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Study Material: UG - 2nd Sem

Biophysical Principles

- Thermodynamics

What is thermodynamics? What do you mean by different system in thermodynamics? What is 1st law of thermodynamics? What is enthalpy and mention its biological application.

Thermodynamics ~~is~~ deals with about energy transformation from one kind to other in a system which consists of multitude of particles. During this transformation of energy, some kind of energy is transformed into other kind equivalent to heat energy as well as some amount of energy is also transformed into mechanical work. Body is also known as thermodynamics as it fulfill different criteria of thermodynamics like 1st law, 2nd law, enthalpy, entropy and free energy.

System :

System consists of multitude of particles consisting of one or more than one type of particles that contains a fixed amount of internal energy. Internal energy is the sum of mechanical energy of the particles involved in a particular system. Any system can able to exchange energy and or matter to the surroundings or is unable to exchange with surroundings. On the basis of this exchange phenomena, systems are devided into 3 types.

1. **Isolated system :** Does not allow heat or matter to pass acorcoss it

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1. Isolated system :

In this system the particles are surrounded by adiabatic boundary wall and as a result these particles are unable to exchange any energy and or matter to the surrounding. So there is no chance in alteration of internal energy of that system.

2. Open system :

In this system particles are surrounded by boundary that can able to exchange both matter and energy to its surrounding. As a result internal energy of that system is existed at non-equilibrium state.

3. Close system :

Here particles are surrounded by diathermal boundary wall that allow the exchange of heat to the surrounding but there is no chance of exchange of matter.

a diathermal wall bet. two thermodynamic system allows heat transfer but not matter transfer across it.

Body is a open thermodynamic system :

All living matters in the system i.e. in the universe which is known as biomass fulfill the open thermodynamic system. As a result both energy and matter are exchange to the surroundings As for example all living green plants absorp solar energy from universe and CO_2 as well as H_2O from the surroundings. In exchange of that these green plants radiate heat energy to the surroundings and starch as well as O_2 to the surrounding.

Living animals also fulfill the open thermodynamic system. All animals including human receive chemical energy in the form of glucose or food-stuffs from surroundings as well as O_2 from surroundings. In exchange of that energy is also

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radiated from the body surface as well as CO_2 also eliminated are exchanged with animal body. Therefore, both energy and matter thermodynamic system, it is clear to us that living being follow the open type of thermodynamic system which is existed at non-equilibrium state. If thermodynamic system where internal energy Death of animal being in body, the equilibrium state of thermodynamic system which internal energy of the body remain fixed. So there is no chance of exchange of energy or matter to the surroundings.

1st law of thermodynamics :

This law deals with the energy transformation from one kind to other which is homologous to energy conservation. According to energy conservation law, there is no chance of annihilation of energy as well as energy creation. So there is no possibility of energy loss or energy gain from this open type of thermodynamic system. Only energy is transformed into one kind to other or some energy is destroyed in the form of mechanical work. Therefore, if we consider the internal energy of this open thermodynamic system, when some amount of energy in the form of heat or heat equivalent of energy is gained by the system, equal amount of energy is lost from this body i.e. open system in the form of heat energy or other kind of energy is heat equivalent. When this 1st law is not obeyed by the system, there is death of the animal.

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If the change of the internal energy (ΔE) of a system is expressed in terms of energy gain or energy loss (ΔQ) and mechanical work perform on the system or by the system (ΔW), then this relation is

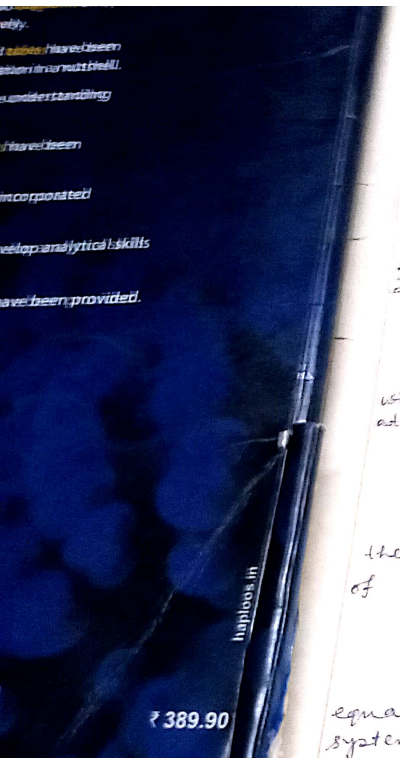
$$\boxed{\Delta E = \Delta Q - \Delta W}.$$

