METABOLISM

بسم الله الرحمن الرحيم

MID – Lecture 1

Bioenergetics (Pt.1)

﴿ وَإِن تَتَوَلَّوْاْ يَسْتَبْدِلْ قَوْمًا غَيْرَكُمْ ثُمَّ لَا يَكُونُوٓاْ أَمْثَٰلَكُم ﴾

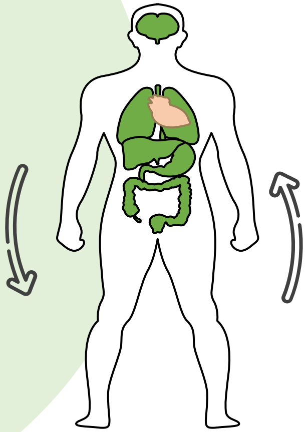
اللهم استعملنا ولا تستبدلنا

Written by:

- Laith Alhuniti
- Mahmood Alabsi

Reviewed by:

- Laith Joudeh



What is ENERGY? Why do we need it?

- **Definition: Capacity to perform work**

- **What for? Mechanical, Active transport, Biosynthesis, Heat**

- **Types of energy:**
  - ✓ **1- Kinetic: Energy in the process of doing work or Energy of motion**

  - ✓ **2- Potential: Energy content stored in a matter such as chemical bonds**
- **Whether a reaction occurs or not!**
- Bioenergetics describes the transfer and utilization of energy in biologic systems

Also, heat is another type of energy.

Purposes of metabolism

- **Metabolism: Sum of all biochemical reactions in living organisms**

Metabolism is distinct from digestion. Digestion breaks down food into smaller components that the body can absorb. Once these nutrients are absorbed into the cells, they become involved in metabolic processes.

- **Mainly for energy generation**
- **Other purposes:**
  - Synthesis of building blocks
  - Synthesis of macromolecules
  - Degradation of biomolecules

Building Blocks are molecules used to build other molecules.

Such as glycogen.

- **Bioenergetics: Energy transformations in the cell**

Free energy terms

- ΔG = the free energy difference of a system at any condition.

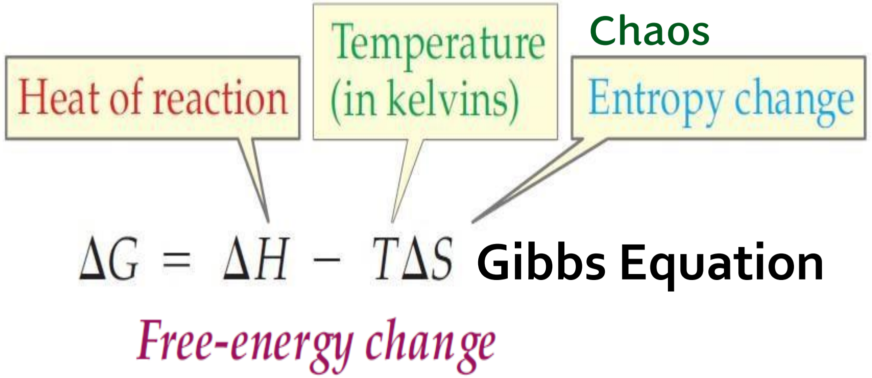
  Alternate definition: $G_{Products} - G_{Reactants}$
- ΔG^o = the free energy difference of a system at standard conditions (25C° & 1 atmospheric pressure, 1M concentration of reactants & products, pH = 7)

Note that:

