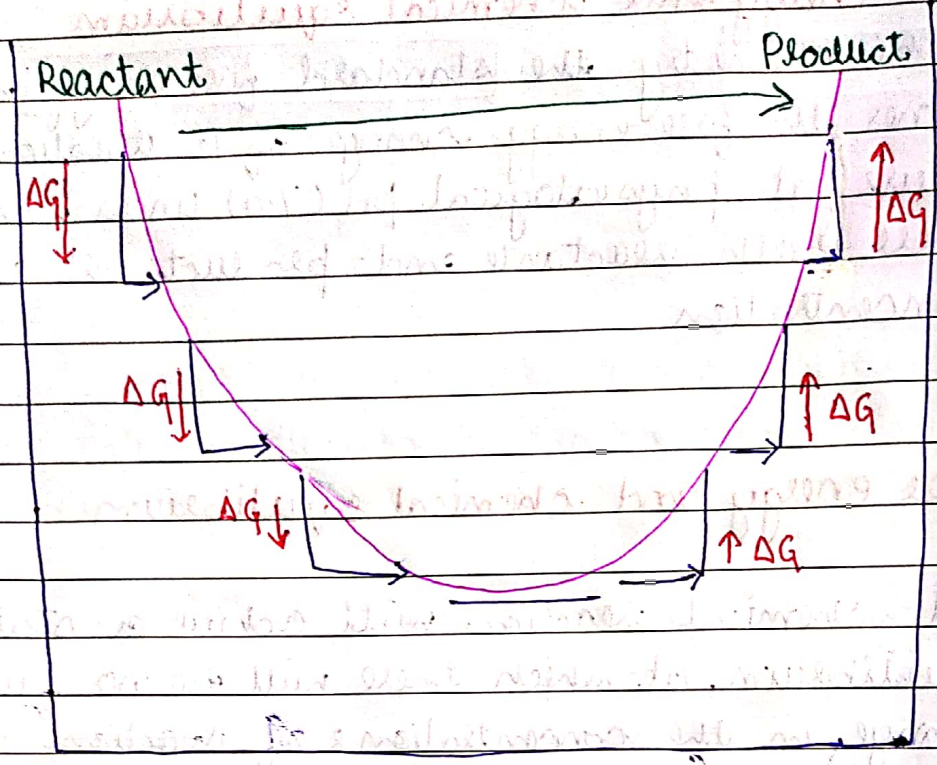
Products have more energy than reactants
Energy required, Non spontaneous Entropy decreased

* In biochemistry the standard free energy change, ΔG° , defines the free energy change of a reaction that occurs at physiological pH (7.0) under conditions where both reactants and products are at unit (1M) concentration.

Free energy and chemical equilibrium

- * All chemical reactions will achieve a state of equilibrium, at which there will be no further net change in the concentrations of ~~reactants~~ reactants and products.
- * There is a straight fairly relationship between free energy and chemical equilibrium.
- * This relationship, which is central to an understanding of bioenergetics is $\Delta H = \Delta G + T\Delta S$.
- * In a reaction where the reactant is converted to a product, K is the equilibrium mass-ratio - the ratio of concentration of products to the concentration of reactants, when the reaction has come to equilibrium.

$$K = \frac{[B]_{eq}}{[A]_{eq}}$$



The free energy of a reaction is a function of its displacement from equilibrium.

Vertical arrow indicate the slope of the free energy curve as change in free energy as reactant is converted into product.

Downward arrow indicate a negative free energy change and upward arrow indicate a positive free energy change.

★ The slope of the line represents the change in free energy ΔG when a small amount of the reactant A is converted to the product B. Several useful points can be obtained from this above diagram.

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1. At equilibrium, the slope of the line is zero. Consequently, the free energy change of reaction at equilibrium is zero.

2. The further mass action ratio is displaced from equilibrium (K), the greater the free energy change for conversion of the small amount of A to B.

66 The free energy change for a reaction is a function of its displacement from equilibrium. The further a reaction is poised away from equilibrium, the more free energy is available as the reaction proceeds toward equilibrium.

3. As A approaches equilibrium, ΔG is negative & free energy is available to do work. As the reaction proceeds past equilibrium towards B, ΔG is positive and energy must be supplied.

65 A system can do work as it moves towards equilibrium.

A If the reaction were initiated with pure B, the direction of the arrow would be reversed and work could be done as B approached equilibrium.

The relationship between the standard free energy (ΔG°) and equilibrium can be expressed quantitatively

$$\Delta G^\circ = -RT \ln K = -2.3 RT \log K \quad -1$$

and the actual free energy (ΔG) of a reaction not at equilibrium is given by

$$\Delta G = \Delta G^{\circ} + 2.3RT \log Q \quad - 2$$

where T equals the observed (i.e. nonequilibrium) mass action ratio. Equation 1 can then be substituted in equation 2 and rearranged to give

$$\Delta G = -2.3RT \log (K/Q) \quad - 3$$

Equation 3 reinforces the observation that the value of ΔG is a function of the degree to which a reaction is displaced from equilibrium.

→ When $T=K$, the reaction is at equilibrium. When T is less than K the value of ΔG is negative, i.e. positive when T is greater than K .

→ Finally, a reaction with a negative ΔG can drive a reaction with a positive ΔG , if they are biochemically coupled.