STUDY OF THERMAL CONDUCTIVITY OF AN He–Ar MIXTURE IN THE TEMPERATURE RANGE OF 400-1500°K ON AN INSTALLATION WITH A MOLYBDENUM MEASURING CELL

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The thermal conductivity of argon–helium mixtures (0.2, 0.4, 0.6, 0.8 He) is studied in a wide range of temperatures by the heated-wire method with an accuracy of ±2-4%. Experimental data above the temperature of 793°K are obtained for the first time.

The current level of development of vacuum and electronic technology and the metallurgy of refractory metals and alloys which extensively employ monatomic gases and their mixtures requires knowledge of the thermal conductivity in a wide range of temperatures, pressures, and concentrations.

The thermal conductivity of mixtures of monatomic gases is insufficiently studied at present. Essentially, these studies in a wide region of the parameters of state are only beginning [1].

The study of the thermal conductivity of an He–Ar mixture in the temperature range of 400-1500°K at the four concentrations of 0.2, 0.4, 0.6, and 0.8 He were conducted on an installation with a molybdenum measuring cell which was used earlier to study the thermal conductivity of pure gases – helium and argon [2, 3]. The method, a schematic diagram of the installation, the design of the molybdenum measuring cell, and the power and measuring systems were discussed in detail in [2].

The installation with a molybdenum measuring cell realizes the absolute method of a heated wire (filament) and differs from those used earlier in the fact that the main element of the measuring cell – a molybdenum tube – is heated by the passage of a current.

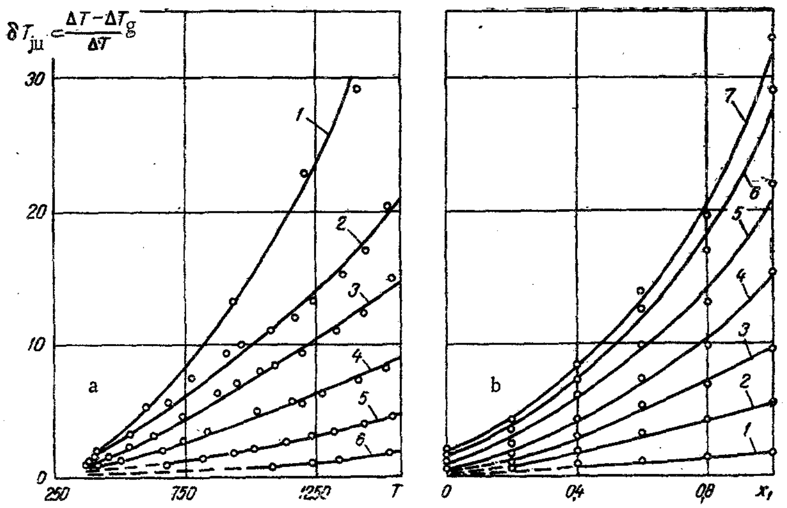

Fig. 1. Temperature dependence (a) and concentration dependence (b) of correction for temperature jump. a: 1) He; 2) 0.8 He; 3) 0.6 He; 4) 0.4 He; 5) 0.2 He; 6) Ar; b: 1) 400; 2) 600; 3) 800; 4) 1000; 5) 1200; 6) 1400; 7) 1500°K. δT_{ju}, %. T, °K.

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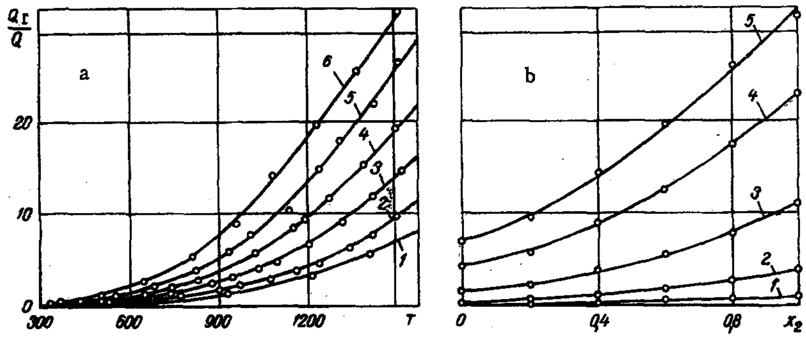

