The phenomenon of relay race molecular transfer of the amount of motion and its relationship with the diffusion phenomenon

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Abstract. The very fact of molecular transfer of the amount of motion, including in an ideal gas in an equilibrium state, has long been well known. However, this fact is still not realized as a physical phenomenon of transfer, equivalent to such transfer phenomena as diffusion, thermal conductivity and viscosity. The key concept used in this paper when describing the phenomenon of relay race molecular transfer of the amount of motion is the concept - "molecular relay race type of motion". A molecular relay race model of an ideal gas in an equilibrium state is proposed, as well as a molecular relay race model of a mixture of two ideal gases at constant temperature and pressure. It is shown that the value of the velocity modulus of diffusion flows is one of the physical characteristics of the mixture as a whole. It is also shown that the total density of the substance carried by the diffusion flows is many orders of magnitude less than the total density of the inhomogeneous multicomponent mixture.

1. Introduction
The phenomenon of relay race molecular transfer of the amount of motion is a specific form of momentum movement or the amount of motion [1]. In this paper, the amount of motion is considered as a really existing material object and is classified as one of the main forms of the existence of matter, equivalent to such forms of the existence of matter as, for example, the amount of substance or mass and the amount of energy. It is essential that the amount of motion is a material object that belongs to the number of unobservable or theoretically established material objects. These are invisible material objects that leave really observable traces of their existence, but they themselves remain unobservable. It is essential that this unobservability is not related to the imperfection of existing measurement devices or research methods.

For example, it is known [2] that the existence of the symmetry properties of space and time cannot be established by studying any actually observed material objects and their properties. The existence of these properties of symmetry can be established only by analyzing the theoretical transformations of space and time. In other words, the symmetry properties of space and time are theoretically established properties of actually unobservable material objects. It is essential that the properties of the symmetry of space are the reason for the existence of the law of conservation of momentum. It is also essential that the law of conservation of momentum is a key law that allows us to distinguish permissible movements of matter from unacceptable ones.
It should also be borne in mind that it is this law that allows us to consider the Universe as a single mechanical system and ensures the integrity and unity of the Universe at all levels of its organization: at the micro level, macro level and mega level. When studying the phenomenon of relay race molecular transfer of the amount of motion, it is important to introduce the concept of "molecular relay race type of motion" into consideration. This is a type of motion in which the processes of converting kinetic energy into elastic energy constantly occur, and in which the transfer of the amount of motion can occur in the absence of macroscopic motion of mass.

It makes sense to say that the molecular relay race type of motion is a physical mechanism that ensures the existence of the phenomenon of relay race molecular transfer of the amount of motion. Therefore, a significant part of this work is devoted to discussing the general properties of the molecular relay race type of motion.

It is essential that the molecular relay race type of motion is the physical mechanism of all transfer phenomena, including the diffusion phenomenon, without exception. It is postulated that the diffusion transfer of mass is carried out due to physical mechanisms identical to the physical mechanisms, due to which the relay race molecular transfer of the amount of motion is carried out.

The study of the general properties of the phenomenon of relay race molecular transfer of the amount of motion is based on the analysis of the general properties of the new proposed theoretical models of an ideal gas in an equilibrium state [1]. While the study of the phenomenon of molecular relay race mass transfer is based on the analysis of the general properties of the new proposed model of a mixture of two ideal gases at a constant temperature and pressure.

Based on the analysis of the general properties of these models, a fractional model of a component of a multicomponent mixture is constructed. The novelty of this model lies in the fact that in this model, each component of an inhomogeneous multicomponent mixture is divided into two fractions.

One of these fractions is the so-called convective fraction, the motion of which can be completely described using Newton's laws of motion. The second of these fractions, for the name of which it is proposed to use the term diffusant, is a part of the component of the mixture, the molecules of which are directly involved in the diffusion transfer of the mass. To describe this diffusive mass transfer, Fick's law should be used.

2. The concept of "substance"

It is postulated that charge, matter, energy, the amount of motion and the moment of the amount of motion, as well as the gravitational field, electric field and magnetic field represent various forms of the existence of matter. As a general name for these forms of the existence of matter in space and time, it is proposed to use the concept and term - substance.

