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P.G. Sem II, CC 7. Unit 1, Subunit 1.1

Topic: Laws of Thermodynamics, Internal Energy, Enthalpy, Entropy.

By

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Energy Transfer in biological System follows the Principles of Thermodynamics. The first law of thermodynamics, that is, the law of conservation of Energy speaks of constancy of quantum of Energy in the universe. In other way, one can say that energy cannot be created or destroyed. However, Energy can be transferred into different forms such as chemical, mechanical, Electrical or heat Energy. It can also be transferred from one place to another. Similarly, in a living System the total amount of Energy remains the same though it can be transferred from chemical to mechanical (muscle Contraction) or to Electrical Energy (transmission of nerve impulse).

Total Energy content in a System is calculated as **Heat Content** and named **Enthalpy** [H]. Enthalpy is, thus, the total Energy content of all chemical bonds present in the reactants and products. Change in Enthalpy due to a reaction is expressed as **ΔH**.

The **Second law of Thermodynamics**, explains that in the universe, there is a spontaneous tendency of increase in disorderliness or randomness called **Entropy (ΔS)**. Entropy can be understood better by visualising a child playing with models of alphabets of a language. When the free alphabets are kept at random in a box or container, the situation is of complete disorder or randomness, that is, entropy rich and does not carry any information in the form of words or sentences. However, when the child takes out the alphabets and arranges them in the a specific sequence to form a word or sentence, an information is created. Because the child puts in physical and mental energy. Thus, change from disorderliness (entropy rich) to orderliness (Entropy poor) requires Energy.

In a Cellular System, synthesis of nucleic acids, proteins and polysaccharides from their monomers require energy. Thus, these synthetic process lead to decrease in Entropy, but with enthalpy

Application of the two laws of Thermodynamics, determining the direction of Energy flow. The relation between ΔH and ΔS at absolute Temperature (T) determines loss or gain of energy, named free energy (ΔG) change.

$$\boxed{\Delta G = \Delta H - T\Delta S.}$$

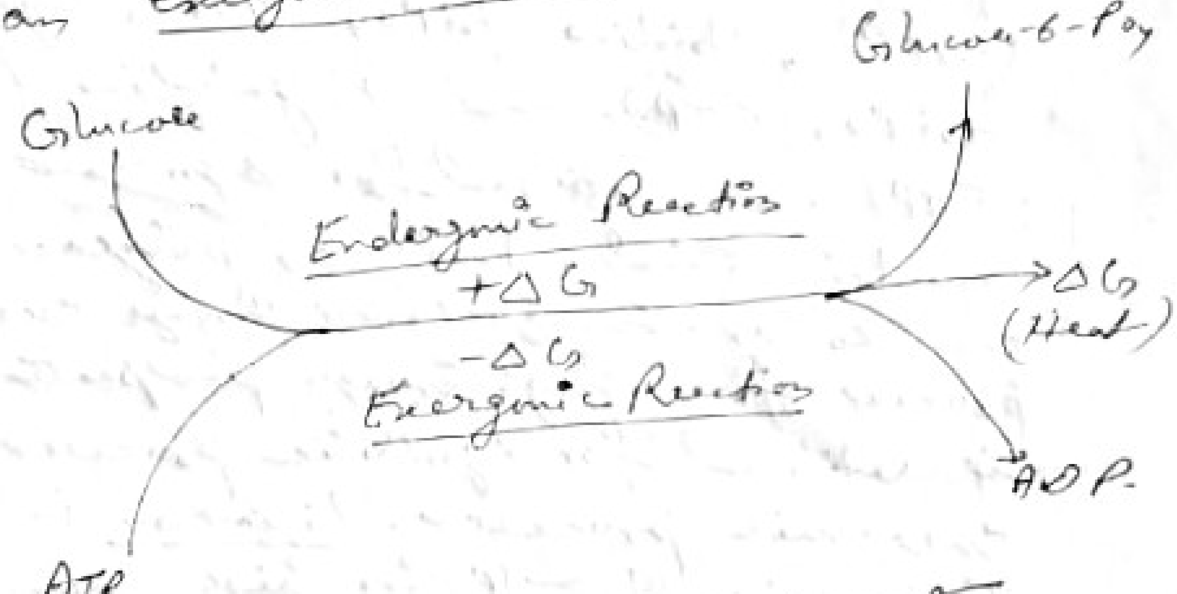
For all purposes practically, ΔH is approximate Total Energy (ΔE). in a living System

$$\boxed{\Delta G = \Delta E - T\Delta S}$$

Here,
ΔG = Change in Free Energy
ΔH = change in Enthalpy
T = Thermodynamic Constant
ΔS = change in Entropy.

Thus, increase in entropy (ΔS higher than ΔE) is due to loss of free energy that is, the reaction is **exergonic** ($-\Delta G$), Converse to it, gain of free energy ($+\Delta G$) leads to decline in entropy, which means the reaction is **Endergonic**. Unit of ΔG, ΔH and ΔE are calorie per mole or joule/mol. ΔS = Joule/mol kelvin or cal/mol kelvin.
T = absolute Temp = 25°C = 298 K.

In biological System, endergonic reactions are coupled with Exergonic reactions. First step of Glycolysis, phosphorylation of glucose to glucose-6-Phosphate, is an endergonic reaction (+ΔG) and is not possible without provision of free energy besides phosphate. Breakdown of Adenosine tri PO_4 (ATP) into Adenosine diphosphate (ADP) and Pi is an exergonic reaction (−ΔG). Hence, the two reactions get coupled by the action of the Enzyme Hexokinase and glucose gets phosphorylated to glucose-6-PO_4. As ATP breakdown generates more of energy than that used by phosphorylation, the surplus energy gets dissipated as heat lost. Hence, in totality phosphorylation of glucose is an <u>exergonic reaction</u>.



Coupling of Endergonic reaction to Exergonic reaction in Phosphorylation of glucose.

The entire biological world, whose basis is metabolic activities, runs on the free energy supplied by the Sun, the ultimate source of Primary Energy for all living organisms, directly or indirectly. Thus, the basic process of Enthalpy and Internal Energy is Photosynthesis, which involves both Exergonic and Endergonic Reactions. Animals utilise plants and their products as nutrients, which are degraded enzymatically to small molecular forms suitable for intestinal absorption and assimilation. The assimilated molecules are utilised for synthesis of high-energy compounds, biopolymers, vitamins and hormones. The high energy phosphates such as ATP, guanosine triphosphate (GTP), Uridine triPO4 (UTP), Cytidine triPO4 (CTP) and thymidine triPO4 (TTP) are utilised for synthesis of nucleic acids, proteins, polysaccharides and so on. Energy comes through exergonic process from high Energy phosphates and is utilised for synthetic processes through energonic processes. Lipmann introduced expression of ~(P) for high Energy bonds in high-energy phosphates. High Energy PO4es possesses different values for ΔG° after their hydrolysis.