Fig. 2. Temperature dependence (a) and concentration dependence (b) of fraction of radiation. a: 1) He; 2) 0.2 Ar; 3) 0.4 Ar; 4) 0.6 Ar; 5) 0.8 Ar; 6) Ar; b: 1) 400; 2) 700; 3) 1000; 4) 1300; 5) 1500°K. Q_r/Q, %.

The measuring filament was made of MR-50 molybdenum–rhenium alloy. The eccentricity of the filament within the opaque tube was determined by fluoroscopy of the measuring cell in two mutually perpendicular planes on an RUP-200 x-ray apparatus and was no more than 0.23 mm, which introduced a maximum correction of about 0.2% into the determination of the thermal conductivity.

The use of a current-carrying molybdenum tube led to the fact that the method of temperature measurements was used which made it possible to measure the filament temperature T_f and the temperature of the tube wall T_w, as well as the temperature drop ΔT between them using the measuring filament (resistance thermometer) at the "nonheating" and "heating" values of the current [4]. This made it possible to study the thermal conductivity of the gas mixture in a rather wide range of temperatures with small temperature drops between the filament and the tube wall (not more than 10°).

For the given installation the effect of free convection was excluded by choosing the geometry of the measuring cell and the temperature drop in the test gas layer so that the Rayleigh number was less than 1000 in the entire temperature range. The use of a measuring filament with three potential leads made it possible to experimentally take into account the heat removal from the ends of the measuring filament. The temperature drop in the wall of the metal tube was negligibly small and comprised less than 0.001°. The correction for thermal expansion of elements of the measuring cell was introduced by means of calculation, while the correction for the temperature jump was introduced experimentally [2]. This correction as a function of the temperature and concentration for an He–Ar mixture is presented in Fig. 1a, b, from which it is seen that the correction for the temperature jump increases with an increase in temperature and, in addition, it is the larger, the smaller the molecular weight of the gas or the mixture. This correction was on the order of 20% for a gas composition of 0.8 He at 1509°K. The concentration dependence of the correction for the temperature jump for "round" values of the temperature was obtained from smoothed and interpolated data on the temperature dependence. The correction for the temperature jump for a gas mixture with a predominance of Ar is small in the entire temperature range under consideration. As for Ar gas alone and a mixture composition of 0.8 Ar, below 800-900°K the accuracy of our measurements did not permit us to reliably obtain this correction for them. Therefore, we estimated it by extrapolation from the region of higher temperatures (the section of the curve in Fig. 1 denoted by dashes). At the maximum temperature of 1516°K for argon the correction for the temperature jump was 1.8% and for a composition of 0.8 Ar at 1518°K it was 4.3%.

These experimental measurements of the correction for the temperature jump have an independent value for estimating the accomodation coefficients of helium, argon, and their mixture at the surface of a molybdenum–rhenium filament.

The effect of radiation and the correction connected with it are important in a study of the thermal conductivity of gas mixtures at high temperatures. The heat transferred by radiation was taken into account by means of calculation by the Stefan–Boltzmann equation. The temperature dependences of the integral hemispherical emissivity and of the ratio of the resistance of the filament to its resistance at 20°C were obtained in special experiments at the All-Union Scientific-Research Institute of Aviation Materials on an installation of V. A. Vertogradskii [5]. The error in the determination of the temperature dependence of the resistance ratio was 0.3% at a confidence probability of 0.95.