It is also postulated that each substance has the properties of objective existence, movement and transformation, as well as the property of qualitative certainty, which makes it possible to distinguish one substance from another substance. The presence of the property of qualitative certainty means that each substance has its own classification distinguishing feature that allows distinguishing his substance from other substances.

The main classification distinguishing features of the substance include:
- tensor rank of the substance;
- the presence or absence of the observability property;
- the presence or absence of the inertia property;
- the presence or absence of the invariance property with respect to the choice of an inertial reference system.

The main properties of substances include:
- conservation property;
- the property of additivity by mass or volume.

It is essential that the reason for the existence of the conservation property for substances with zero or scalar tensor rank is the property of uniformity in time [2]. While the reason for the presence of the conservation property in substances with the first or vector tensor rank is the property of uniformity
and isotropy of space. It is also significant that a well-known case is when the absence of the observability property of a substance – "thermal energy" became the reason and sufficient reason for refusing to classify thermal energy as a substance.

It is known [3] that for a long time physicists were sure that heat is some kind of indestructible liquid substance, which meant a calorific liquid or caloric. However, after the creation of the molecular kinetic theory, the hypothesis of the existence of caloric was proved to be invalid, which served as the basis for the classification of thermal energy not as a substance, but as a physical quantity.

3. The main classification distinguishing features of substances

In this paper, all substances are divided into the really observable substances, which belong to the number of really observable forms of the existence of matter, and into the theoretically established or unobservable substances, which belong to the number of theoretically established or unobservable forms of the existence of matter. Accordingly, it also makes sense to divide all the material objects that form the really observed substances and the theoretically established or unobservable substances into the really observed material objects and into the theoretically established or unobservable material objects.

In [4], all physical quantities were divided into absolute physical quantities, the values of which do not depend on the choice of an inertial reference system, for example, such as charge and mass, and relative physical quantities, the values of which depend on the choice of an inertial reference system, for example, such as kinetic energy and the amount of motion. A similar method of division makes sense to use when classifying substances, divide all substances into absolute substances, for example, such as the substance "amount of mass", and into relative substances, for example, such as the substance "amount of motion". In [5], all material objects were divided into material objects that have the property of inertia or physical bodies, and into material objects that do not have the property of inertia or physical fields.

It makes sense to extend a similar method of classifying material objects to the classification of substances. To do this, it is necessary to divide substances into inertial substances that have the property of inertia, for example, such as the substance "amount of mass", and for non-inertial substances that do not have the property of inertia, for example, such as the substance "amount of motion".

4. The main classification distinguishing features of the substance "amount of motion"

It is postulated that the substance "amount of motion" refers to the number of theoretically established or unobservable substances. This means that the existence of the substance "amount of motion" and the presence of its basic properties can be established only by conducting appropriate theoretical studies.

It is postulated the substance "amount of motion" has the following classification distinguishing features:
- belongs to the number of theoretically established unobservable substances,
- belongs to the number of substances of the first tensor rank,
- belongs to the number of relative substances,
- belongs to the number of non-inertial substances,
- has the property of conservation due to the isotropy of space.

It is essential that the conservation law for this theoretically established unobservable substance can be written for any rectangular Cartesian reference system XYZ and for an arbitrary direction in this reference system. This is the meaning of Noether's theorem, according to which the conservation property for the substance "amount of motion" exists due to the properties of uniformity and isotropy of space [2].

It is also essential that since the substance "amount of motion" does not have the property of inertia, the motion of this substance, generally speaking, cannot be described using Newton's laws of
motion. Therefore, when describing the motion of the substance "amount of motion", in each particular case, it is necessary to postulate both the laws of motion of individual theoretically established unobservable material objects that are part of the physical system under study, and the laws of their interaction with each other and with similar external objects.

5. Poly-velocity and molecular relay race types of motion

By definition, poly-velocity type of motion means motion, for the correct description of which it is necessary to use several velocity fields. It is easy to make sure that all substances associated with the Earth make a poly-velocity type of movement.

The best way to realize this is by the example of poly-velocity movement, which is performed by all bodies located on the surface of the Earth. It is well known that all these bodies simultaneously participate in the movement of the Earth around its axis, in the movement of the Earth around the Sun, in the movement of the Sun in our Galaxy and in the movement of our Galaxy in the Universe.

It is obvious that not only the part of the substance "amount of mass" belonging to the Earth, but also parts of all other substances associated with the Earth, participate in this poly-velocity type of motion.