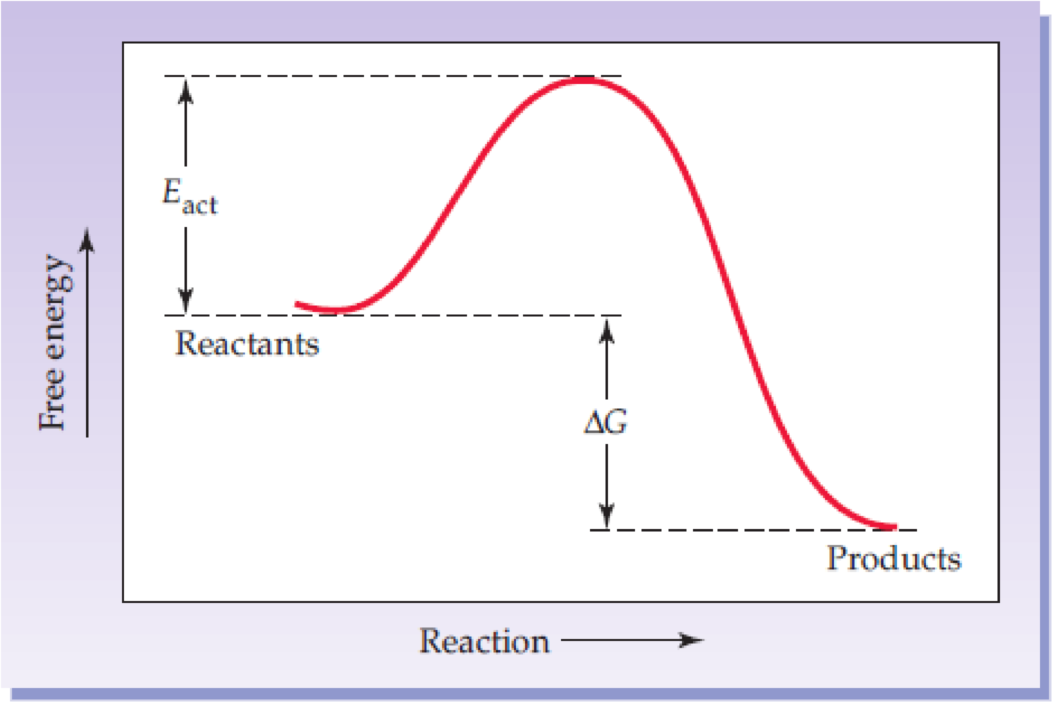
Physiological conditions often differ from standard laboratory conditions. A 1M concentration is significantly higher than typical physiological concentrations, which are usually much lower. Moreover, the standard laboratory temperature does not match the body's temperature.

Why do chemical reactions occur?

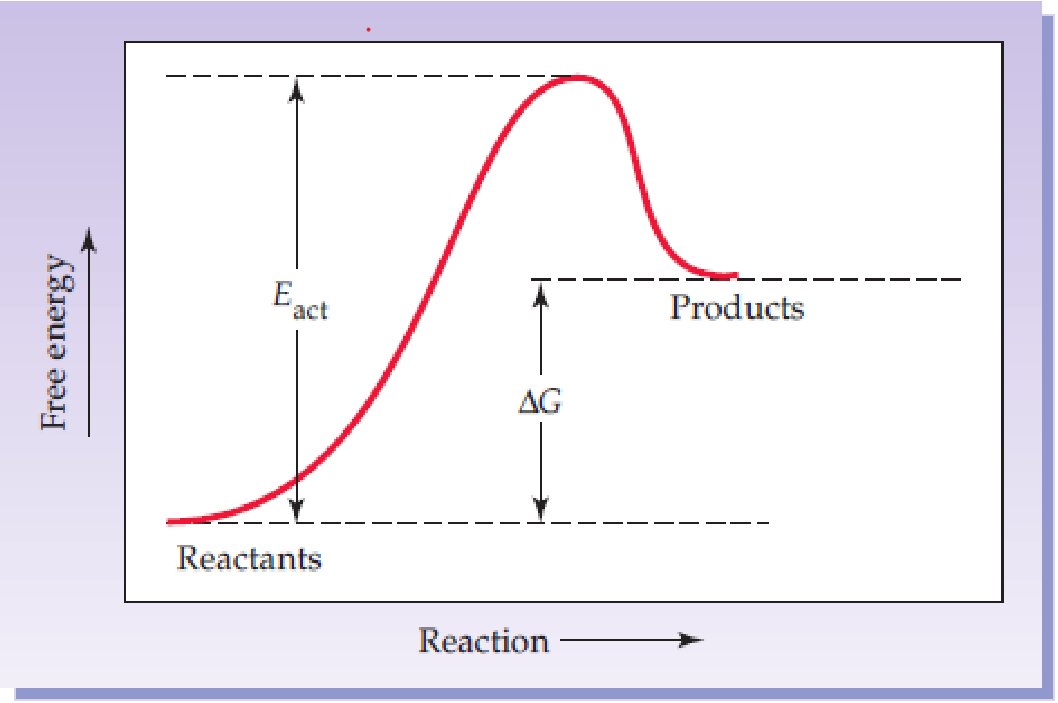
- Free energy change; with respect to its temperature
- Enthalpy; Entropy; Exergonic vs. endergonic; spontaneity
- The concept of activation energy



ΔH: Change in enthalpy.
Enthalpy is a type of energy, so it doesn't represent the entire ΔG; it is only a part of it.



