P.G. Sem II. CC 7. Unit-1, Subunit 1.2

Topic: Concept of Free Energy, Redox Potential, Energy Rich Compounds. (Part-I.)

By
Dr. Sunita Kumari Sharma
A.P. & P.G. Head
P.G. Dept. of Zoology
Maharaja College
Ara 802301

Concept of Free Energy:- Free Energy is that part of total Energy in a system, which is used (+ΔG) or released (−ΔG) for a reaction (here a biological metabolic reaction) to proceed. ΔG stands for change in free energy, in the honor of famous chemist J. W. Gibbs. In a Reversible reaction, free energy of a forward reaction is equal to the free energy of the backward reaction.

$$A + B \underset{-\Delta G}{\overset{+\Delta G}{\rightleftharpoons}} C + D$$

However, if a system fails to change, that is, the reaction doesnot proceed, the ΔG required is very high. Likewise, if the reactants maintain equilibrium; that is, no change is experienced in the system; free energy is zero.

In Exergonic reaction, after the loss of free energy, ΔG reaches zero and equilibrium is established. At equilibrium reaction, rates of both forward and backward reactions are equal, reactants and products are interchanging and ratio of their concentration remains constant.

Standard Free Energy (ΔG°)

When concentration of reactants and products are kept at 1 mol/L at standard conditions of pressure (gas pressure) and temperature (absolute temperature), the free energy is designated as ΔG°. In biological reactions, pH too is a component of standard conditions besides temp., pressure and concentrations of reactants and products. Standard free energy (ΔG°) at pH 7 is denoted by ΔG°. However, In physiological conditions, standard conditions of reactants, products, temperature, pressure and pH are not found. The symbol used for standard free energy is ΔG°. The relationship of ΔG to ΔG° has been derived as

$$\Delta G = \Delta G^{\circ} + RT. \ln \frac{[C][D]}{[A][B]}$$

where, ΔG = Free Energy

ΔG° = standard Free Energy.
R = gas Constant = 8.315 J/mol.K (Kelvin)
T = Absolute Temperature = 25°C = 298K
1 Cal = 4.184 Joule
ln = natural logarithm
[A] and [B] = molar Concentration of reactant.
[C] and [D] = molar Concentration of products.

It has been observed that ΔG equals ΔG° when concentration of reactants and products equal 1 mol/Lit under standard conditions of pressure and temperature.

$$\Delta G = \Delta G^\circ + RT. \ln \frac{[C][D]}{[A][B]}$$

$$= \Delta G^\circ + RT. \ln \frac{[1 mol/L][1 mol/L]}{[1 mol/L][1 mol/L]}$$

$$= \Delta G^\circ + RT. \ln 1$$

$$= \Delta G^\circ + RT \times 0$$

$$= \Delta G^\circ$$

Hence, ΔG° equals ΔG and direction of reaction can be predicted. However, ΔG° cannot predict direction of reaction under physiological conditions as follows.

1/ A reaction will proceed in forward direction even when ΔG° is positive. This is possible when the ratio of concentration of products and reactant is sufficiently small making RT.ln

$[C][D]/[A][B]$, large and negative causing overall ΔG negative.

2. Irrespective of actual concentration of reactants and products, rate of conversion of reactants and products into their subsequent changes; are equal. As far as equilibrium is maintained ratio of reactants and products will remain constant. The ratio of concentration of products and reactants at equilibrium is called Equilibrium Constant.

$$K_{eq} = \frac{[C]_{eq}[D]_{eq}}{[A]_{eq}[B]_{eq}}$$

3. If Equilibrium is maintained at standard conditions of pressure and temperature, overall free energy (ΔG) remains zero.

$$\Delta G = 0 = \Delta G^\circ + RT \ln \frac{[C]_{eq}[D]_{eq}}{[A]_{eq}[B]_{eq}}$$

$$\Delta G^\circ = -RT \ln \frac{[C]_{eq}[D]_{eq}}{[A]_{eq}[B]_{eq}}$$

$$= -RT \ln K_{eq}$$

4. If sum of overall free energy changes in different consecutive reactions is negative ($-\Delta G$), the reaction will continue even if free energy change at any particular reaction is positive [$+\Delta G$].

Contd - Part II