EXPERIMENTAL DETERMINATION OF THE ACCOMMODATION COEFFICIENTS OF ARGON AND XENON ON NICKEL AT HIGH TEMPERATURES

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The accommodation coefficients of argon and xenon on nickel are obtained in the temperature range from 940 to 1150°K. The data are obtained for measurements of the temperature change determining the thermal conductivity of gases by the coaxial cylinders method.

The accommodation coefficients of monatomic gases on tungsten and platinum have been studied in detail [1] mainly at low temperatures (300-400°K). Experimental results are given in [2] for the accommodation coefficient of argon on silver. For argon and nickel only one experimental point $\alpha = 0.935$ has been obtained [3] at a temperature of 298°K. There are no results for the accommodation coefficient of xenon on nickel in the literature.

In this paper values of the accommodation coefficients are obtained from measurements of the temperature change for argon and xenon. The experiments were made on two setups for determining the thermal conductivity of gases using coaxial cylinders made of nickel.

When working with argon the dimensions of the measuring cell were as follows (mm): the working diameter of the inner cylinder was 12.91, the working diameter of the surrounding cylinder was 14.09, the working gap was 0.59, the thickness of the cylinder walls was 1.0, the length of the working part was 100.3, and the length of the cylinders was 200. The temperature change for xenon was measured on apparatus with a smaller working gap in order to reduce the heat transmitted by radiation. The dimensions of the cylinders of the second apparatus were as follows (mm): the working diameter of the inner cylinder was 10.70, the working diameter of the surrounding cylinder was 11.10, the working gap was 0.20, the thickness of the cylinder walls was 1.0, the length of the working part was 78.7, and the length of the cylinders was 230.

The radial flow of heat was produced by an internal heater, which had a main and two protective windings. Three platinum—platinum-rhondium thermocouples were placed on the walls of the inner and surrounding cylinders along the length of the working part. The temperature difference between the cylinders was 20-46°K. The nonuniformity of the temperature field over the working part was not greater than 0.1-0.2°K.

The measuring cylinders were kept in a thermostat with automatic temperature control.

The temperature change for argon was measured at temperatures of 943, 1083, 1098, and 1148°K, and at pressures from 3 to 760 mm Hg, and for xenon at a temperature of 1089°K and pressures from 5 to 100 mm Hg. Before admitting the gases the apparatus was first degassed for 5 hours at a temperature of 900°K.

The value of the temperature change was found from the well-known relation [4]

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TABLE 1. Experimental Data for Determining the Accommodation Coefficient of Argon and Xenon on Nickel

Number of points	T_{gas}, °K	ΔT_p, °K	ΔT_{gas}, °K	W_{tot}, W	W_λ, W	p, mm Hg	1/p, mm Hg	ΔT_{red}, °K	α
				Argon					
1	943	23,2		8,659	6,772	762	0,0013	23,3	
2	"	23,2		8,699	6,797	355	0,0028	23,2	
3	"	23,4		8,732	6,802	99	0,0101	23,4	
4	"	24,4		8,709	6,698	33	0,0303	24,8	
5	"	25,0	23,1	8,762	6,700	23	0,0435	25,4	0,80
6	"	26,5		8,760	6,582	12,5	0,080	27,4	
7	"	27,5		8,796	6,535	9,5	0,105	28,6	
8	"	28,7		8,796	6,438	6,5	0,154	30,3	
9	"	31,7		8,796	6,163	4,0	0,250	35,0	
10	"	34,2		8,742	5,893	3,0	0,333	39,4	
11	1083	28,5		13,386	9,530	752	0,0013	28,5	
12	"	28,6		13,368	9,485	352	0,0028	28,7	
13	"	29,3		13,354	9,380	97	0,0103	30,0	
14	"	30,5	28,4	13,347	9,205	34	0,0294	31,6	0,644
15	"	31,6		13,340	9,046	22,5	0,0445	33,2	
16	"	34,4		13,284	8,595	10,0	0,100	38,1	
17	"	38,5		13,279	8,011	5,5	0,182	45,8	
18	"	45,6		13,325	6,995	3,0	0,333	62,0	
19	1098	27,9		13,100	9,034	680	0,0015	27,9	
20	"	28,3		13,066	8,912	116	0,0086	28,6	
21	"	30,4	27,7	13,066	8,596	23,4	0,0427	31,9	0,649
22	"	33,2		13,071	8,196	10,4	0,096	36,6	
23	"	37,5		12,957	7,433	5,5	0,182	45,5	
24	1148	28,1		14,596	9,708	752	0,0013	28,1	
25	"	28,2		14,499	9,591	353	0,0028	28,5	
26	"	28,8		14 508	9,505	94,5	0,0106	29,4	
27	"	30,4	28,0	14,462	9,243	39,5	0,0253	31,9	0,624
28	"	31,2		14,445	9,002	21,5	0,0465	33,6	
29	"	33,4		14,348	8,532	11,5	0,087	38,0	
30	"	40,2		14,075	6,972	4,0	0,250	55,8	
				Xenon					
1	1089	19,0		6,089	4,646	100	0,010	19,0	
2	"	20,0		6,078	4,567	47	0,0213	20,4	
3	"	22,4	17,5	6,179	4,499	21	0,0476	23,1	0,758
4	"	24,6		6,128	4,219	11	0,091	27,1	
5	"	29,9		6,092	3,784	5,5	0,182	36,7	