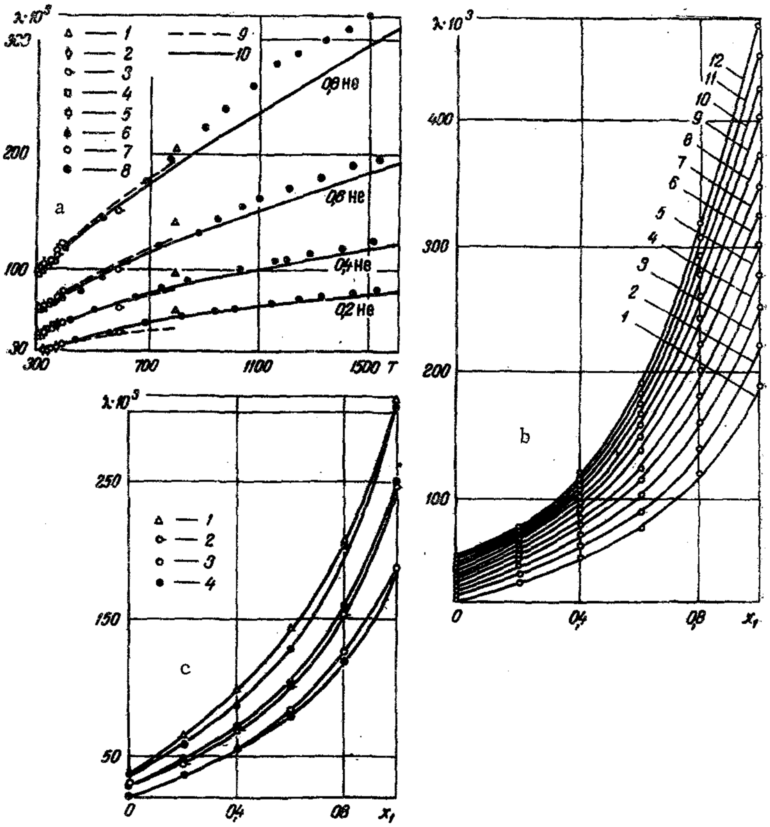

Fig. 3. Temperature dependence (a) and concentration dependence (b and c) of thermal conductivity of He−Ar mixture and comparison of experimental values obtained with the data of other authors and with the data of graphic correlations. a: 1) [14]; 2) Saxena; 3) [15]; 4) Gambhir and Saxena; 5) Rychkova and Golubev; 6) [11]; 7) [12]; 8) our data; 9) graphic correlation of [17]; 10) graphic correlation of [8]; b: 1) 400; 2) 500; 3) 600; 4) 700; 5) 800; 6) 900; 7) 1000; 8) 1100; 9) 1200; 10) 1300; 11) 1400; 12) 1500°K; c: 1) 793°K [14]; 2) 589°K [15]; 3) 390°K [12]; 4) our data. $\lambda \cdot 10^3$, W/m · deg.

The temperature and concentration dependences of the ratio of the radiant flux to the effective heat flux for the pure gases and an He−Ar mixture are presented in Fig. 2a, b. It is seen from these graphs that the fraction of radiation in the overall flux increased with an increase in temperature and reached a maximum value on the order of 33% for the heavy gas argon at 1516°K, while for the light gas helium it was only 6% at a temperature of 1413°K. In addition to these factors, thermal diffusion has a certain effect in measurements of the thermal conductivity of gas mixtures [6].

We calculated the correction for thermal diffusion for the maximum temperature of 1500°K by the method of [7] using the modified Buckingham potential (exp-6). The calculation showed that the corrections $\lambda_D T/\lambda$ for the four concentrations of 0.2, 0.4, 0.6, and 0.8 He are 1.44, 1.82, 1.55, and 0.9%, respectively, i.e., it does not exceed 2%. Only the effect of thermal diffusion can be judged on the basis of these calculations. It is impossible to calculate this correction exactly in a quantitative respect, since a comparison of experimental data (concentration and temperature dependences) on the thermal diffusion constant for an He−Ar mixture [18] with the theoretical data showed that the calculated α_T data obtained with the use of different potential functions are not in satisfactory agreement with the experimental data. Moreover, the experiment of [18] showed that the temperature dependence of α_T does not agree even qualitatively with that given by a calculation based on strict kinetic theory.