An important and well-known special case of a poly-velocity type of motion is the complex motion of a mechanical system, which includes a portable motion in an inertial frame of reference, and the relative motion of this mechanical system in a non-inertial frame of reference.

The molecular relay race type of motion is a type of motion, the distinguishing features of which are:
- constant ubiquitous processes of converting mechanical energy into elastic energy and vice versa.
- different composition of molecules moving in a given direction at different times.
- the dependence of the average value of the velocity of the molecular relay race motion of molecules on the characteristics of the component of the mixture to which these molecules belong.

6. A tubular version of the classical model of molecular transfer of matter and momentum in an equilibrium ideal gas

The classical molecular model is a well-known model of an ideal gas in an equilibrium state from statistical physics [1]. In this model, the atoms or molecules of an ideal gas are considered as absolutely elastic balls moving with an average thermal velocity $v_T$. In addition, in this model, the chaotic thermal motion of atoms or molecules is represented as six one-dimensional flows $I^+_x$ and $I^-_x$, $I^+_y$ and $I^-_y$, $I^+_z$ and $I^-_z$, which are directed parallel to the axes of the Cartesian coordinate system XYZ. It is postulated that in each of these six streams, for example, in the stream $I^+_x$, the number of molecules is equal to

$$I^+_x = (1/6)n_c v_T,$$

where $n_c$ is the concentration of molecules of the ideal gas $C$ [1].

Knowing the flow of the number of particles $I^+_x$, it is not difficult to find the flow of the mass $I^+_{x\mu}$ carried by these particles. To do this, it is enough to use an expression of the form

$$I^+_{x\mu} = \mu I^+_x,$$

where $\mu$ is the mass of one molecule.

The essence of the tubular version of the classical molecular model of an equilibrium ideal gas $C$ is that all the molecules of the six one-dimensional flows $I^+_x$ and $I^-_x$, $I^+_y$ and $I^-_y$, $I^+_z$ and $I^-_z$ are placed in the so-called molecular tubes. In each of these molecular tubes, the molecules placed in them without touching each other, move in the same direction with the same speed, the magnitude of the modulus of which is equal to the value of the average velocity of the thermal motion of the molecules $v_T$. 

4
It is assumed that the axes of these molecular tubes are parallel to the axes of the rectangular Cartesian coordinate system XYZ. It is also assumed that the centers of all molecules are located on the axes of these tubes, and that the distance between neighboring molecules in all molecular tubes is the same and equal to the free path length $\lambda$ (Figure 1).

**Figure 1.** Model of a collisionless molecular tube.

Below, the term "degenerate molecular relay race or collisionless tubes" will be used for the name of this type of tubes, and the symbol $\text{Tub}_{\text{ncol}}$ will be used for their designation. It is essential that the classical model described above and its tubular version are invariant with respect to both the choice of the reference point of the XYZ coordinate system and the choice of the direction of its axes.

It is also significant that when using the models described above, the answer to the question remains open: where do the molecules that reach the boundaries of the volume occupied by the ideal gas in question come from and disappear to. For example, in the tubular version, it is unclear how the molecules reaching the end surfaces of the tubes and moving in the direction of the boundary pass into tubes in which the molecules move in the opposite direction.

7. **Tubular relay race model of molecular transfer of the amount of motion in an equilibrium ideal gas**

Tubular molecular relay race model of the molecular transfer of the amount of motion can be easily obtained from the tubular version of the classical model of molecular transfer of matter and momentum in an equilibrium ideal gas described above. The procedure for constructing this tubular molecular relay race model of the molecular transfer of the amount of motion is as follows.

First, you need to make pairs consisting of the collisionless molecular tubes $\text{Tub}_{\text{ncol}}$ described in the previous paragraph, containing molecules moving in the opposite direction. Then it is necessary to renumber all the molecules located in these tubes, starting at one end of each tube and ending at the other end (Figure 2).

**Figure 2.** Model of two antiparallel collisionless molecular tubes.

After that, let’s mentally rearrange all the even or odd molecules from one tube to another. Having done this, we get the desired molecular relay race tubes $\text{Tub}_{\text{col}}$ (Figure 3).

