Elementary carrier of thermal energy: derivation from the classical equations of thermodynamics

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Abstract— **Analyse the fundamental Gibbs's equations allow to make a conclusion that the transfer of thermal energy is carried out by elementary particles. The total differential of the state functions U, H, A, G and S includes the parameter $\Sigma \mu_i dn_i$, which shows the change in the energy characteristic of an open system due to a change in the number of material objects. On the basis of the classical equations of thermodynamics and experimental data in the reference literature, we have justified the existence of an elementary particle - "theplotron" – carrier of heat. These particles form "combinations" with other elementary particles of atomic-molecular structures and are manifested as a result of the process. The release or absorption of heat occurs as a result of the break-up or formation of these "combinations" and, accordingly, change the "chemical potential" of the system.**

Index Terms— **Elementary carrier of heat, chemical potential, heat, work, characteristic functions, "chemical individual", "combined particles".**

I. INTRODUCTION

The main purpose of studying the thermal processes occurring between material objects is to improve the existing and create new technologies based on the fundamental laws of natural science. Historically, the transfer of heat was described within the "phlogiston theory", which even allowed predicting the results of the process if the initial conditions were known [1]. At present, it is argued that "phlogiston theory" is over [2], but, as suggested in [3], to describe the energy flow, this theory is widely used in practice to explain heat transfer, for example, using the Fourier's law in form of the equation:

$$\Phi = -\lambda \; (\partial T / \partial x) \; S$$

where Φ- is the heat flow; λ - is the coefficient of thermal conductivity; $\partial T/\partial x$ -is the temperature gradient; S- is the cross-section of the conductor through which the heat flow proceeds.

Here, "heat flow" is adopted as a form of motion, and the physical meaning of the concept of "participants in the movement" remains outside the discussion. This leads to different interpretations of the heat transfer mechanism. In this connection, in order to solve the problem, it is necessary to understand the deep essence of the processes taking place, to find general laws on which such phenomena arise, operate and develop. And immediate tasks of the research are a detailed study of the mechanism of the process and

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management. It is generally accepted that the direction of physicochemical processes is determined by the "chemical potential" of the system. In this paper, elementary heat carriers, as forms of energy transfer, and the relationship with "chemical potential" are considered.

Discussion

According to general thermodynamics, the change in the state of the system in energy-exchange processes for an open system is described by the fundamental Gibbs's equations [1-5]:

$$dU = TdS - pdV + \Sigma \, \mu_i dn_i$$
$$dH = TdS + Vdp + \Sigma \, \mu_i dn_i$$
$$dA = - \, pdV - SdT + \Sigma \, \mu_i dn_i$$
$$dG = VdP - SdT + \Sigma \, \mu_i dn_i$$

Here, U (internal energy), H (enthalpy), A (Helmholtz's energy) and G (Gibbs's energy) are state functions and their total differentials of various variables are presented on the left-hand side of the equation. In such cases, the function becomes characteristic and its derivatives of various orders express in an explicit form other properties of the system in the process. The state functions U, H, A, G and S express energy characteristics that directly relate to a certain type and number of material objects constituting the system. And on the right side of the equation, the term - $\Sigma \mu_i dn_i$ shows the change in the energy characteristic of an open system due to a change in the number of material objects (particles, ions, etc.). According to the properties of the total differential of functions, their partial derivatives with respect to the i- th amount of a material object, with the constancy of other variables, express the corresponding types of potentials (thermochemical, electrochemical, etc.), the sum of which represents the chemical potential of the system. Consequently, the partial derivative with respect to the number of elementary particles related to thermal phenomena, with the constancy of other parameters of the system, expresses the chemical potential (μ_i) of the material object under consideration, i.e.:

$$\mu_i = (\partial U / \partial n_i) \; S,V,n_j = (\partial H / \partial n_i)S,p \; n_j = (\partial A / \partial n_i)T,V,n_j = (\partial G / \partial n_i) \; T,p, \; n_j$$