(a) An exergonic reaction



(b) An endergonic reaction

ΔG, GIBBS FREE ENERGY

$$A \rightleftharpoons B$$

Equilibrium refers to a state where the forward and reverse reactions, from A to B and from B to A, occur at the same rate, resulting in no net change in the concentrations of reactants and products. Equilibrium can only occur in reversible reactions.

- This equilibrium is not determined by enzymes but determined by thermodynamics.

- If equilibrium is shifted more towards A, you will not change the equilibrium by adding any amount of enzyme to the reaction.

- What determines the equilibrium between them? Gibbs free energy.

- ΔG which is related to equilibrium constant and can be used to determine if the reaction is favorable or not:
- if $\Delta G < 0$, reaction is spontaneous,
- if $\Delta G > 0$, reaction is not spontaneous
- if $\Delta G = 0$, reaction is at equilibrium

Is ΔG affected by the mechanism of the reaction?

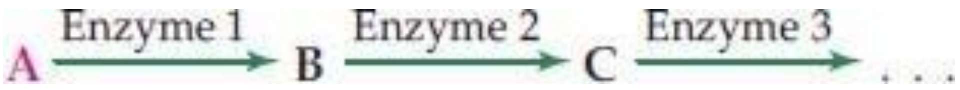
- **ΔG is not affected by the mechanism of the reaction**
- ΔG depends only on initial state and final state of biochemical pathways

$$A \rightarrow B \rightarrow C$$

$$\Delta G_{A\rightarrow B} = \cancel{GB} - GA$$

$$\Delta G_{B\rightarrow C} = GC - \cancel{GB}$$

$$GC - GA = \Delta G_{A\rightarrow C}$$



ΔG represents the overall reaction, no matter how many steps there are or what the reaction mechanism is.

- Combustion of glucose in calorimeter

$$Glucose + O_2 \rightarrow CO_2 + H_2O$$

ΔG = - 680 kcal/mol

Exergonic

In the cell

$$Glucose \rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow CO_2 + H_2O$$

ΔG = - 680 kcal/mol

Same value regardless of the pathway

ΔG is affected by concentration

Reversible reaction

$A \longrightarrow B$ — ΔG = - - - — In this case we have a forward reaction, and we have a large negative difference in ΔG.

$A \rightleftharpoons B$ — ΔG = - — Also forward but with less negative value.

$A \rightleftharpoons B$ — ΔG = zero — Equilibrium, equal rates but not necessarily concentrations.

$A \rightleftharpoons B$ — ΔG = ++ — Backward reaction is favorable due to higher concentrations of B, resulting in a negative ΔG value for the reverse reaction.

ΔG measures the tendency of the reaction to proceed towards equilibrium

ΔG^o, the standard free energy change

- Concentrations of reactants and products = 1 mole/L

Equilibrium is not the same as standard conditions.

- $\Delta G = \Delta G^o + RT \ln \frac{[Products]}{[Reactants]}$

R is the gas constant (1.987 cal/mol K)
T is the absolute temperature (K)

- $\Delta G = \Delta G^o + RT\ 2.3 \log \frac{[Products]}{[Reactants]}$

A reaction with a positive ΔG0 can proceed in the forward direction if the ratio of products to reactants ([B]/[A]) is sufficiently small (that is, the ratio of reactants to products is large) to make ΔG negative.

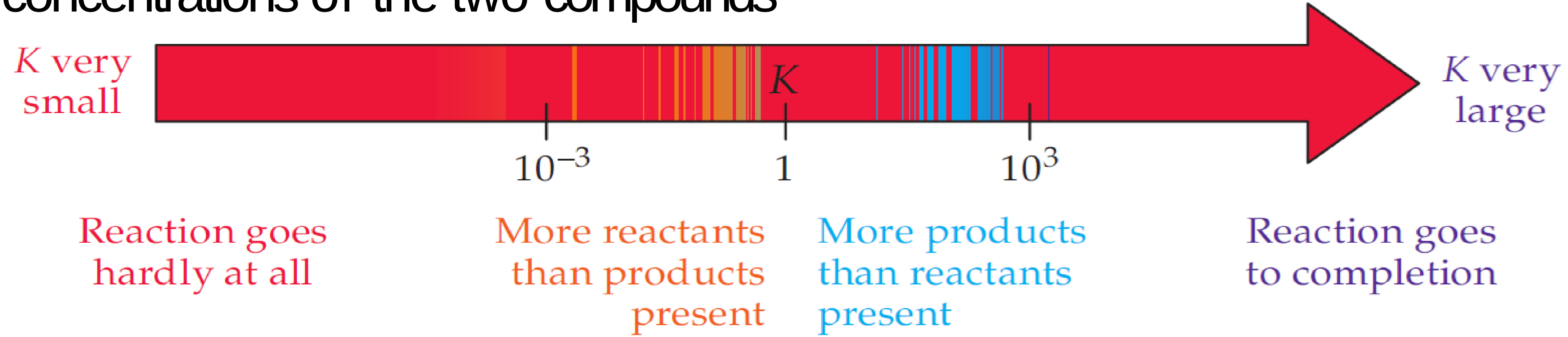
✓ ΔG^o is constant For a certain reaction.