**Figure 3.** Model of two molecular relay race tubes.
It is easy to make sure that in this model, in each molecular relay race tube $Tub_{col}$, there are constantly two counter flows of the amount of motion, providing a permanent transfer of the amount of motion from one end of the molecular tube to the other end. It is also easy to make sure that there are no flows of mass in the proposed molecular relay race model.

The tubular molecular relay model of molecular transfer of the amount of motion in an equilibrium ideal gas is a set of resting collisional molecular tubes $Tub_{col}$, shown in Figure 3.

It is obvious that in this model, a counter-through transfer of the amount of movement from one end surface of the tube to another end surface is possible due to instantaneous elastic collisions of molecules with each other. In this collision, the molecules transmit to each other an impulse, the transporters of which they are. With this transfer of momentum, the details of the transmission mechanism itself do not matter, but only the final result of this transfer is important, which is that with elastic collisions, the total momentum and the total kinetic energies of the colliding molecules do not change.

This model indicates that the transfer of the amount of motion in an equilibrium ideal gas can also occur in the absence of a transfer of matter. From the point of view of mathematics, this means that in an equilibrium ideal gas, flows of the amount of motion representing fields of tensors of the second rank, can exist in the absence of flows of matter representing fields of tensors of the first rank. In addition, it follows from the analysis of this model that in an equilibrium ideal gas, the magnitude of the modulus of the transfer rate of the amount of motion in any direction should be considered equal to the value of the average velocity of the thermal motion of the molecules $v_T$.

8. The phenomenon of molecular relay race transfer of the amount of motion in equilibrium ideal gas

Suppose we have an ellipsoid of rotation, the volume of which is equal to $V_0$. Let us also assume that the volume $V_0$ is filled with an ideal gas $C$, which is in an equilibrium state. Consider the section of this ellipsoid with a plane passing through its center and dividing the volume $V_0$ into two equal parts. Let's choose two arbitrary points $A$ and $B$ on the border of this section (Figure 4). Let's construct a rectangular Cartesian coordinate system $XYZ$ in such a way that the center of this coordinate system is located in the middle of the segment connecting points $A$ and $B$, and the segment $AB$ itself belongs to one of the axes of this coordinate system.

Let us construct in this coordinate system the molecular relay race tube $Tub_{col}$ described above, one end of which coincides with point $A$, and the other end coincides with point $B$. It was shown above that two counter flows of the amount of motion must constantly exist in this tube, providing a permanent transfer of the amount of motion from one end of the tube to the other end, at a speed whose modulus is equal to the value of the average velocity of the thermal motion of the molecules $v_T$.

![Figure 4](image)

**Figure 4.** A diagram explaining the method of selecting a reference system.

All the above arguments are valid for an arbitrary closed volume $V$ containing an equilibrium ideal gas $C$, and for any two points $A$ and $B$ inside this volume that can be connected by a segment $AB$ that does not contain boundary points inside it.

By definition, the phenomenon of molecular relay race transfer of the amount of motion is the phenomenon of a constant counter transfer of the amount of motion between any two internal points of
a closed volume containing an equilibrium ideal gas, provided that these points can be connected by a segment in which only its end points can belong to the boundaries of this volume.

9. Differentiated relay race molecular tubes and poly-velocity relay race molecular tubes

In the previous paragraphs, the molecular tubes $\text{Tub}_{\text{nocol}}$ and $\text{Tub}_{\text{col}}$ were introduced into consideration, which make it possible to design tubular models of an equilibrium ideal gas. One of these models $\text{Tub}_{\text{nocol}}$ was a tubular analogue of the classical equilibrium ideal gas model, and the second model $\text{Tub}_{\text{col}}$ was a tubular model of the transfer of the amount of motion in an equilibrium ideal gas. In this and subsequent paragraphs, a tubular model of a binary mixture of ideal gases $C_{i,1} + C_{i,2}$, consisting of two isotopes $C_{i,1}$ and $C_{i,2}$ of an ideal gas C and located at constant temperature and pressure, will be discussed.

To create tubular models of this mixture, the collisionless molecular tubes $\text{Tub}_{\text{nocol}}$ and molecular relay race tubes $\text{Tub}_{\text{col}}$ introduced above are not enough. To create these models, it is necessary to introduce two more types of molecular tubes into consideration: the differentiated molecular relay race type of tubes $\text{Tub}_{\text{difcol}}$ and the poly-velocity molecular relay race type of tubes $\text{Tub}_{\text{polycol}}$.