In order to decrease the effect of thermal diffusion in our installation with a molybdenum measuring cell the measurements of the thermal conductivity of gas mixtures were performed with small temperature

TABLE 1. Measurement Data and Experimental Values of Thermal Conductivity of He–Ar Mixture for Concentrations of 0.2, 0.4, 0.6, and 0.8 He at P = 1 atm (I_0 = 0.002 A)

R_l^0	R_s^0	I	R_l	R_s	$\frac{R_{ef}^0}{R_{ef}^{20}}$	$\frac{R_{ef}}{R_{ef}^{20}}$	T_w	ΔT	T_f	ΔT_g	$\bar{T}$	$Q\cdot 10^6$	$Q_r\cdot 10^6$	$Q_t\cdot 10^6$	$\lambda\cdot 10^4$	δT_{ju}	$\frac{Q_r}{Q}$
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							0,2 He —	0,8 Ar									
2,5511	0,9771	0,12000	2,5814	0,9889	1,0596	1,0721	331,6	7,9	339,5	7,89	336	22926	46	22880	31,5	0,2	0,2
2,8993	1,1011	0,12460	2,9287	1,1123	1,2106	1,2228	429,8	7,86	437,66	7,84	434	28193	130	28063	38,8	0,3	0,46
3,3141	1,2481	0,12619	3,3432	1,2591	1,3909	1,4031	547,6	7,84	555,44	7,8	552	33179	345	32834	45,6	0,5	1,04
3,7868	1,4173	0,12768	3,8157	1,4282	1,5952	1,6073	678,2	7,81	686,0	7,76	682	38912	809	38103	53,2	0,7	2,08
4,3071	1,6090	0,12698	4,3363	1,6202	1,8164	1,8285	816,4	7,8	824,2	7,7	820	43783	1703	42080	59,2	1,3	3,9
4,7249	1,7684	0,12611	4,7536	1,7794	1,9904	2,0023	926,8	7,77	934,57	7,65	931	47289	2801	44488	63,0	1,6	5,9
5,0024	1,8809	0,12600	5,0308	1,8918	2,1015	2,1132	1000,9	7,75	1008,65	7,61	1004	49823	3885	45938	65,4	1,8	7,8
5,4993	2,0716	0,12560	5,5276	2,0825	2,3076	2,3193	1133,4	7,7	1141,1	7,52	1137	54335	6231	48104	69,3	2,3	11,5
5,8793	2,2209	0,12597	5,9073	2,2317	2,4629	2,4745	1233,6	7,66	1241,26	7,45	1237	58311	8732	49579	72,1	,7	15,0
6,1793	2,3400	0,12666	6,2069	2,3506	2,5847	2,5961	1312,8	7,65	1320,45	7,4	1316	61851	11099	50752	74,3	3,2	18,0
6,6025	2,5032	0,12841	6,6298	2,5137	2,7597	2,7710	1427,3	7,62	1434,92	7,33	1431	67855	15554	52301	77,3	3,8	22,9
6,9050	2,6208	0,13029	6,9348	2,6311	2,8862	2,8973	1514,4	7,6	1522	7,27	1518	73040	19554	53486	79,7	4,3	26,8
							0,4 He —	0,6 Ar									
2,6670	1,0177	0,15788	2,7008	1,0308	1,1103	1,1243	364,5	8,8	373,3	8,74	369	41622	76	41546	51,5	0,7	0,18
2,8460	1,0815	0,15996	2,8791	1,0943	1,1879	1,2016	414,5	8,78	423,28	8,7	419	45663	128	45535	56,7	0,9	0,28
3,1469	1,1894	0,16215	3,1795	1,2020	1,3178	1,3313	499,8	8,75	508,55	8,65	504	51985	244	51741	64,8	1,1	0,47
3,6710	1,3783	0,16251	3,7034	1,3905	1,5435	1,5571	645,9	8,78	654,68	8,61	650	61074	748	60326	75,9	1,9	1,2
4,0063	1,5012	0,16218	4,0407	1,5141	1,6865	1,7001	735,2	8,77	743,97	8,53	739	66446	1250	65196	82,8	2,7	1,9
4,3736	1,6421	0,16088	4,4071	1,6555	1,8389	1,8524	830,4	8,73	839,13	8,43	835	71207	2032	69175	88,9	3,4	2,85
5,0675	1,9046	0,15895	5,0993	1,9169	2,1293	2,1425	1018,7	8,65	1027,35	8,25	1023	80392	4577	75815	99,8	4,9	5,7
5,5401	2,0876	0,15733	5,5746	2,0987	2,3270	2,3400	1146	8,6	1154,6	8,12	1150	86024	7318	78706	105	5,6	8,5
5,7034	2,1519	0,15762	5,7375	2,1665	2,3909	2,4041	1187,4	8,62	1196,02	8,13	1191	88704	8407	80297	107	5,7	9,5
6,0259	2,2793	0,15864	6,0571	2,2912	2,5223	2,5353	1272,1	8,64	1280,74	8,09	1276	94760	11119	83641	112	6,4	11,7
