Thermodynamics and living organisms

Thermodynamics of living organisms examines their biological processes from the point of view of thermodynamics. Using the principles of classical and statistical thermodynamics, we can describe the thermodynamic processes taking place in complex organs such as the lungs or heart, down to the individual reactions of enzymes and proteins. Using thermodynamic principles, it is also possible to understand the molecular mechanisms of a whole range of biological functions, such as enzymatic catalysis, cell signaling, cellular respiration, or photosynthesis.

Living systems and thermodynamic theorems

The first principle of thermodynamics

The first thermodynamic principle states that the increase in the internal energy of a system is equal to the sum of the mechanical work supplied and the heat supplied. The first to verify the validity of this principle in living systems were Messrs. Antoine Lavoisier and Pierre-Simon Laplace. They placed the guinea pigs in the calorimeter, which was in a container with snow, and measured the amount of melted snow in the form of the volume of water that was captured in the bottom of the calorimeter. They also measured the amount of carbon dioxide consumed, equivalent to the amount of oxygen consumed by the animal. Similarly, they determined the amount of heat and carbon dioxide produced when a candle burns. The results were almost the same, which proves the equivalence of the chemical energy that is released in the organism during metabolism and the thermal energy that the organism releases into the surrounding environment.

Lavoisier and Laplace's method, which was named the method of indirect calorimetry, is based on the fact that the normal consumption of oxygen and release of carbon dioxide in the organism of a homoiothermal (warm-blooded) animal is closely related to the amount of heat it produces.

The second thermodynamic principle

The second theorem of thermodynamics axiomatically introduces the state function S called entropy and determines the natural development of all thermodynamic processes. According to the given principle, the disorder of a thermodynamic system should theoretically grow until it reaches a maximum value. However, when we look into living systems, we find that the maximum value of entropy is rare and sometimes its reduction is even noticeable. This apparently contradicts the second law of thermodynamics, leading to suspicion of its invalidity in living systems.

In fact, it is conditioned by the fact that the entropy of an open thermodynamic system, such as a living organism, can be changed by interventions of two kinds:

- entropy change due to internal irreversible changes dSi, which can be positive or zero according to the 2nd thermodynamic theorem,
- the change in entropy conditioned by the interaction with the external environment dSe, which can take on any value: positive, negative, or zero.

It is characteristic of living systems that they are able to control and regulate most of the interactions with the external environment by themselves, e.g. by enzymatic activity, thereby negatively influencing the growth of entropy. Another specificity is the stationary state in which dSi = - dSe, i.e. dS=0, where the main difference from the equilibrium state is the fact that S does not reach maximum values. The ability of living organisms to maintain a stationary state is called auto stabilization.

From the point of view of thermodynamics, living organisms are open systems far from thermodynamic equilibrium.

Definition of life

According to thermodynamic principles, life is defined as a process or system whose direction of development is opposite to the direction of other, "inanimate" objects in the universe and tends to decrease its own entropy.

Links

Related articles

- Entropy
- Thermodynamic theorems
- Thermodynamic system

External links

- WIKIPEDIA,. *Calorimeter* [online]. [cit. 2013-10-21]. <https://en.wikipedia.org/wiki/Calorimeter>.

Sources

- ANTONOV, V. F. – KORŽUJEV, A. V., et al. *Fyzika a biofyzika. Kurz přednášek pro studenty lékařských fakult.* 1. edition. GEOTAR-MED, 2004. 192 pp. ISBN 80-201-0046-6.
- OPRITOV, V. A.. *Entropie biosystémů* [online]. [cit. 2013-10-21]. <http://cih.ru/a1/f69.html>.