The specificity of the differentiated molecular relay race type of tubes $\text{Tub}_{\text{difcol}}$ is that, unlike the molecular relay race tubes $\text{Tub}_{\text{col}}$, they contain two different varieties of molecules. At the same time, by definition, the sets of these types of molecules are located strictly on different sides of each other and start from different end surfaces of the tube (Figure 5).

Figure 5. Model of a "differentiated" molecular relay race tube.

While the specificity of poly-velocity molecular relay race tubes $\text{Tub}_{\text{polycol}}$ is that, unlike resting molecular relay race tubes $\text{Tub}_{\text{col}}$, they move in the direction of their axes with a constant velocity $v = v_0 = \text{const}$ (Figure 6).

Figure 6. Model of "poli-velocity" molecular relay race tube.

10. A tubular model of an inhomogeneous mixture of two ideal gases at constant temperature and pressure

Consider a rectangular parallelepiped, the length of which is 1 m, and the cross-section is a square, the side of which is 0.01 m. Let the axis of the parallelepiped coincides with the $x$ axis of the rectangular Cartesian reference system $XYZ$, and its side end surfaces have coordinates $x=0$ and $x=1$. It is also assumed that a mixture of two isotopes of $C_{i,1}$ and $C_{i,2}$ of the ideal gas C is located in this parallelepiped and that the values of the concentrations $n_{C1}$ and $n_{C2}$ of these isotopes vary linearly along the axis of the parallelepiped. In addition, it is assumed that the concentration $n_{C1,2} = n_{C1} + n_{C2}$ of the mixture of $C_{i,1} + C_{i,2}$ is constant ($n_{C1}(x) + n_{C2}(x) = n_{C1,2} = \text{const}$) and that the mixture of $C_{i,1} + C_{i,2}$ is at a pressure of 1 atm. and a temperature of 300 K$^0$.

It is known from statistical physics [1] that under stationary boundary conditions on the side surfaces of the parallelepiped under consideration, in this parallelepiped there must exist two counter stationary diffusion flows $\mathbf{J}_{C1}$ and $\mathbf{J}_{C2}$ of molecules of the isotopes $C_{i,1}$ and $C_{i,2}$. These flows must be equal to each other in modulus ($|\mathbf{J}_{C1}| = |\mathbf{J}_{C2}|$) and opposite in direction ($\mathbf{J}_{C1} = -\mathbf{J}_{C2}$).
It is easy to make sure that the three types of molecular tubes $\text{Tub}_{\text{col}}$, $\text{Tub}_{\text{difcol}}$ and $\text{Tub}_{\text{polycol}}$ described above are sufficient to construct a tubular model of a mixture $C_{\text{is,1}} + C_{\text{is,2}}$ isotopes $C_{\text{is,1}}$ and $C_{\text{is,2}}$ of the equilibrium ideal gas $C$, placed in the above-mentioned rectangular parallelepiped.

In this model, tubes of the molecular relay race type $\text{Tub}_{\text{col}}$ must be used to build tubular models of homogeneous parts of the isotopes $C_{\text{is,1}}$ and $C_{\text{is,2}}$ and tubes of the differentiated molecular relay race type $\text{Tub}_{\text{difcol}}$ must be used to build tubular models of linearly varying parts of these isotopes. While tubes of poly-velocity molecular relay race type $\text{Tub}_{\text{polycol}}$ must be used to construct tubular models of parts of the isotopes $C_{\text{is,1}}$ and $C_{\text{is,2}}$, carried by oncoming diffusion flows $J_{\text{c1}}$ and $J_{\text{c2}}$.

11. The magnitude of the velocity modulus of diffusion flows as one of the main thermodynamic characteristics of an inhomogeneous mixture consisting of two isotopes of an equilibrium ideal gas

Currently, the hydrodynamic form of recording concentration diffusion flows $J_n$ is widely used in hydrodynamics, which has the form [5]

$$J_n = n_j w,$$

where $n_j$ is the density of the concentration diffusion flow $J_n$ and $w$ is its velocity.