Note. T_{gas} is the mean temperature of the gas in the gap; ΔT_p is the temperature drop between the cyclinders; W_{tot} is the measured total heat flux; W_λ is the heat flux transmitted by conduction; p is the pressure of the gas in the experiment; ΔT_{red} is the reduced temperature drop; α is the accommodation coefficient, and $\Delta T_c = \Delta T_p - \Delta T_{gas}$.

$$\Delta T_p = \Delta T_{gas} + B\left(\frac{1}{p}\right),$$

where ΔT_p is the temperature drop at a given pressure, and T_{gas} is the temperature drop as $p \to \infty$.

On the basis of experimental results for the thermal conductivity of argon and xenon, and a comparison of the values obtained with the data in the literature, we determined the correction to the contact resistance of the thermocouples, and the temperature drop on the walls of the nickel cylinders. This correction was from 3 to 10%, and was made to the measured temperature difference.

During the experiments at different pressures, due to the change in T_p the amount of heat transmitted by radiation W_r as a fraction of the total flux W varied somewhat, and, consequently, the flux W_λ was not constant. Hence, for each isotherm we calculated

$$\Delta T_{red} = \Delta T_p \frac{W_{\lambda_{max}}}{W_\lambda},$$

where $W_{\lambda_{max}}$ is the maximum value of heat flow, due to thermal conductivity, for a given isotherm, and W_λ is the heat flow for the remaining points of the isotherm.

The experimental data are given in the Table 1.

The accommodation coefficient is found from the well-known relation [5]

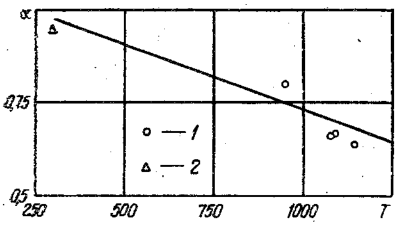

Fig. 1. Graph of α = f(T) for argon. 1) Our data; 2) the data given in [3]. T, °K.

$$\frac{\Delta T_p}{Q} = \frac{\ln \frac{r_2}{r_1}}{2\pi\lambda l} + \frac{A}{p}\left(\frac{\sqrt{T_1}}{r_1} + \frac{\sqrt{T_2}}{r_2}\right), \tag{1}$$

where

$$A = \sqrt{\frac{2\pi M}{R}} \cdot \frac{1}{2\pi l} \cdot \frac{2-\alpha}{2\alpha\left(\frac{C_V}{R} + \frac{1}{2}\right)} = \frac{K(2-\alpha)}{2\pi l\alpha}$$

and

$$\frac{\ln \frac{r_2}{r_1}}{2\pi l\lambda} = \frac{\Delta T_{gas}}{Q}; \tag{2}$$

Q is the heat flux, transmitted by conduction, λ is the thermal conductivity, α is the accommodation coefficient, M is the molecular weight of the gas, C_V is the heat capacity of the gas at constant volume, R is the universal gas constant, p is the pressure of the gas, r_1 and r_2 are the radii of the internal and external cylinders, and l is the length of the working part.

The coefficients K depend solely on the properties of the gas

$$K = \sqrt{\frac{2\pi M}{R}} \cdot \frac{1}{2\left(\frac{C_V}{R} + \frac{1}{2}\right)}.$$

The relative value of temperature change can be represented as

$$\delta T_c = \frac{\Delta T_p - \Delta T_{gas}}{\Delta T_{gas}} = \frac{\Delta T_c}{\Delta T_{gas}}. \tag{3}$$

Using Eqs. (2) and (3), Eq. (1) can be converted to form

$$\delta T_c = \frac{2\pi l\lambda A}{p \ln \frac{r_2}{r_1}}\left(\frac{\sqrt{T_1}}{r_1} + \frac{\sqrt{T_2}}{r_2}\right). \tag{4}$$

Since the gap h between the cylinders is much less than their diameters we have

$$\ln \frac{r_2}{r_1} = \ln\left(1 + \frac{h}{r_1}\right) \approx \frac{h}{r_1}. \tag{5}$$

Using relations (5) and the fact that $T_1 \approx T_2$, and $r_1 \approx r_2$, from Eq. (4), the accommodation coefficient is given by

$$\alpha = \frac{2{,}74\lambda\sqrt{TM}}{1{,}37\lambda\sqrt{TM} + ph\,(\delta T_c)}, \tag{6}$$

where T = $(T_1 + T_2)/2$, °K; δT_c, %; p, N/m^2; λ, W/m·deg; h, m; M, kg/k·mole.

The accommodation coefficients of argon and xenon calculated from Eq. (6) are given in the Table. The error in determining α is ±8%.

The figure shows our data and also the experimental value of α obtained in [3] for argon on nickel. It can be seen from the figure that the agreement is quite satisfactory.

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