6,4624	2,4475	0,15857	6,4935	2,4595	2,7029	2,7158	1389	8,63	1397,63	8,0	1393	101417	15752	85665	116	7,3	15,5
6,8871	2,6161	0,16066	6,9176	2,6279	2,8753	2,8879	1507	8,61	1515,61	7,89	1511	110707	21852	88855	122	8,4	19,7
							0,6 He —	0,4 Ar									
2,7372	1,0448	0,20000	2,7756	1,0597	1,1394	1,1552	383,2	10	393,2	9,9	388	68629	106	68523	75,0	1,1	0,15
2,9722	1,1301	0,20000	3,0096	1,1446	1,2401	1,2556	449,4	9,95	459,35	9,81	454	74593	201	74392	82,2	1,4	0,27
3,2415	1,2273	0,20353	3,2780	1,2413	1,3560	1,3711	524,6	9,9	534,5	9,68	529	84361	367	83994	94,0	2,2	0,44
3,5601	1,3424	0,20551	3,5971	1,3566	1,4930	1,5083	614,3	9,9	624,2	9,6	619	94621	688	93933	106	3,0	0,73
4,0014	1,5039	0,20528	4,0383	1,5180	1,6814	1,6967	732	9,9	741,9	9,44	737	106191	1396	104795	120	4,6	1,3
4,5276	1,7013	0,20000	4,5640	1,7153	1,9026	1,9178	870,1	9,83	879,93	9,19	875	113937	2773	111164	131	6,5	2,4
4,7853	1,8008	0,20368	4,8211	1,8145	2,0092	2,0241	939,3	9,8	949,1	9,1	944	124718	3762	120956	144	7,2	3,0
5,1125	1,9263	0,20400	5,1479	1,9395	2,1450	2,1600	1028,8	9,82	1038,62	9,02	1033	133508	5409	128099	154	8,1	4,1
5,3559	2,0214	0,20447	5,3912	2,0346	2,2449	2,2597	1093,5	9,79	1103,29	8,96	1098	140318	6915	133403	161	8,5	4,9
5,7580	2,1772	0,20216	5,7932	2,1906	2,4107	2,4253	1200,3	9,72	1210,02	8,8	1205	147226	9944	137282	169	9,5	6,8
6,1766	2,3376	0,20217	6,2120	2,3512	2,5845	2,5992	1312,7	9,65	1322,35	8,6	1317	157786	16473	141313	178	11,0	9,0
6,6040	2,5015	0,20013	6,6378	2,5145	2,7619	2,7759	1428,8	9,6	1438,4	8,38	1433	165131	19699	145432	188	12,7	12,0
6,9337	2,6280	0,19888	6,9674	2,6410	2,8987	2,9126	1522,9	9,56	1532,46	8,14	1527	171111	25341	145770	194	14,9	14,8
							0,8 He —	0,2 Ar									
2,7903	1,0674	0,20000	2,8242	1,0862	1,1599	1,1701	396,1	6,45	402,5	6,35	399	69520	76	69437	119	1,5	0,11
3,2623	1,2400	0,20000	3,2861	1,2497	1,3615	1,3709	528,3	6,3	534,6	6,1	531	81448	240	81208	144	3,2	0,29
3,8233	1,4480	0,20000	3,8474	1,4573	1,5991	1,6091	680,8	6,2	687	5,85	684	95594	639	94955	176	5,6	0,67
4,1404	1,5626	0,20000	4,1636	1,5712	1,7354	1,7453	765,9	6,15	772,05	5,7	769	103686	1033	102653	195	7,3	1,0
4,6359	1,7490	0,20000	4,6583	1,7570	1,9435	1,9532	895,9	6,1	902	5,55	899	116040	1905	114135	223	9,0	1,6
4,9094	1,8558	0,20000	4,9309	1,8636	2,0557	2,0650	970,3	6,05	976,35	5,45	973	122680	2640	120040	239	9,9	2,2
5,2887	2,0013	0,20000	5,3101	2,0092	2,2131	2,2222	1072,9	6,0	1078,9	5,35	1076	132023	3888	128135	259	10,8	2,9
5,6155	2,1271	0,20000	5,6380	2,1362	2,3485	2,3575	1159,9	5,95	1165,85	5,25	1163	140058	5273	134785	278	11,8	3,8
5,8992	2,2373	0,19768	5,9204	2,2452	2,4653	2,4742	1235,2	5,95	1241,15	5,15	1238	143602	6795	136807	288	13,4	4,7
6,2880	2,3864	0,19396	6,3096	2,3947	2,6266	2,6356	1339,5	5,90	1345,4	5,0	1342	147264	9270	137994	299	15,2	6,3
6,5997	2,5064	0,19251	6,6172	2,5133	2,7557	2,7628	1424,5	5,9	1430,4	4,9	1427	152091	11874	140217	310	17,0	7,8
6,8855	2,6153	0,18974	6,9063	2,6233	2,8748	2,8834	1506,7	5,9	1512,6	4,7	1509	154176	14925	139251	321	20,3	9,7