From the analysis of the tubular model described above of an inhomogeneous mixture of two isotopes $C_{\text{is,1}}$ and $C_{\text{is,2}}$ of an ideal gas $C$, located at constant temperature and pressure, it follows that the magnitude of the modulus $|w|$ velocity $w$ of the oncoming diffusion flows $J_{\text{c1}}$ and $J_{\text{c2}}$ is one of the main thermodynamic characteristics of this inhomogeneous mixture, since it is equal to the value of the average velocity of thermal motion of molecules $v_T$. The validity of this statement can be justified as follows.

It was noted above that under stationary boundary conditions on the lateral surfaces of the parallelepiped, the counter stationary diffusion flows $J_{\text{c1}}$ and $J_{\text{c2}}$ should be equal to each other in modulus ($|J_{\text{c1}}| = |J_{\text{c2}}|$) and opposite in direction ($J_{\text{c1}} = - J_{\text{c2}}$). In addition, due to the stationarity of these boundary conditions of the amount of matter, the amounts of momentum and the amount of kinetic energy of each isotope that enter and leave this parallelepiped through its end side surfaces must be equal to each other. This means that in this case, a mixture of isotopes $C_{\text{is,1}}$ and $C_{\text{is,2}}$ placed in a parallelepiped is nothing more than an intermediary providing the exchange of matter and momentum and energy between external objects located to the left and right of the end surfaces of the parallelepiped.

It is easy to make sure that this is possible only if the magnitude of the modulus $|w|$ velocity $w$ of the oncoming diffusion flows $J_{\text{c1}}$ and $J_{\text{c2}}$ remains constant along the axis of the parallelepiped.

Let's imagine that somehow we managed to instantly transform all the molecules of the isotopes $C_{\text{is,1}}$ and $C_{\text{is,2}}$ contained inside the parallelepiped into molecules of an ideal gas $C$, and also instantly make the end surfaces of the parallelepiped impenetrable. As a result of these actions, an isolated thermodynamic system containing an equilibrium ideal gas $C$ will instantly arise in the parallelepiped. Naturally, the main thermodynamic characteristics of this system, including the average speed of thermal motion of molecules, should completely coincide with the main thermodynamic characteristics of the mixture of isotopes $C_{\text{is,1}}$ and $C_{\text{is,2}}$ contained in the parallelepiped. The reverse course of reasoning is also fair.

Obviously, the transporters of the amount of substance, the amounts of momentum and the amount of kinetic energy that enter and exit this parallelepiped through its end side surfaces and which must be equal to each other are the counter diffusion flows $J_{\text{c1}}$ and $J_{\text{c2}}$. It is easy to make sure that the conditions according to which the amount of substance and the amounts of momentum and the amount of kinetic energy that enter and exit the parallelepiped must be equal to each other, can be performed only if the magnitude of the module $|w|$ velocity $w$ of the oncoming diffusion flows $J_{\text{c1}}$ and $J_{\text{c2}}$ is equal to the value of the average velocity of thermal motion of molecules $v_T$. 
Considering this circumstance, as well as using the well-known form of writing an arbitrary vector \( \mathbf{a} \), having the form \( \mathbf{a} = | \mathbf{a} | \mathbf{i}_a \), where \( \mathbf{i}_a \) is the directing ort vector \( \mathbf{a} \), can be easily obtained from expression (3) an expression of the form

\[
\mathbf{J}_n = n_j v_j \mathbf{i}_j ,
\]

where \( \mathbf{i}_j = \mathbf{w} / |\mathbf{w}| \) is the unit guiding vector of the diffusion flow \( \mathbf{J}_n \).

In conclusion of this paragraph, it should be noted that the result obtained in it does not contradict the generally accepted opinion that the phenomenon of diffusion is a slow-flowing physical process. This opinion is based on estimates of the rate of change in the concentration of a substance in inhomogeneous mixtures due to the phenomenon of diffusion.

The fact is that the magnitude of the rate of "diffusion" change in the concentration of a substance is determined not by the magnitude of the velocity modulus of the vector fields of concentration diffusion flows \( \mathbf{J}_n \), but by the magnitude of their scalar divergence functions \( q_{Jn} \equiv \text{div} \mathbf{J}_n \). For example, from the fact that inside the parallelepiped the value of the divergence function \( q_{Jn} = \text{div} \mathbf{J}_n \) of concentration diffusion flows \( \mathbf{J}_n \) is zero (\( q_{Jn} = 0 \)), it does not follow that the magnitude of the modules \( |\mathbf{w}| \) velocities \( \mathbf{w} \) of the oncoming diffusion flows \( \mathbf{J}_{C1} \) and \( \mathbf{J}_{C2} \) should be zero.

