THERMAL CONDUCTIVITY AND VISCOSITY OF LITHIUM VAPORS

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We give the calculated values of the thermal conductivity and viscosity of lithium vapors (T = 800–2000°K, p = $3 \cdot 10^{-3}$–3 bar). No experiment was conducted for lithium. A comparison with experiments conducted on sodium and potassium is given.

1. The thermophysical properties of the alkali metals have been intensively studied in recent years, both in the gaseous [1–4] and in the condensed [1, 5, 6] phases. This is due to practical needs and to properties of transfer processes in vapors which are of interest for theoretical purposes. Researchers have accumulated a considerable amount of experimental material on the transfer properties of Na, K, Rb, and Cs vapors. From an analysis and processing of such data published up to 1978 [2, 4], it has been possible to make some important generalizations and to clarify a number of laws governing the behavior of alkali-metal vapors. Attention should be given to the fact that calculations performed thus far on the transfer properties of alkali-metal vapors [1, 7, 8] yield results for a number of important quantities which differ not only quantitatively but qualitatively as well from the experimental results: a) in the experiments the viscosity decreases with increasing pressure, whereas according to the theory it increases; b) in the calculations the contribution of the energy transfer of the dissociation reaction to the total heat flux was much higher than the value indicated by experiments. Under present-day conditions the development of theoretical research on the transport properties of alkali-metal vapors is of great importance. The reason for this is the lack of experimental results for Li and the narrow temperature range in which the experimental investigations are usually conducted, and also the interesting properties of the behavior of alkali-metal vapors.

Analysis [2, 4] indicates that the main reason for the divergence between theory and experiment is the very low accuracy of the calculation of the monomer–dimer scattering cross section. In order to remove this defect, in [9] we calculated the anisotropic monomer–dimer potentials for Li, Na, and K. An analysis of the potential curves and a comparison of these curves with a number of experimental data enabled us to calculate by a unified method the monomer–dimer transport cross sections $\sigma^2\Omega_{1-2}^{(2,2)*}$ for lithium, sodium, and potassium in the 800–1500°K range, as well as the monomer–dimer cross section for lithium [10, 11], reduced in accordance with [9] by 20%, and for sodium and potassium [4]. We used the data of this table in calculating the kinetic coefficients. Taking account of the low dimer concentration, we can use the approximate formula $\sigma^2\Omega_{2-2}^{(2,2)*} = 2\sigma^2\Omega_{1-2}^{(2,2)*} - \sigma^2\Omega_{1-1}^{(2,2)*}$ for dimer–dimer scattering cross sections.

As is shown in [4], for all experimentally investigated alkali-metal vapors $A_{1-2}^{*} = \sigma^2\Omega_{1-2}^{(2,2)*}/\sigma^2\Omega_{1-2}^{(1,1)*} = 1.2$ and $B_{1-2}^{*} = (5\Omega_{1-2}^{(1,2)*} - 4\Omega_{1-2}^{(1,3)*})/\Omega_{1-2}^{(1,1)*} = 1.2$. These values were also used for lithium.

2. The transfer coefficients were calculated on a computer according to the exact formulas of the kinetic theory of rarefied gases [14]. The results of [9, 4] were used as the transport cross sections (Table 1) and the data of [12, 13] were used for the thermodynamic quantities. In the 1500–2000°K range we used cross sections obtained by extrapolation of the data of Table 1. The results of the calculations are shown in Figs. 1–4 and Tables 2 and 3.

The main difference between the results shown here for the viscosity of Li and the results of other theoretical calculations is that the viscosity decreases with increasing pressure (Table 2, Fig. 1). This is due to the high value of the ratio $\beta^{(2)} = \Omega_{1-2}^{(2,2)*}/\Omega_{1-1}^{(2,2)*} \simeq 2.54$ obtained in [9], in comparison with $\beta^{(2)} \simeq 1$, obtained in [1, 7, 8], As was predicted above, the negative sign of the pressure effect is confirmed experimentally and is a general property of alkali-metal vapors.