It should be noted that only in the process manifest forms of energy transfer in the form of heat, light, electricity, work, etc. In this connection, under stationary conditions, it is rather difficult to study phenomena that end with the termination of the process. However, on the basis of the universal law of conservation and transformation of matter and energy, it is possible to assume with certainty that the named forms of energy transfer realized by "**elementary particles**", when **interacting with material objects, are formed by other types of material world.** For example, light consisting of optical photons possessing a quantum of energy, when interacting with the constituent elements of the environment, are transformed into other forms of matter. In [6] it is noted

that "at the atomic-molecular level, there are many other more subtle types of matter - light, heat, field, and something more subtle, to which scientists have not yet come up with a name." Consequently, consideration of the individual nature of the vectors of heat and other manifestations is valid only during the course of the process. In this respect, the fundamental Gibbs equations allow us to consider the system in the process and conclude from the characteristic properties of functions that there are elementary heat carriers.

On the basis of analyse of a lot of number experimental data and the achievements of modern science, which consider in a complex of the micro- and macroscopic properties of the material world, we proposed in [7-14] that heat transfer is realized by elementary particles - "theplotrons". A new elementary particle - "theplotron" manifeste in the process, brings clarity in the transfer of energy in the form of heat and allows us to disclose the physical meaning of thermal phenomena. The presence of such "elementary particles" is reflected in the structural-energy states of "**chemical individuals**" [15], representing the "**thermochemical**" and "**electrochemical**" component of the **chemical potential.** That is, the theory of "phlogiston", which was rejected by science, which represented heat as a weightless "fluid" contained in bodies in more or less quantity, determining the body temperature and escaping from the substance during combustion [1], in principle, had a materialistic character . This view was held by S. Carnot and E. Clapeyron, the founders of the principles of the action of thermal machines, "whose purpose is to convert heat into work." They represented heat, as a special weightless fluid - "heat". Hence the question arises where the elementary carriers of heat are contained in material objects?

To answer the question, let us consider an exothermic reaction, in particular, the combustion of hydrocarbons. When they are burned, as a result of changes in the structural-energy state of the system, the thermochemical and electrochemical potentials change with the allocation of a huge amount of heat and light, i.e, chemical work is performed with the formation of new compounds and the separation of various elementary particles. In this case, in particular, **the number of electrons participating in the process does not change, but their location in the chemical bonds of the "chemical individual" only changes**. Similarly, for all biological, electrical and other processes, the work performed is characterized by the movement of elementary particles, in particular electrons, shown by M. Faraday [16]. The experimental material obtained by various authors allows us to judge that "theplotrons", photons, etc. form "combinations" with electrons in the "chemical individual". Feynman, similar combinations of elementary particles with electrons called "connection", "compound" or "interaction" [17]. In the structure of "combinations", these particles do not exhibit individual characteristics of "**theplotrons**" or **photons**. Consequently, it makes no sense, under stationary conditions in material objects, to explicitly seek the presence of **heat** and **light**. For example, gaseous hydrogen and oxygen, as a result of a chemical combination, forms water in which the properties of hydrogen or oxygen do not appear, but if necessary, these substances can be obtained by destruction of water molecules. Also, during the decay of these "combinations" can occur release the heat (theplotrons) , light (photons) and etc. The concentration of the allocated

"heat-carriers" from "combinations" in a free form characterizes **the temperature**, and their quantity is equal to the heat released and expresses the change in the "**thermochemical potential**" of systems . Hence, the evolving heat from the combustion of fuels represents a set of chaotically moving "heat-carriers" and dissipates into the environment. It is accepted that the driving force behind the performance of a chemical work is the difference between the chemical potentials of the initial and reaction products proceeding according to the equation:

$$C_xH_y + [(2x + y) / 4] O_2 \rightarrow xCO_2 + (y / 2) H_2O - \Delta_r H$$
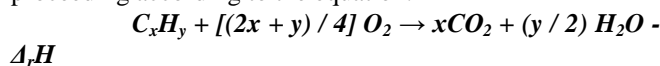
The change in the internal energy of the system is as follows:

$$dU = \delta W_1 + \delta Q + pdV + \Sigma \mu_i dn_i$$

where δW_1 . is an infinitesimal amount of perfect chemical work, δQ - is the amount of heat released in this chemical work, pdV is the expansion work, $\Sigma \mu_i dn_i$ is the change in the corresponding type of system potentials due to the allocation of dn of the number of "elementary particles". The difference of chemical potentials of "chemical individuals" between initial and final products is described by the equality:

$$\Delta\mu = (\mu_1 + E) - \mu_2$$

where μ_1 and μ_2 are the chemical potentials of the initial and reaction products, E is the activation energy of chemical reactions (Fig. 1).
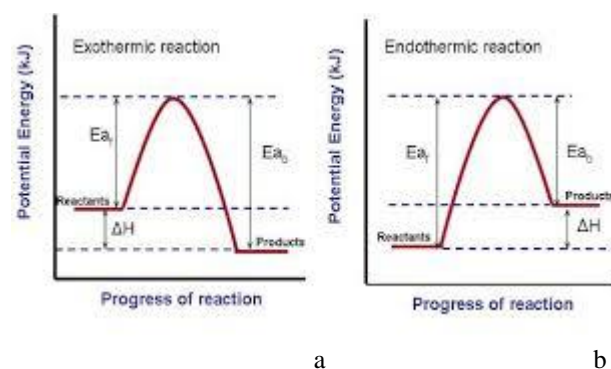

Fig.1. Energy profiles for exothermic (a) and endothermic (b) reactions

It is common knowledge that for activations of reacting substances, it is necessary to exert influence on the system by heat ("theplotrons"), light (photons) or other factors from outside, which lead to a change in the state of combinations of "teplotrons" with electrons, etc. Moreover, the structural-chemical individuals", in particular, thermochemical and electrochemical potentials of substances. With an activation energy of E_a (Fig. 1), optimal values of the thermochemical and electrochemical potentials are obtained for the interaction between the structural elements of the "chemical individuals" of the "activated complex" and the irreversible, purposeful redistribution of electrons in chemical bonds [18]. This process is accompanied by the decay of combinations of "theplotrons" with electrons and change in the electrochemical and

thermochemical potentials with the release of heat. Depending on the amount of "heat-carriers" emitted (absorbed), exothermic (Fig. 1a) or endothermic (Fig. 1b) takes place. Regardless of the type of reaction, in both cases, the fundamental principle of I.Prigozhin is fulfilled, where nonequilibrium processes serve as a source of self-organization [19]. In endothermic processes, the

"heat-carriers" transferred to the system accumulate in a "chemical individual" forming "combinations" with electrons, etc., i.e, heat accumulation takes place (for example, photosynthesis). The above results indicate that the "electrochemical and thermochemical potentials" are part of the chemical potential of the "chemical individual". In turn, for ideal gas mixtures, the standard chemical potential - μ_0- depends only on the nature of the individual i-th substance and temperature according to the equation [20]:

$$\mu_0 = C_v T + U_0 + RT - C_p T \ln T - S'T$$

In this case, "nature" defines the physical and chemical essence of a material object., Which (according to existing concepts) consists of oppositely charged particles, for which the stationary value of the electrochemical potential is characteristic, for a given temperature of the system. The chemical potential (μ) of the i-th substance in an ideal gas mixture depends on the standard chemical potential, temperature and pressure:

$$\mu = \mu_0 + RT \ln P$$

The relationship between the temperature (T) and the "heat sink" was considered by us in [21]. Based on spectroscopic data of radiation frequencies, M. Planck's equations and molecular-kinetic theories of elementary particles, an equation is proposed in the form:

$$T = 0.959 \cdot 10^{-11} \cdot v.$$

where v - is the frequency of the pulsation of the heat carriers - the "theplotrons". Here, the temperature is a physical quantity that quantitatively expresses the degree of heating of the system as a function of pulsations "theplotron", a free set of which directly expresses heat. Consequently, the "theplotron" in combinations with the electron, under stationary conditions, characterizes the **thermochemical** and **electrochemical potentials** and are components of the **chemical potential** of the **"chemical individual"** of the system. In the general case, the change in the **chemical potential** shows the course of the process, which manifests itself in the form of heat, light, electricity, work, etc., and characterize by state parameters of system. At the same time, with the transition to single particles, it is difficult to determine their composition, their differences, and also the physical meaning of certain parameters, such as temperature and pressure. To reveal the micro-macroscopic interrelation of these quantities in the system under consideration, we transform the equation $PV = RT$ into one elementary particle in the form:

