The mean-square spread in the results obtained on the same specimens in different experiments was 2%, despite the fact that the surface of the specimens was not given any special processing. This slight effect of the contact thermal resistances is due to the fairly large thickness of the specimens and the absence of a thermal flux at the center of the composite place where the junction of the differential thermocouple measuring the temperature drop in the specimen is placed.

Using this calorimeter we measured the thermal conductivities of different polymer materials at temperatures from −100 to 300°C.

NOTATION

λ_0, λ_T, a_0, a_T, thermal conductivities and thermal diffusivities of the specimen and heat standard, respectively; q_0, q_T, heat fluxes applied to the specimen and the heat standard; b, rate of heating; R_0, R_T, thicknesses of the specimen and the heat standard; k_T, l_T, constants of the heat standard; C_T, ρ_T, specific heat capacity and density of the heat standard; C_0, C_T, total heat capacities of the specimen and the heat standard; θ_0, θ_T, temperature drops in the specimen and the heat standard; t, temperature.

LITERATURE CITED

1. E. S. Platunov, Thermal Measurements under Monotonic Conditions [in Russian], Énergiya, Moscow (1973).
2. T. Gast, K. H. Hellwege, and E. Kohlepp, Kolloid-Z., 152, 1 (1957).
3. D. A. Sergeev, Metrological Principles of Thermal Measurements [in Russian], Standartgiz, Moscow (1972).
4. L. L. Vasil'ev and Yu. E. Fraiman, Thermal Properties of Poor Heat Conductors [in Russian], Nauka i Tekhnika, Minsk (1967).

EXPERIMENTAL INVESTIGATION OF THE TEMPERATURE DEPENDENCE OF THE ACCOMMODATION COEFFICIENTS FOR THE GASES He, Ne, Ar, AND Xe ON A Pt SURFACE

S. F. Borisov, S. A. Litvinenko,
Yu. G. Semenov, and P. E. Suetin

UDC 533.06

This paper presents measurements of accommodation coefficients for the gases He, Ne, Ar, and Xe on a Pt surface in the temperature range 100-500°K. An improved unsteady hot-wire method at low pressure is used.

The experience of thermophysical investigations in gases has pointed out the need to study phenomena occurring at the gas–solid interface and adjacent to it. An important factor in the study of these phenomena is knowledge of the energy accommodation coefficients for gas molecules on the surface of solids, particularly on the surface of metals. The accommodation coefficient describes the degree of energy exchange of the gas molecules and the solid surface and is given by the expression [1]

$$\alpha_E = \frac{E_i - E_r}{E_i - E_w}, \tag{1}$$

where E_i is the energy arriving with the incident molecules; E_r is the energy carried away by reflected molecules; and E_w is the energy which would be carried away by reflected molecules if they acquired the surface temperature.

Expression (1) is valid only when the incident molecule temperature differs very little from the surface temperature.

S. M. Kirov Ural Polytechnic Institute, Sverdlovsk.

Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 34, No. 5, pp. 880-884, May, 1978. Original article submitted April 19, 1977.

0022-0841/78/3405-0603$07.50

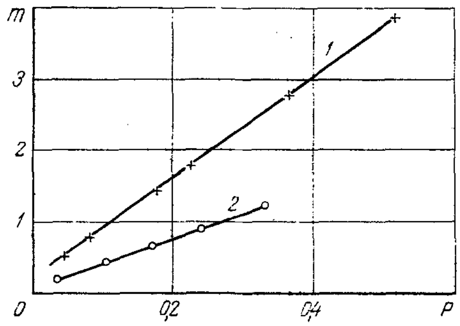

Fig. 1. Cooling rate of a 30-μm-diameter platinum wire as a function of gas pressure: 1) He; 2) Ar. m, sec^{-1}; P, torr.

In this paper the difference between the incident molecule temperature and that of the surface was kept to a minimum and was about 1-2°C. In investigating the temperature dependence of α_E, we could thus obtain results with a high temperature precision.

The instrumentation to investigate the temperature dependence of α_E consisted of a fine platinum wire located in a gas volume with given temperature, an emf source to supply the heating pulses, and a device for recording small changes in wire temperature. The equipment has been described in [2], where it was used to investigate the thermal diffusivity and thermal conductivity of gases. The instrument used here differs from that reported in [12] only in that an RC oscillator was used to record small temperature changes.