✓ ΔG^o represents energy changes at non-physiologic concentrations of reactants and products

Reversible reaction and chemical equilibrium

In metabolism, both directions of the reaction must be catalyzed by the same enzyme, otherwise it is not considered a reversible reaction. Irreversible reactions can be run in the reverse direction utilizing a different enzyme.

- What is a reversible reaction?
- What is the chemical equilibrium? Chemical equilibrium is an active, dynamic condition
- At equilibrium, no further net chemical change takes place (that is, when A is being converted to B as fast as B is being converted to A)
- At equilibrium, are concentrations equal? No, but they are constant.
- At equilibrium, the ratio of [B] to [A] is constant, regardless of the actual concentrations of the two compounds



Standard free energy change (ΔG^o) and equilibrium constant Keq

K_{eq} is obtained by dividing [products] by [reactants] when the reaction reaches equilibrium

- At equilibrium

  $0 = \Delta G^o + RT \ln K_{eq}$

  $\Delta G^o = - RT \ln K_{eq}$

- At standard conditions

  $\Delta G = \Delta G^o + RT\, 2.3 \log 1$

  $\Delta G = \Delta G^o$

$$K_{eq} = \frac{[Products]}{[Reactants]}$$

Equilibrium is different from standard conditions.

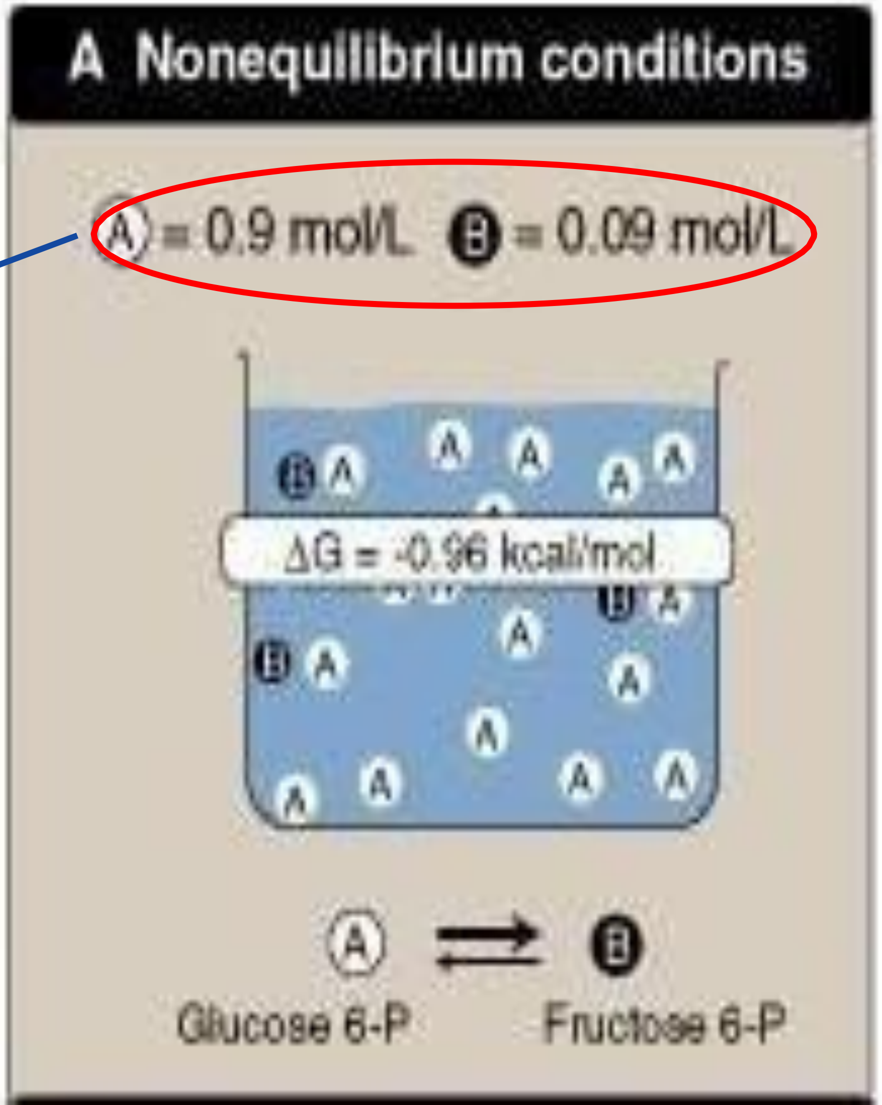
✓ ΔG0 cannot predict the direction of a reaction under physiologic conditions because it is composed solely of constants (R, T, and Keq and is not, therefore, altered by changes in product or substrate concentrations.