drops between the filament and the wall of the molybdenum tube. In addition, the molybdenum tube, heated by the passage of an electric current, was surrounded by coaxial finned shields with a gap of no more than 5 mm between them. The number of shields was chosen so that the temperature difference between shields was no more than 50°. The entire "hot" volume of our installation, divided by the shields into separate "hot" volumes, was greater than the cold volume. The vacuum valves disconnecting the communicating vacuum hoses were placed directly on the housing of the installation, thereby obtaining the minimum "cold" volume for the construction. In experimentally determining the correction for the temperature jump it was important to keep the composition of the test mixture constant at all pressures. Therefore, in the study of gas mixtures, in contrast to pure gases, when changing from one pressure to another the housing of the installation with the measuring cell was carefully evacuated to 10^{-4} mbar, and only then was it filled with a mixture of the same composition but different pressure. The installation was filled with gas from tanks through a reducer and the pressure was measured with an MBP vacuum manometer with an accuracy of ±0.05 mbar.

The gas mixtures were prepared in the measuring cell and the housing of the installation with an accuracy no worse than ±0.5%. High-purity helium (99.993%) and argon (99.957%) were used in the experiments. The measurement of the thermal conductivity of argon and an He–Ar mixture was performed on a measuring cell with the following parameters: inner diameter of tube $d_2 = 5.700 \pm 0.005$ mm, outer diameter of tube $D = 6.300 \pm 0.001$ mm, diameter of measuring filament $d_1 = 0.100 \pm 0.001$ mm, length of long section of filament $l_l = 96.516 \pm 0.001$ mm, length of short section of filament $l_s = 37.117 \pm 0.001$ mm, eccentricity $a = 0.23$ mm, resistance of long section of filament at 20°C $R_l^{20} = 2.4136 \pm 0.0004\ \Omega$, resistance of short section of filament at 20°C $R_s^{20} = 0.9282 \pm 0.0002\ \Omega$, effective length $l_{ef} = l_l - l_s = 59.399 \pm 0.001$ mm, and effective resistance at 20°C $R_{ef}^{20} = R_l^{20} - R_s^{20} = 1.4854 \pm 0.0003\ \Omega$.