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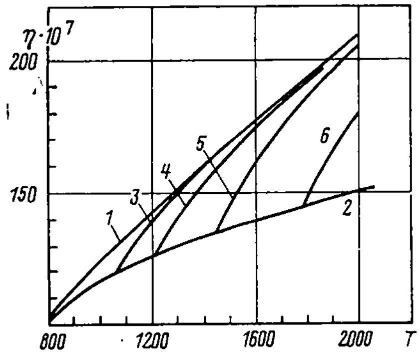

Fig. 1

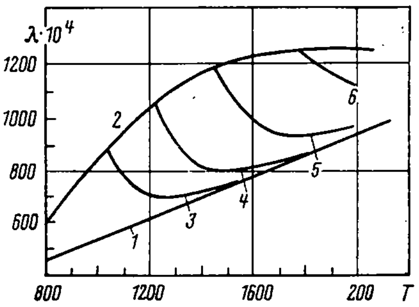

Fig. 2

Fig. 1. Variation of the viscosity η of lithium vapors as a function of temperature T and pressure p: 1) monatomic vapor; 2) saturation curve; 3) $p = 3 \cdot 10^{-3}$; 4) $3 \cdot 10^{-2}$; 5) $3 \cdot 10^{-1}$; 6) $p = 3$. η, Pa · sec; T, °K; p, bar.

Fig. 2. Variation of the thermal conductivity λ of lithium vapors as a function of temperature and pressure. The notation is the same as in Fig. 1. λ, W/(m · °K).

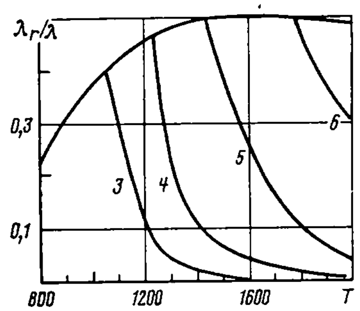

Fig. 3. Variation of the ratio λ_r/λ as a function of temperature and pressure. The notation is the same as in Fig. 1.

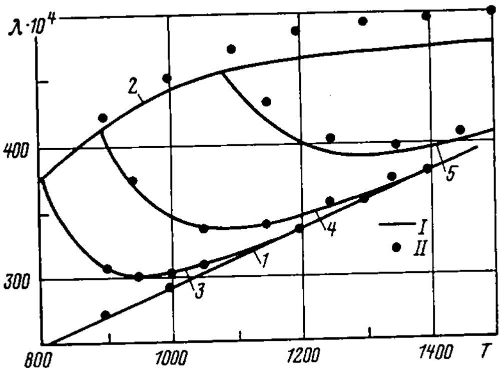

Fig. 4. Comparison of the calculated results for the thermal conductivity of sodium vapor with experimental results: I) calculated [1) monatomic vapor; 2) saturation curve; 3) $p = 0.01$; 4) 0.05; 5) 0.5]; II) generalized experimental data of [4]. λ, W/(m · °K); T, °K; p, bar.

TABLE 1. Integrals of Monomer–Monomer and Monomer–Dimer Collisions, Å^2

Substance		T, °K								literature
		800	900	1000	1100	1200	1300	1400	1500	
Li	Ω_{1-1}	19,5	18,9	18,4	17,9	17,5	17,0	16,7	16,3	[9–11]
	Ω_{1-2}	50,6	48,6	46,8	45,2	43,8	42,8	41,6	40,7	[9]
Na	Ω_{1-1}	20,1	19,5	19,0	18,5	18,0	17,6	17,2	16,8	[4]
	Ω_{1-2}	54,5	52,2	50,3	48,7	47,2	45,5	44,5	43,4	[9]
K	Ω_{1-1}	30,3	28,7	27,2	26,0	24,9	23,9	23,1	22,3	[4]
	Ω_{1-2}	75,1	73,0	70,2	67,1	64,9	62,8	61,3	59,8	[9]

Remark. $\Omega_{1-1} = \sigma^2\Omega_{1-1}^{(2,2)*}$; $\Omega_{1-2} = \sigma^2\Omega_{1-2}^{(2,2)*}$.