Here ΔQ represent the energy gained by the system or energy lost from the system.

(When energy is gained by the system then ΔQ is positive and in 2nd case i.e. when energy is lost by from the body then it is negative. Similarly ΔW indicates the change of external work or mechanical work by the system or on the system. This is negative when work is performed on the system and this is positive when system performed work on the surroundings.)

Body fulfill 1st law of thermodynamics:

Total energy of the body at any moment is constant. Animal bodies receive several nutrients or food stuffs and as a result chemical energy is gained by which is a kind of heat energy. Simultaneously



$H = E + PV$

(where E = internal energy of the system.
P = pressure
V = volume)

Therefore, change of enthalpy (ΔH) of a system is equal to change of internal energy (ΔE) plus change of pressure and volume i.e. ΔPV.

$\Delta H = \Delta E + \Delta PV$

We know product of pressure and volume when energy from initial state then there is a change in the work done by the system and we shall call it

$\Delta H = \Delta E + \Delta W$

where ΔW equivalent to work done by the system. Some of the biochemical processes are carried without change of pressure but volume is changed. In at that condition enthalpy change is

$\Delta H = \Delta E + P\Delta V$

or, $\Delta H = \Delta E + \Delta W$

We know ΔE is equal to $\Delta q - \Delta W$. Therefore, putting the ~~therefore~~, ~~putting~~ value of ΔE in the eqn = of enthalpy change then the formula would be

$\Delta H = \Delta q - \Delta W + \Delta W$
$= \Delta q.$

So in biological system, enthalpy change is equal to change of energy gain or energy loss by the system or from the system.

physiological work like rhythmicity of heart, contraction and relaxation of breathing muscle, motility of G.I. tract, heat radiation from cutenious bed, active reabsorption and transport of different substance along all membrane, maintenance of resting potential as well as heat dissipation through excreta. Beside this some biomolecules are also synthesised in our body like protein, DNA, RNA, glycogen etc where some amount of energy is stored as well as some amount of energy is also required for the formation of these bond. As a result the total heat gain by the body is equal to total energy lost plus energy stored in the body.

Enthalpy :

This is derived from 1st law of thermodynamics which deals with the total energy content of a system which is equal to the internal energy (E) of the system plus the product of pressure (P) and volume (V) change of that system. This is expressed by the formula, i.e

$$H = E + PV$$

(Where E indicates internal energy of the system,
P = Pressure ;
V = Volume ;)

Therefore, change of enthalpy (ΔH) of a system is equal to change of internal energy (ΔE) plus change of pressure and volume i.e. ΔPV, so

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Application of enthalpy or how to tell the enthalpy :

As biochemical reactions itself are going on without change of volume. So any pressure but in relation to fulfil the equation enthalpy in biological system i.e.

$$\Delta H = \Delta E$$

Enthalpy change of any biochemical reaction is equivalent to enthalpy change of reactant and enthalpy change of its products.

$$\Delta H \text{ reaction} = \Delta H \text{ reactants} - \Delta H \text{ products}$$

As for example if we consider the ΔH of glycolysis, then we know one molecule of glucose is converted into 2 molecules of pyruvate and in anaerobic state it forms 2 molecules of lactate. We know energy value of one molecule of glucose is 686 cal and of each molecule of lactate is 326 cal. Therefore, ΔH of glycolysis is equal to $686 - 2 \times 326 = 34$ cal. This amount of energy which is released in glycolysis is used for production of ATP.