The results of the measurements are presented in Table 1.

The temperature dependence of the thermal conductivity of an He–Ar mixture for four concentrations and the concentration dependence of the thermal conductivity at different "round" values of the temperature every 100° in the temperature range of 400-1500°K are presented in Fig. 3a, b, c. The experimental data obtained on the thermal conductivity of an He–Ar mixture were compared with the experimental values of other authors both for the temperature dependence (Fig. 3a) and for the concentration dependence (Fig. 3c), as well as with the data of a graphic correlation [8] and with the theoretical values of [9].

The graphic correlation of [8] did not include more recent works [10-13]; the other works of authors indicated in Fig. 3a are presented in the bibliography of [8]. Of experimental works on the study of the thermal conductivity of this mixture at elevated temperatures we know of only [12, 14, 15]. The thermal conductivity of this mixture has been measured on shock tubes starting practically with temperatures of 1200-1500°K and above [16, 13], i.e., the temperature interval of 800-1500°K has not been studied at all. At the same time, the graphic correlation of [8] showed that the data of [14] are systematically overstated, and our experiments confirmed this (Fig. 3c). The data of [14] in comparison with our data are overstated by an average of 9.3% for the four concentrations at a temperature of 793°K. The experimental values of [15], on the other hand, are understated by an average of 4.4% at a temperature of 589°K. In comparing the data of [15] with our experimental data we obtained a result almost analogous with that of a comparison of their data and the data of the graphic correlation of [8]. As for the data of [14], in a comparison with our experiments their average deviation was found to be 3.4% lower than in a comparison with the results of a graphic correlation. The deviation of the values of [14] from our experimental values for the concentration of 0.8 He is the lowest and comprises 1.5%, whereas for the other concentrations the deviations are seven to eight times larger. The curve of the graphic correlation of [8] passed in such a way that the point of [14] for this concentration lay 7.7% higher. The present experiments showed that this point [14] lies closest of all to our experimental data in the size of the deviation. This fact indicates the inconsistency of the absolute values of the deviation of the data of [14]. At the same time the large decrease in the deviation of these data from 7.7 to 1.5% indicates that our experimental points for this temperature are somewhat overstated for a content of 0.8 He.

A comparison of our data and the values of [12] at a temperature of 390°K shows that our results agree well with [12] for concentrations of 0.2 and 0.4 He, and somewhat worse for 0.6 and 0.8 He. For these two concentrations the data of [12] are higher than ours by 7.5 and 5.5%, respectively.

In Fig. 3a we also present data on the thermal conductivity obtained through the graphic correlations of [8] and [17], for which we made a detailed comparison in [8]. It should be noted that in the temperature region above 1000°K the correlation of [8] is based on experimental data obtained on a shock tube with an accuracy of ±15-20% [16]. A "matchup" of the unequally accurate experimental data of the two temperature intervals of 300-800°K (2-3%) and 1000-5000°K (15-20%) was performed in [8]. It is seen from Fig. 3a that the data of the graphic correlation and the experimental values obtained in the range of 400-700°K agree well with each other for all the concentrations. As for a range of 700-1500°K, here the results of the graphic correlation are systematically understated. A quantitative estimate of the deviations of the data of the graphic correlation from the experimental values shows that for the concentration of 0.2 He the average deviation calculated for the eight "round" temperature values starting with 800°K is 3.8%, for 0.4 He it is 4.5%, for 0.6 He it is 4.4%, and for 0.8 He it is 9.1%. For a composition of 0.8 He we obtained an average deviation about two times larger than for the other compositions. This evidently indicates that our experimental data for this concentration are somewhat overstated. This overstatement of the values of the thermal conductivity for the concentration of 0.8 He can be explained in part by the effect of the thermal diffusion and the eccentricity, which lead to overstatement of the experimental values of the thermal conductivity. At the same time, the values obtained above for the deviations of the data of the graphic correlation from the experimental data indicate that the graphic "match" of unequally accurate (having different "weights") experimental data for the two temperature ranges was performed rather successfully.