12. Physical limitations imposed on the mathematical formulation of stationary boundary value problems of the diffusion theory

We will briefly discuss the physical limitations imposed on the mathematical formulation of a stationary boundary value problem, the solution of which allows us to find stationary distributions of concentrations of \( n_{C1} \) and \( n_{C2} \) molecules of isotopes \( C_{is,1} \) and \( C_{is,2} \) contained in the parallelepiped considered above. These limitations are related to the determination of the concentrations of molecules of the isotopes \( C_{i,1} \) and \( C_{i,2} \) in the vicinity of the end surfaces \( x = 0 \) and \( x = 1 \) of the aforementioned parallelepiped, at which two of the above-mentioned stationary diffusion flows \( \mathbf{J}_{C1} \) and \( \mathbf{J}_{C2} \) can exist.

It is known from statistical physics [1] that the values of the diffusion flows \( \mathbf{J}_{C1} \) and \( \mathbf{J}_{C2} \) can be found using Fick’s law:

\[
\mathbf{J}_n = -D_n \nabla n ,
\]

where \( \mathbf{J}_n \) is the concentration diffusion flow, \( n \) is the three-dimensional concentration field of the considered variety of molecules, and \( D_n = (1/3) \lambda v_T \) is the diffusion coefficient (here \( \lambda \) is the free path length, and \( v_T \) is the average speed of thermal motion of the considered variety of molecules). In addition, it is known [1] that under the above conditions in the parallelepiped under consideration, the diffusion coefficients \( D_{C1} \) and \( D_{C2} \) must be constant and equal to each other (\( D_{C1} = D_{C2} = \text{const} \)).

We will now show how, using Fick’s law (5), it is possible to obtain, up to the second order of smallness, an estimate of the magnitude of the modulus \( |\mathbf{J}_{C1}(x)| \) one-dimensional diffusion flow \( \mathbf{J}_{C1}(x) \).

Using expression (5) it is easy to get an estimate of the form

\[
|\mathbf{J}_{C1}(x)| \approx (1/3) \lambda v_T |n'_{C1}(x)| \approx (1/3) \lambda v_T (n_{C1}(x + \Delta x) - n_{C1}(x)) |/\Delta x .
\]

With a linear dependence of the change in the values of the concentration function \( n_{C1}(x) \) on the argument \( x \), without violating the generality of the presentation of the material, we can take the value of \( \Delta x \) in the right part of the expression (6) equal to one (\( \Delta x = 1 \)). Having done this, it is easy to get an expression of the form

\[
|\mathbf{J}_{C1}(x)| \approx (1/3) \lambda v_T |(n_{C1}(0) - n_{C1}(1))|/1
\]

It is obvious that the maximum "mathematical" value of the modulus function \( J_{C1}^{\text{max}} = |\text{max}\mathbf{J}_{C1}(x)| \) reaches in the case when on one end side surface of the parallelepiped the concentration value \( n_{C1}(0) = 0 \), and on the other end surface the concentration value \( n_{C2}(1) = 0 \) and when \( n_{C2}(0) = n_{C1}(1) = n_{C1,2} \).

From the above, it follows that the expression of the form

\[
|\mathbf{J}_{C1}(x)| \approx (1/3) \lambda v_T |(n_{C1}(0) - n_{C1}(1))|/1
\]
J_{x1}^{\text{max}} = (1/3)\lambda v_T n_{C1,2} \quad (8)

is valid.

It is essential that the conditions \( n_{C1}(0) = 0 \) and \( n_{C2}(0) = n_{C1,2} \), as well as the conditions \( n_{C1}(1) = n_{C1,2} \) and \( n_{C2}(1) = 0 \) are physically incorrect, since it is obvious that when these conditions are met, the concentration diffusion flows \( J_{x1} \) and \( J_{x2} \) cannot exist in the considered parallelepiped.