$pV = kT$ or taking into account $T = 0.959 \cdot 10^{-11} \cdot v;\ pV = k \cdot 0.959 \cdot 10^{-11} \cdot v$

Analyse of these equations make it possible to reveal the physical meaning of the pressure (P- is the parameter of the macroscopic state) for an elementary particle, which is the "elastic force" - p-necessary for the pulsation of an elementary particle – of the "theplotron" in the pulsating volume V, k -is the Boltzmann's constant; $0,959 \cdot 10^{-11}$ - temperature coefficient, v - pulsation frequency of the "theplotron". If, the concentration of free "theplotrons" and their ripple frequency (v) characterizes the temperature (T), then the "elasticity of particle pulsations" (p) in the set determine their pressure (P) [22]. The change in the chemical potential in the course of a chemical reaction alters the structural and energy state of "chemical individuals" and is equivalent to changing internal energy, performing various

types of work, releasing heat and other types of manifestations according to the equation:

$$\Delta\mu = (\mu_1 + E) - \mu_2 = \Delta U + W_1 + Q + other.$$

where ΔU is the change in the internal energy of the system as a result of chemical reactions, W_1 is the amount of chemical work due to a change in the electrochemical potential due to redistribution of electrons, Q is the amount of heat released during chemical work, which represents the uncompensated heat of Clausius and others are other types of energy manifestations. For the conversion of heat Q into the useful mechanical work W_2, additional conditions are necessary that contribute to the directed collective movement of the particles - heat carriers, where one of the technical solutions is the use of internal combustion engines based on the Carnot cycle principle [3-5, 20]. In this case: $Q = W_2 + Q^1$, where Q^1 - is the amount of heat dissipated into the environment. Thermal efficiency reversible Carnot cycle does not depend on the nature of the working fluid and is determined only by the temperatures of the "heater" and the "refrigerator". This condition directly means that for the transfer of heat directly responsible are the elementary particles carriers of heat energy - "theplotrons" [23]. In addition, the heated products of combustion of hydrocarbons, carbon dioxide and water vapor having received a pulse of energies from the "theplotrons", also moves together with them along the cylinder, and in the absence of such an adaptation the heat is completely dispersed into the environment. A clear example of the accomplishment of only chemical work and the extraction of heat is the well-known process: the "self-propagating high-temperature synthesis" (SHS), whose founder is Academician A. Merzhanov [24]. In our opinion, for the flow of the SHS process, the initiator is the "theplotron". When the system is activated by free "heat-carriers", the temperature rises and the structural-energy state changes, which leads to a change in the stationary value of the thermochemical and electrochemical potentials of the system. At a certain value of them, electrons are redistributed and the process proceeds toward to decrease in the chemical potential with the formation of a new "chemical individual". As a result of the purposeful movement of electrons, chemical work is performed, which is accompanied by the disintegration of combinations of "theplotrons" creating a huge amount of heat (heat-carriers), which then initiates the process.

Conclusion

In the fundamental Gibbs's equations, the state functions U, H, A, G and S express the energy characteristics of material objects, and these quantities change as a result of various physicochemical processes. Analyse of the parameters of the total differential of these functions shows that the elementary particles called "theplotrons" can be considered the carriers of heat. "Teplotrons" under stationary conditions, forming "combinations" with electrons, characterize the thermochemical and electrochemical potential of the "chemical individuals" and are components of the chemical potential (μ_i). The release of heat from the system can mean the decay (reduction of the thermochemical potential), and the absorption of heat - the formation of combinations of "heat-electrons" with electrons (heat accumulation and growth of the thermochemical potential). Undoubtedly, a huge number of possible combinations of elementary particles can cause exotic energy manifestations.

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The elucidation of the nature of the carriers of heat "theplotrons", which are released as a result of a change in the thermochemical and electrochemical potentials, will expand the range of knowledge in the field of the atomic-molecular structure of substances. The organization of a purposeful flow of "theplotrons" from heat sources will significantly affect the technical progress.

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