With this equipment the temperature sensitivity is 10^3 Hz/deg. A frequency meter was used as an indicator. In addition, there was a system which allowed any temperature in the range 100-500°K to be obtained and monitored.

During the experiment the wire was supplied with heating pulses by connecting it for short periods to an emf source. Thereafter the wire began to cool, acquiring the temperature of the surrounding gas. The gas pressure was chosen to achieve molecular conditions relative to the wire radius. The wire temperature change was determined from the frequency change of the RC oscillator. The oscillator frequency was measured using a frequency meter.

In the experiment the basic measured quantity was chosen to be the wire cooling rate. If the temperature difference between the wire and gas at some zero time is ΔT_M, and is ΔT_i ($\Delta T_i < \Delta T_M$) at a subsequent time t_i, then a relation of the type

$$\frac{\Delta T_i}{\Delta T_{\text{M}}} = \exp[-mt_i] \tag{2}$$

describes the wire cooling rate m with a logarithmic rate of change of wire temperature as long as the wire is cooling and giving heat to molecules of the surrounding gas. The amount of heat carried off by the gas molecules from the wire surface in unit time can be expressed [3] by

$$Q = 2\pi rl \frac{P}{\left(2\pi \frac{\mu}{N_0} kT_0\right)^{-\frac{1}{2}}} \left(\frac{\mu C_v}{N_0} + \frac{k}{2}\right) \alpha_E \Delta T_i\,. \tag{3}$$

The efflux of heat from the wire to the gas leads to a reduction in the initial heat charge. From heat balance we have

$$Q = -\frac{d}{dt}\,[\rho\pi r^2 l C_p \Delta T_i]. \tag{4}$$

Integration of Eq. (4), allowing for Eqs. (2) and (3), gives an expression relating the wire cooling rate m and the energy accommodation coefficient α_E:

TABLE 1. Measured Values of Accommodation Coefficients α_E for the Gases He, Ne, Ar, and Xe on a Pt Surface and Data of Other Authors (taken from [4])

Our data				Data from other authors, for comparison			
gas	T, °K	α_E	error, %	T, °K	α_E	error, %	author and year
He	92	0,332	4,2	77,4	0,43		Rolf, 1944
He	150	0,305	7,5	193,2	0,071		Rolf, 1944
He	284	0,312	2,3	273,2	0,16		Rolf, 1944
He	373	0,277	3,2	290	0,36		Khavkin, 1955
He	473	0,251	2,5	293	0,338		Knudsen, 1915
He				373	0,35		Mann, 1933
Ne	110	0,874	2,3				
Ne	295	0,634	2,1	293	0,653		Knudsen 1915
Ne	404	0,452	2,2	314,3	0,446		Tomas, 1954
Ne	473	0,366	2,2	483,5	0,356		Tomas, 1954
Ar	163	0,788	3,1				
Ar	293	0,660	2,9	290	0,81		Khavkin, 1955
Ar	373	0,608	3,3	363	0,76	4,5	Frolova, 1971
Ar	473	0,498	2,2	425	0,56		Frolova, 1971
Ar	573	0,401	15,5				
Xe	120	1,00	3,0				
Xe	133	0,937	2,5				
Xe	293	0,728	2,1	290	0,86		Khavkin, 1955
Xe	373	0,631	3,2	306	0,97		Esh and Fron, 1973
Xe	473	0,560	3,5				

$$\alpha_E = \frac{C_p \rho r \left(2\pi \frac{\mu}{N_0} k T_0\right)^{\frac{1}{2}}}{2\left(C_v \frac{\mu}{N_0} + \frac{k}{2}\right)} \cdot \frac{m}{P}. \tag{5}$$

For low values of the temperature drop ΔT_i the relation between the frequency change of the RC oscillator and temperature can be written in the simple form

$$\frac{\Delta T_i}{\Delta T_M} = \frac{\Delta F_i}{\Delta F_M} = \exp[-m t_i], \tag{6}$$

where ΔF_i is the drop in oscillator frequency, corresponding to a temperature drop ΔT_i; ΔF_M is the frequency drop corresponding to the initial heating of the wire.

The logarithm of Eq. (6) gives an expression for the cooling rate:

$$m = -\frac{1}{t_i} \ln \frac{\Delta F_i}{\Delta F_M}. \tag{7}$$

During the measurement we determined the drop in frequency appearing in Eq. (7) and the corresponding time values t_i. By a least-squares method we calculated the wire cooling rate m. The accommodation coefficients α_E were determined from Eq. (5).