In order to obtain the physical constraints on the concentrations \( n_{C1}(0), n_{C2}(0), n_{C1}(1) \) and \( n_{C2}(1) = 0 \) it is necessary to use the hydrodynamic form of recording diffusion flows, which has the form (4) and with which it is easy to obtain an expression of the form

\[
J_{x1}^{\text{max}} = n_{j}^{\text{max}} v_T .
\]

Equating the right parts of expressions (8) and (9), we get

\[
(1/3)\lambda n_{C1,2} = n_{j}^{\text{max}} ,
\]

whence follows the validity of the expression of the form

\[
n_{j}^{\text{max}} / n_{C1,2} = (1/3)\lambda .
\]

Thus, it turns out that the value of the ratio \( n_{C1,2}^{\text{max}} / n_{C1,2} \) is proportional to the value of the free path length \( \lambda \).

Considering that at room temperature and atmospheric pressure, the value of the average free path length \( \lambda \) for air can be considered approximately equal to \( 6.5 \times 10^{-8} \) m, it is logical to conclude that in the general case, the concentration value \( n_{j} \) of molecules forming concentration diffusion flows \( J_{j} \) is negligible compared to the total concentration of molecules forming the inhomogeneous multicomponent mixtures.

It follows from expression (9) that the maximum modulo value of the diffusion flow \( J_{x1}^{\text{max}} \) corresponds to the maximum value \( n_{C1,2}^{\text{max}} \) of the number of molecules carried by this diffusion flow. Naturally, the number of molecules of the isotope \( C_{i,1} \) carried by the diffusion flow \( J_{x1}^{\text{max}} = n_{C1}^{\text{max}} v_T J_{C1} \) cannot be greater than the number of molecules of this isotope, which in principle can reach the end surface \( x = 0 \) of the parallelepiped at the existing concentration level \( n_{C1}(0) \) molecules of the isotope \( C_{i,1} \) in the vicinity of the end surface \( x = 0 \).

This means that the physical restriction imposed on the concentration value \( n_{C1}(0) \) molecules of the isotope \( C_{i,1} \) in the vicinity of the end surface \( x = 0 \) can be represented as an inequality

\[
n_{C1}(0) > 6n_{j}^{\text{max}} .
\]

13. Fractional diffusant model of a component of a multicomponent inhomogeneous mixture

In this paper, it is postulated that each component \( N_{i} \) of an inhomogeneous multicomponent mixture \( N_{0} \) consists of two fractions: a convective fraction \( N_{vi} \) and a diffusant fraction or simply a diffusant \( N_{wi} \).

The main classification distinguishing feature of the convective fraction \( N_{vi} \) is its mono-velocity type of motion, which means motion, for the description of which it is sufficient to use the field of convective velocities \( v \), for calculating the values of which it is sufficient to use Newton's laws of motion.

The basis for dividing the mixture component \( N_{i} \) into the convective fraction \( N_{vi} \) and the diffusant \( N_{wi} \) is the presence of two physical and one mathematical classification distinguishing features of the diffusant \( N_{wi} \), which the convective fraction \( N_{vi} \) does not possess.

The first physical classification distinguishing feature of the diffusant \( N_{wi} \) is its gender and poly-velocity type of movement, for the description of which it is necessary to use two different mono-velocity velocity fields. One of these mono-velocity types of motion is the aforementioned mono-velocity convective type of motion. The second of these two mono-velocity types of motion is the...
 mono-velocity molecular relay race type of motion, for the description of which the diffusant velocity field $w_i$ should be used.

The second physical distinguishing feature of the diffusant is that the magnitude of the modulus $|w_i|$ of diffusant velocity field $w_i$ of the diffusant belongs to the main thermodynamic characteristics of a multicomponent inhomogeneous mixture.

The main mathematical distinguishing feature of the diffusant is that the diffusant velocity field $w_i$ of the diffusant belongs to the number of layered vector fields [6]. The presence of any of these three distinctive features of a diffusant is sufficient for a reasonable introduction to the consideration of the very concept of "diffusant".

14. Conclusions
The main results of this work are:
1. The concept of "poly-velocity type of motion" is introduced.
2. The concept of "molecular relay type of motion" is introduced.
3. The phenomenon of relay race molecular transfer of the amount of motion is described.
4. The tubular model of an inhomogeneous mixture of two ideal gases is constructed.
5. The fractional diffusant model of the multicomponent inhomogeneous mixture component is proposed.

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