TABLE 2. Viscosity of Lithium Vapor, $\eta \cdot 10^7$, Pa · sec

T, °K	Monatomic vapor	p, bar									On saturation
		$3 \cdot 10^{-3}$	$3 \cdot 10^{-2}$	$3 \cdot 10^{-1}$	1	2	3	5	7	8,5	
800	103										101
900	113										109
1000	122										115
1100	132	126									121
1200	141	138									125
1300	150	149	140								129
1400	159	158	153								133
1500	167	167	144								135
1600	176	176	174	160							138
1700	184	184	183	173	156						141
1800	192	192	191	185	171	157	147				144
1900	201	201	200	195	185	173	164	150			146
2000	209	209	208	205	197	187	180	166	157	152	149

TABLE 3. Thermal Conductivity of Lithium Vapor, $\lambda \cdot 10^4$, W/m · °K

T, °K	Monatomic vapor	p, bar									On saturation curve
		$3 \cdot 10^{-3}$	$3 \cdot 10^{-2}$	$3 \cdot 10^{-1}$	1	2	3	5	7	8,5	
800	463										586
900	507										707
1000	550										830
1100	592	794									944
1200	633	701									1040
1300	673	699	899								1120
1400	712	723	816								1180
1500	751	757	801	1110							1230
1600	790	792	815	1000							1240
1700	827	829	841	951	1140						1260
1800	864	866	873	939	1070	1180	1250				1270
1900	902	902	906	947	1030	1120	1180	1250			1270
2000	938	938	941	966	1020	1090	1140	1210	1240	1260	1270

It can be seen from Fig. 3 that the fraction of the heat flux due to the transfer of the energy of the dissociation reaction is nowhere greater than 50%. Thus, the effect of the dissociation reaction on the thermal conductivity of lithium vapor is much less than indicated by the data of [1, 7, 8], and this is due to the large value of $\beta^{(2)}$.

The calculations for sodium and potassium are in good agreement with the available experimental data [4]. To illustrate the degree of reliability of our calculations, in Fig. 4, as an example, we compare the results of our study on the thermal conductivity of sodium vapor with experimental values from [4]. The difference is less than 10%, and therefore, in the absence of experimental data for lithium, the accuracy of the calculated values (Figs. 1-3, Tables 2, 3) may also be estimated as about ±10%.

NOTATION

$\sigma^2\Omega_{1-1}^{(2,2)*}$, integral of monomer–monomer collisions; $\sigma^2\Omega_{1-2}^{(1,1)*}$, $\sigma^2\Omega_{1-2}^{(1,2)*}$, $\sigma^2\Omega_{1-2}^{(1,3)}$, $\sigma^2\Omega_{1.2}^{(1,3)*}$, $\sigma^2\Omega_{1-2}^{(2,2)*}$, integrals of monomer–dimer collisions; $\sigma^2\Omega_{2-2}^{(2,2)*}$, integral of dimer–dimer collisions; $\beta^{(2)}$, ratio $\sigma^2\Omega_{1-2}^{(2,2)*}/\sigma^2\Omega_{1-1}^{(2,2)*}$; A_{1-2}^* is the value of $\sigma^2\Omega_{1-2}^{(1,1)*}/\sigma^2\Omega_{1-2}^{(1,1)*}$; B_{1-2}^*, is the value of $(5\Omega_{1-2}^{(1,2)*} - 4\Omega_{1-2}^{(1,3)*})/\Omega_{1-2}^{(1,1)*}$; λ, thermal conductivity of the vapor; λ_r, component of the thermal conductivity that is due to the transfer of the energy of the chemical reaction; T, temperature; p, pressure; η, viscosity of the vapor.

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DETERMINATION OF CERTAIN PHYSICAL PROPERTIES OF A SOLID ON THE BASIS OF THE INTERATOMIC INTERACTION POTENTIAL

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UDC 539.2

The method of computing the dependence of the specific volume of a solid on the pressure and temperature on the basis of the interatomic interaction potential, which is a function of the internal atom energy, is considered. The results obtained are compared with experimental data.

The interaction potential of atoms of a condensed body, which is a function of the atom internal energy, is obtained in [1, 2]. In conformity with this potential, the force f with which a given atom acts on another atom at a remote distance r can be represented as follows

$$f = a\left[(h_0/r)^{\alpha+2} - (h_0/r)^{\beta+2}\right] + bE\,(h_0/r)^{\gamma+2}. \tag{1}$$

Here h_0 is the spacing between two isolated atoms in the equilibrium state ($f = 0$) at an absolute zero temperature ($E = 0$), and α, β, γ, a, b are positive constants.

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