A comparison between the experimental data obtained on the thermal conductivity of an He—Ar mixture and the theoretical values of [9] showed that our experimental values of the thermal conductivity of an He—Ar mixture at temperatures above 1000°K are in satisfactory agreement with the theoretical values calculated using the modified Buckingham potential (exp-6) and the Morse potential. The comparison in [9] of the experimental values with the calculated data of other authors showed that the (9-6) potential is not at all acceptable for calculating the thermal conductivity of the given mixture in the indicated temperature range.

On the basis of the equation

$$\frac{\Delta\lambda}{\lambda}=\frac{\Delta A}{A}+\frac{\Delta Q_t}{Q_t}+\frac{\Delta(\Delta T_g)}{\Delta T_g}$$

an estimate was made of the maximum relative error of the thermal conductivity values for helium, argon, and their mixture for the initial and final temperatures of the measurement range, and it showed that with an increase in the temperature the average value of the maximum error increases from ±2% at 400°K to ±4% at 1500°K. It is interesting to note that for the temperature of 400°K the limiting errors of the thermal conductivities of helium, argon, and their mixtures differ little from the average value of ±2%, which for these temperatures is determined mainly by the error in measuring the temperature drop in the gas layer. At high temperatures the maximum error increases with an increase in the argon concentration in the mixture. This is explained by the fact that the error in determining the radiant flux, which increases when the heavy gas predominates in the mixture because of the increase in the radiation fraction in the effective thermal flux, has a considerable effect through $\Delta Q_t/Q_t$ on the maximum error of the thermal conductivity at high temperatures. A calculation showed that at 1500°K the maximum relative errors of the thermal conductivities will be ±3% for He, ±3.2% for 0.2 Ar, ±3.3% for 0.4 Ar, ± 3.4% for 0.6 Ar, ±4.1% for 0.8 Ar, and ±5.3% for Ar.

NOTATION

d_1, diameter of measuring filament, mm; d_2, inner diameter of tube, mm; D, outer diameter of tube, mm; l_l, length of long section of filament, mm; l_s, length of short section of filament, mm; R_l^{20}, resistance of long section of filament at 20°C, Ω; R_s^{20}, resistance of short section of filament at 20°C, Ω; l_{ef}, effective length, mm; R_{ef}^{20}, effective resistance at 20°C, Ω; I_0, value of "nonheating" current, A; R_l^0, resistance of long section of filament with "nonheating" current, Ω; R_s^0, resistance of short section of filament with "nonheating" current, Ω; R_l, resistance of long section of filament with "heating" current, Ω; R_s, resistance of short section of filament with "heating" current, Ω; R_{ef}^0, effective resistance with "nonheating" current, Ω; R_{ef}, effective resistance with "heating" current, Ω; T_w, wall temperature of molybdenum tube, °K; T_f, temperature of measuring filament, °K; ΔT, temperature difference between filament and wall, °K; ΔT_g, true temperature drop in gas layer, °K; $\bar{T}$, mean temperature, °K; Q, effective heat flux, W; Q_t, heat flux transferred by thermal conduction, W; Q_r, heat flux transferred by radiation, W; I, value of "heating" current, A; δT_{ju}, correction for temperature jump, %; Q_r/Q, radiation fraction, %; $\lambda_D T/\lambda$, correction for thermal diffusion, %; α_t, thermal diffusion constant; λ, thermal conductivity of gas mixture, W/m · deg; Δλ/λ, relative error of measured values of thermal conductivity; ΔA/A, relative error of continuous-measurement molybdenum cell; $\Delta Q_r/Q_r$, relative error of value of heat flux transferred by thermal conduction; $\Delta(\Delta T_g)/\Delta T_g$, relative error of true temperature drop in gas layer.

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