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EVALUATION OF THE RATE OF CHANGE OF TRANSFER POTENTIALS IN POROUS SOLID BODIES

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A formula for calculating the potential diffusivity of energy in porous solid bodies has been obtained, which made it possible to express the velocity of propagation of the energy field in the form of a relation of the type of an equation of heat conduction with a constant coefficient. Under the same boundary conditions, the velocity of propagation of the energy field is intermediate in value between the velocities of propagation of the temperature and concentration fields.

The kinetics of the change of different transfer potentials (T, C, p_1, p_2) is usually described by equations of the type of equations of heat conduction with the corresponding kinetic coefficients a_h, $D_{s.liq}$, $a_m c_p \rho$, and K/g [1], and the time of propagation of the fields of the corresponding potentials, evaluated by the quantity l^2/a or l/v, can differ by several orders of magnitude [2]. In the latter case, there is no practical need to solve equations of combined transfer; it will suffice to solve an equation with a single potential whose propagation time is much larger than the propagation time of the other potentials. This problem remains unsolved in relation to enthalpy. It can be solved with the use of the energy characteristics of porous solid bodies [3].

As shown in [3], $W_{s.liq}$ is, by definition, the quantity of energy that must be expended in order that with a distance δ between holes in the liquid 1 mole (kg) of the substance overcome the resistance of the structure proper of the solid body and the liquid found in it (the solvent).

A traditional expression for the resistance to mass transfer in the steady state is δ/a. When the kinetics (the motion of the molecules) is considered in accordance with [4], we can write, taking into account the velocity of motion of the molecules δ/τ_{eq},

$$L_m = \frac{\delta \dfrac{\delta}{\tau_{eq}}}{W_{s.liq}} . \tag{1}$$

In accordance with [2; 4, p. 223], for a porous solid body saturated with a liquid, it can be assumed that $\delta^2/\tau_{eq} = 6D_{s.liq}$, and then

$$L_m = \frac{6D_{s.liq}}{W_{s.liq}} . \tag{2}$$

By definition, L_m is the quantity of the substance (mole, kg) that is transferred a distance of 1 m at a velocity of 1 m/sec with an energy expenditure of 1 J.

The energy transfer is described by the expression

$$L_e = \frac{6D_{s.liq}}{W_{s.liq}} i . \tag{3}$$

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TABLE 1. Results of Calculation of the Potential Diffusivity of Energy

Solid phase	Liquid phase (solvent)	T, K	$D_{s.liq} \cdot 10^{12}$, m^2/sec	$W_{s.liq}$, kJ/kg	i, kJ/kg	$L_e \cdot 10^{12}$, m^2/sec	$L_e/D_{s.liq}$
Kernel of soy seeds	Extractive gasoline	293	0.24	24.4	200.3	11.82	49.2
		293	0.27	24.0	200.3	12.00	44.4
Kernel of peanut seeds	The same	293	2.43	18.9	200.3	154.8	63.6
	"	309	3.08	19.5	231.3	219.0	71.4
	"	325	3.74	20.9	262.7	282.0	75.6
	"	341	5.53	20.9	296.2	470.4	85.2
Microatomic sections of peanut seeds of different thickness	Commercial hexane	298	0.71	22.2	209.9	40.26	57.0
		298	0.72	22.2	209.9	40.86	57.0
		298	0.63	22.5	209.9	35.28	55.8
		298	0.34	23.6	209.9	18.12	53.4
Crumpled sunflower:							
without husks	Hexane	323	0.21	32.3	259	10.2	48.6
5% husks	"	323	0.05	30.2	259	2.58	51.6
10% husks	"	323	0.05	30.2	259	2.58	51.6
15% husks	"	323	0.06	29.7	259	3.12	52.2
25% husks	"	323	0.21	26.7	259	12.24	58.2
	Extractive gasoline	328	9.1	25.2	269	583.2	64.2
		328	15.2	23.8	269	1030.8	67.8
		328	17.3	23.0	269	1213.8	70.2
		328	7.1	23.5	269	487.8	69.0
Damp soy petals of different thickness	Dichloroethane	328	6.4	26.9	269	384.0	60.0
	"	328	15.4	22.3	269	1114.8	49.8
	"	328	21.7	20.5	269	1708.2	79.2
	"	328	16.8	20.0	269	1356.6	81.0
	Extractive gasoline	325	0.38	25.6	263	23.4	61.8
		325	0.30	26.1	263	18.12	60.6
		328	2.59	21.2	269	197.4	76.2
	Trichloroethylene	300	5.1	17.4	214	435.6	73.8
		300	8.5	17.6	214	620.4	73.2
	The same	300	19.1	14.9	214	1645.8	96.4
		300	10.8	16.1	214	861.6	79.8
Soy grits	Extractive gasoline	328	3.11	20.4	269	246.0	79.2
Grits of coriander waste	The same	328	0.65	24.3	269	43.2	66.6
Prepressed sunflower petal	Hexane	323	16.1	22.3	259	1122.0	69.6

Since the chemical potential per unit volume of the substance is

$$\mu = \rho\,(\mu_0 + RT \ln C)\,, \tag{4}$$

the material and energy fluxes expressed in terms of it will, respectively, be equal to

$$q_{\mathrm{m}} = L_{\mathrm{m}}\,\rho RT\,\frac{\partial}{\partial x}(\ln C)\,, \tag{5}$$

$$q_{\mathrm{e}} = L_{\mathrm{e}}\,\rho RT\,\frac{\partial}{\partial x}(\ln C)\,, \tag{6}$$

L_{e} is an analog of the coefficients a_{h} and $D_{\mathrm{s.liq}}$; therefore, in the case where it is constant, we can write an equation for the velocity of propagation of the chemical potential:

$$\frac{\partial \mu}{\partial \tau} = L_{\mathrm{e}}\nabla^2\mu\,. \tag{7}$$

Results of calculation of L_{e} are presented in Table 1. The data on $D_{\mathrm{s.liq}}$ are taken from the works cited in [3], while i is taken from [5]. As is seen from the table, in the cases considered, the quantity L_{e} is intermediate between $D_{\mathrm{s.liq}}$ and a_{h} [6], i.e., under the same boundary conditions the velocity of propagation of the energy field (the field of μ) in porous solid bodies is also intermediate in value between the velocities of propagation of the fields of T and C. This is natural, since μ is a function of T and C.

NOTATION

T, temperature; C, concentration; p_1, unrelaxed vapor pressure; p_2, hydrodynamic pressure of the liquid or the liquid mixed with the vapor (gas); a_{h}, thermal diffusivity; $D_{\mathrm{s.liq}}$, diffusivity in the solid–liquid system; $a_{\mathrm{m}}c_p\rho$, potential diffusivity of unrelaxed vapor pressure; a_{m}, potential diffusivity of mass transfer; ρ, density; c_p, heat capacity of the moist air in the porous body; K, filtration coefficient; g, free-fall acceleration; a, potential diffusivity (a_{h}, $D_{\mathrm{s.liq}}$, etc.); δ, elementary displacement of a molecule; v, velocity of propagation of the field; l, dimension of a particle (radius of the sphere, half of the thickness of the plate); τ_{eq}, time of oscillation of a molecule about the equilibrium state in the liquid inside the porous body ("time of settled life"); i, enthalpy of the diffusing substance; L_{e}, potential diffusivity of energy; μ, chemical potential; R, gas constant; q_{m}, material flux; q_{e}, energy flux; μ_0, chemical potential in the steady state; τ, current time; x, coordinate.

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