GLUCOSE 6- PHOSPHATE ⇌ Fructose 6- phosphate

Isomerization

The concentrations determine the direction of the reaction.

It is reversible as the same enzyme can catalyze both directions of the reaction.



Is this a standard condition?

No, it is not.

$\Delta G^o = +0.4$ kcal/mol

$\Delta G = \Delta G^o + RT\ 2.3 \log 0.09/0.9$

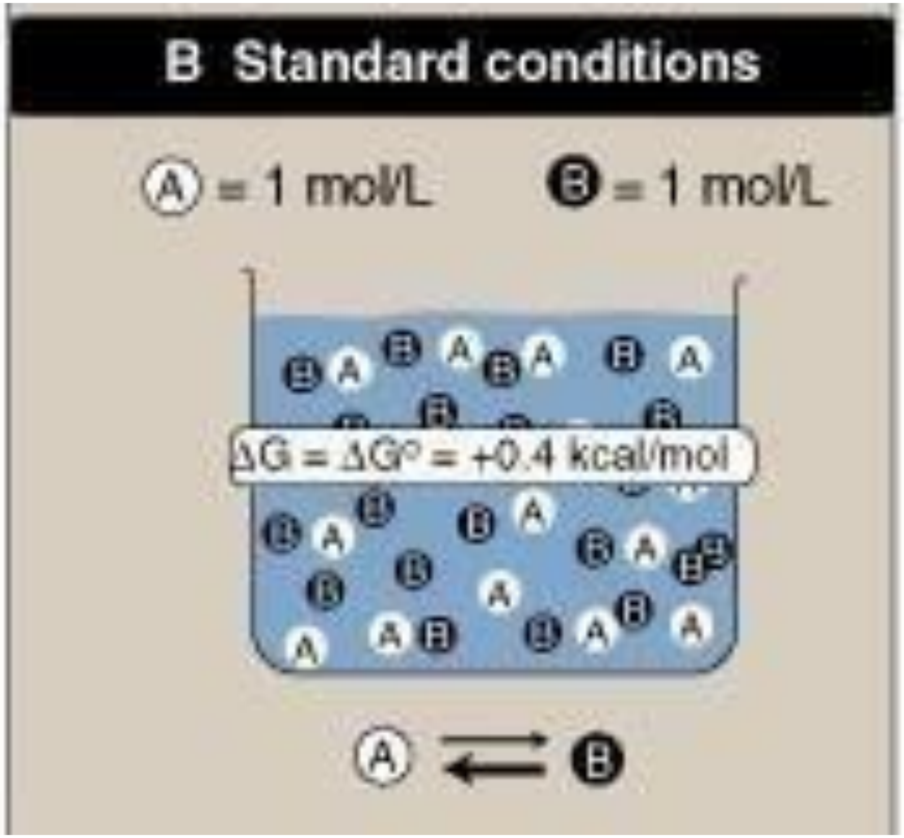
$\Delta G = -0.96$ (negative)

Reaction goes forward

So, the reaction is favorable and spontaneous.