Since the total wire cooling rate was determined in each individual measurement, and it includes heat loss by radiation and heat loss at the end of the wire, in addition to heat transfer to the gas, to obtain α_E one needs the wire cooling rate at different gas pressures. Relations of the type m = f(P) were constructed and investigated. These relations were found to be linear (Fig. 1) under molecular conditions with respect to wire radius and therefore α_E could be found from the tangent of the slope of the line, fitted by least squares.

Table 1 shows the results of investigating the temperature dependence of α_E for the gases He, Ne, Ar, and Xe on the surface of a platinum wire of diameter 30 μm. Table 1 also shows data of other authors, obtained at different times by the low-pressure method. These data were taken from [4]. The form of the temperature dependence of α_E for the gases investigated is shown in Fig. 2.

By analyzing the data obtained, two main conclusions can be drawn.

1. For all the gases investigated a monotonic increase of α_E with reduction in temperature is observed.

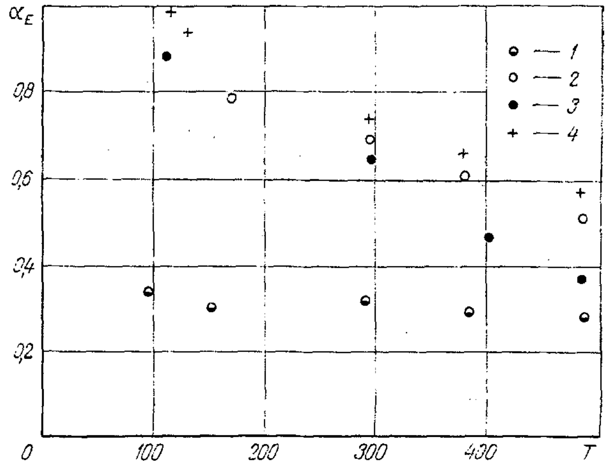

Fig. 2. Temperature dependence of α_E for He, Ar, Ne, and Xe on Pt: 1) He; 2) Ar; 3) Ne; 4) Xe. T, °K.

2. The accommodation coefficient α_E depends on the purity of the surface, and the presence of protective impurities (films of oil or water) leads to a reduction in accommodation coefficient α_E, in comparison with a surface cleaned of impurities by baking at high temperature.

This experimental investigation of the temperature dependence of the accommodation coefficients for a number of rare gases by an unsteady low-pressure method has yielded a series of results which we have combined within one technique and which span a wide temperature range — from 100 to 500°K. For the gases Ne, Ar, and Xe in the low-temperature range the accommodation coefficients were measured for the first time.

By using a high-sensitivity temperature-measuring device in the form of an RC oscillator we could improve the accuracy of the low-temperature method and also reduce its difficulty. There is reason to believe that this improvement may find further application in thermophysical investigations.

NOTATION

α_E, thermal accommodation coefficient, dimensionless; Q, heat flux from the hot wire to the gas, W/m²; m, wire cooling rate, sec^{-1}; ρ, density of wire material, kg/m³; C_p, heat capacity of wire material, J/kg·deg; T_0, gas temperature, °K; l, wire length, m; r, wire radius, m; C_V, specific heat of gas, J/kg·deg; μ, gas molecular weight, kg/mole; N_0, Avogadro's number, mole^{-1}; P, gas pressure, N/m²; k, Boltzmann constant, J/deg.

LITERATURE CITED

1. M. N. Kogan, Rarefied Gas Dynamics, Plenum Press (1969).
2. Yu. A. Gorshkov, V. V. Koroleva, A. S. Umanskii, and D. L. Timrot, "Measurement of the thermal conductivity of a gas by a transient method," in: Thermophysical Properties of Gases. Papers of the Third All-Union Thermophysics Conference on Properties of Matter at High Temperature, Baku, October, 1968 [in Russian], Nauka, Moscow (1970).
3. H. S. W. Massey and E. H. S. Burhop, Electronic and Ionic Impact Phenomena, Oxford Univ. Press (1952).
4. O. A. Kolenchits, Author's Abstract of Candidate's Dissertation, A. V. Lykov Institute of Heat and Mass Transfer, Academy of Sciences of the Belorussian SSR, Minsk (1975).