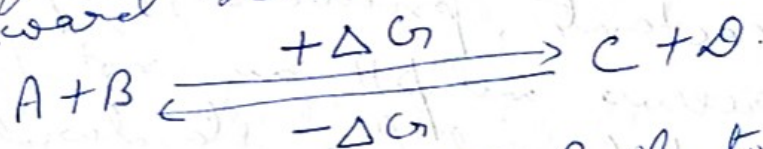


Topic: Concept of Free Energy, Redox Potential, Energy Rich Compounds.  
(Part-I)

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Concept of Free Energy:- Free Energy is that part of total energy in a system which is used (+ $\Delta G$ ) or released (- $\Delta G$ ) for a reaction (here a biological metabolic reaction) to proceed.  $\Delta G$  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.



However, if a system fails to change, that is, the reaction does not proceed, the  $\Delta G$  required is very high. Likewise, if the reactants maintain equilibrium, that is, no change is experienced in the system, free energy is zero.

(152)

In Exergonic reaction, after the loss of free energy,  $\Delta G$  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 concentrations remains constant.

### Standard Free Energy ( $\Delta G^\circ$ )

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  $\Delta G^\circ$ . In biological reactions, pH too is a component of standard conditions besides temp., pressure and concentrations of reactants and products. Standard free energy ( $\Delta G^\circ$ ) at pH 7 is denoted by  $\Delta G'^\circ$ . However, in physiological conditions, standard conditions of reactants, products, temperature, pressure and pH are not found. The symbol used for standard free energy is  $\Delta G^\circ$ . The relationship of  $\Delta G$  to  $\Delta G^\circ$  has been derived as

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

where,  $\Delta G$  = Free Energy

$\Delta G^\circ$  = standard Free Energy

R = gas Constant = 8.315 J/mol.K (Kelvin)

T = Absolute Temperature = 25°C = 298K

~~1 Cal~~ 1 Cal = 4.184 Joule

ln = natural logarithm

[A] and [B] = molar concentration of reactants

[C] and [D] = molar concentration of products

It has been observed that  $\Delta G$  equals  $\Delta G^\circ$  when concentrations of reactants and products equal 1 mol/lit under standard conditions of pressure and temperature.

$$\begin{aligned} \Delta G &= \Delta G^\circ + RT \ln \frac{[C][D]}{[A][B]} \\ &= \Delta G^\circ + RT \ln \frac{[1 \text{ mol/l}][1 \text{ mol/l}]}{[1 \text{ mol/l}][1 \text{ mol/l}]} \\ &= \Delta G^\circ + RT \ln 1 \\ &= \Delta G^\circ + RT \times 0 \\ &= \Delta G^\circ \end{aligned}$$

Hence,  $\Delta G^\circ$  equals  $\Delta G$  and direction of reaction can be predicted. However,  $\Delta G^\circ$  cannot predict direction of reaction under physiological conditions as follows.

1 A reaction will proceed in forward direction even when  $\Delta G^\circ$  is positive. This is possible when the ratio of concentrations of products and reactants is sufficiently small making  $RT \ln$

$[C][D]/[A][B]$ , large and negative causing overall  $\Delta G$  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 concentrations 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 ( $\Delta G$ ) 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 of any particular reaction is positive  $[+\Delta G]$ .

Control - part II