Glucose 6- phosphate ⇌ Fructose 6- phosphate

1 mol/L　　　　1 mol/L

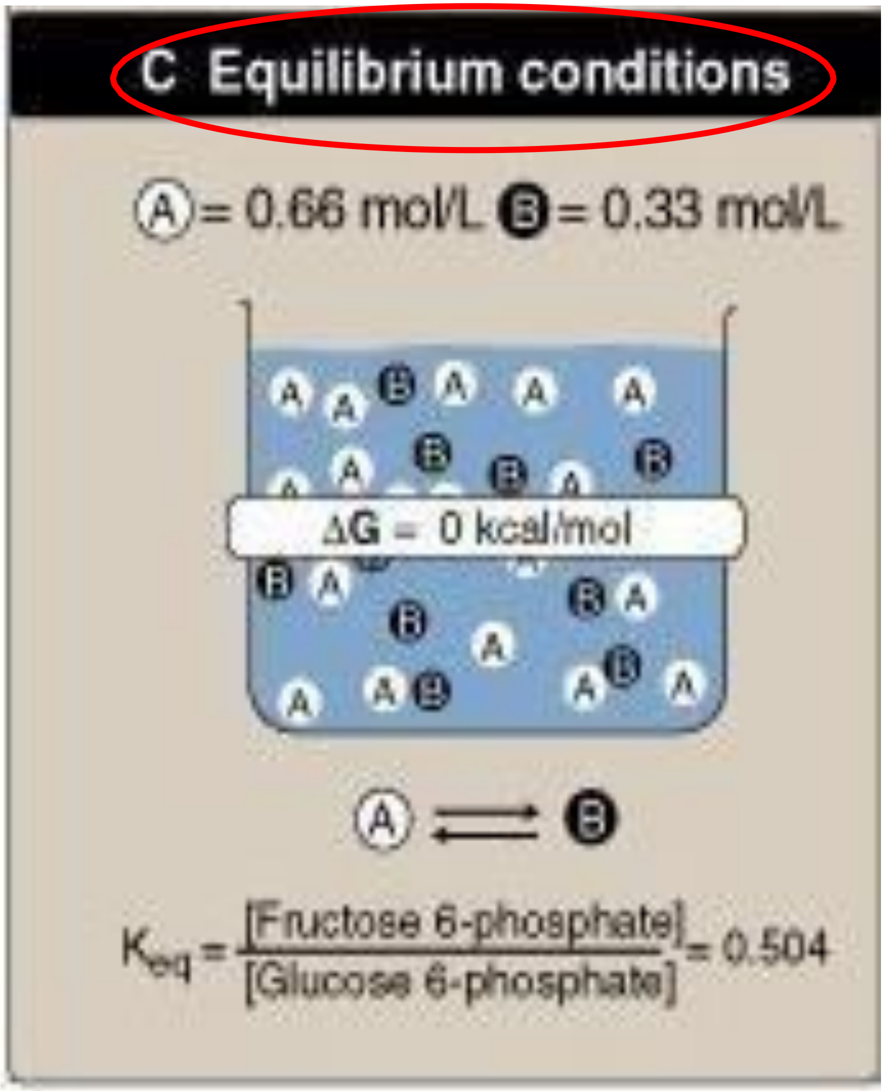


$\Delta G = \Delta G^{o} + RT\ 2.3 \log 1/1$

$\Delta G = \Delta G^{o}$

GLUCOSE 6- PHOSPHATE ⇌ **Fructose 6- phosphate**

0.66 mol/L 0.33 mol/L



$\Delta G = \Delta G^{o} + RT\ 2.3 \log 0.33/\ 0.66$

$\Delta G^{o} = +\ 0.4$ kcal/mol

$\Delta G = 0$

Here we have unequal concentrations but equal rates, therefore the reaction is at equilibrium and the concentrations will remain constant throughout the equilibrium state.

For any feedback, scan the code or click on it.

Corrections from previous versions:

Versions	Slide #	Before Correction	After Correction
V0 → V1	3	---	Added: "**Building Blocks are molecules used to build other molecules.**"
	4	---	Added: Alternate definition: $G_{Products} - G_{Reactants}$
	5 (top right)	---	Added "Chaos" = entropy
	14	---	Added the *underlined* phrase
V1 → V2			

Additional Resources:

رسالة من الفريق العلمي:

Lippincott® Illustrated Reviews: Biochemistry, unit 2, chapter 6.

قال رسول الله صلى الله عليه وسلم:
"من كانت الآخرة همه، جعل الله غناه
في قلبه، وجمع له شمله، وأتته الدنيا
وهي راغمة، ومن كانت الدنيا همه،
جعل الله فقره بين عينيه، وفرق عليه
شمله، ولم يأته من الدنيا إلا ما قدر له".

مع تمنيات فريق الليوث
العابسة التوفيق للجميع.