DEPENDENCE OF THE THERMODIFFUSION CONSTANT OF A MIXTURE OF TWO GASES ON THE ADDITION OF A THIRD GAS TO IT

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The dependence of the thermodiffusion constant of a mixture of two gases on the addition of a third gas, whose molecular mass is larger than the molecular mass of the light component of the mixture and smaller than the molecular mass of its heavy component, to it was investigated. The investigations were carried out for different compositions of the initial binary mixture and different concentrations and masses of the additional component. Good agreement between the calculation and measurement data on the indicated constant has been obtained within the limits of the calculation and experimental errors.

Keywords: binary and ternary gas systems, thermodiffusion separation, experiment.

Introduction. The study of the thermodiffusion in multicomponent gas mixtures is of indubitable scientific and technological interest. A quantitative characteristic of the thermodiffusion in a gas system is its thermodiffusion constant (TDC) [1, 2]. Investigations of the thermodiffusion separation of ternary gas mixtures [3–15] have shown that the TDC of a gas mixture depends strongly on its composition and, which is characteristic of the majority of gas systems, only slightly on the temperature of the mixture.

Traditionally, in investigations of ternary gas systems, the dependence of the TDC of a binary mixture having a definite composition on the mole fraction of a third component added to it is determined for the case where the difference between the temperatures of the hot and cold regions of the mixture is constant. There is a small number of works [12–15] in which the dependence of the TDC of a ternary gas mixture not only on the concentration of the additional third component but also on the composition of the initial binary mixture was investigated. Investigations on this dependence have shown that the addition of a third component to a binary gas mixture causes its TDC to increase or decrease as compared to the TDC of the initial binary mixture. For some gas mixtures of different compositions this dependence can has maxima and minima, and their TDC can take zero and negative values. To thoroughly analyze the influence of the addition of a third component to a gas mixture on its TDC, it is necessary to experimentally investigate this phenomenon for different gases in wide ranges of their concentrations.

Formulation of the Problem and the Measurement Procedure. It is known that the TDC of a ternary gas mixture depends substantially on the molecular mass of the gases participating in the separation of the mixture [1, 2, 16, 17]. The molecular mass of the additional third component in such a mixture can be larger, smaller, or intermediate as compared to the molecular masses of the gas components of the initial binary mixture. In the present work, results of investigations of the change in the TDC of some pairs of gases in the case of addition of a third gas, whose molecular mass is intermediate between the molecular masses of the initial gas components, to them are discussed.

The measurements were carried out with the use of a modified two-flask apparatus described in [11, 18]. A gas mixture subjected to thermodiffusion separation was analyzed, as in the works [11, 13, 18], by the gravimetric and interferometric methods. The experiments were carried out with the use of argon, helium, and neon with a volume fraction of 99.999%, hydrogen and nitrogen with a volume fraction of 99.99%, and carbon dioxide and methane with a volume fraction of 99.9% at temperatures $T_1 = 280$ K and $T_2 = 800$ K and a pressure $p = 0.1$ MPa. The volumes of the cold and hot flasks were selected such that their geometric factor $f = V_1 T_2 / V_2 T_1$ [5] was equal to 0.99–1.01. In this case, the second and subsequent expansion terms of the logarithm of the separation coefficient of a mixture $\ln q_{ij}$ [5, 11, 13] are practically equal to zero and both methods of calculating the TDC of a mixture give identical results. In our experiments we analyzed a gas mixture after its separation,
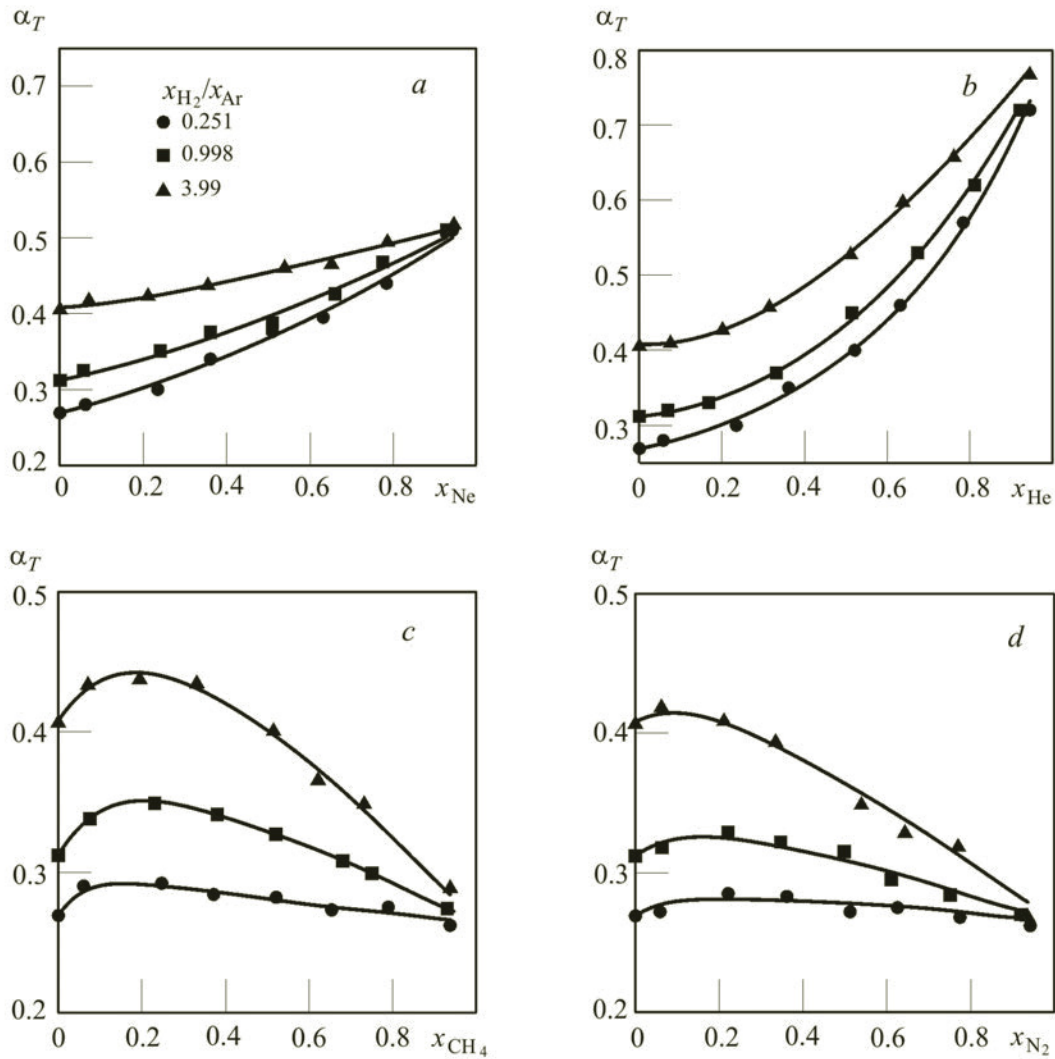
Fig. 1. Dependence of the thermodiffusion constant $\alpha_T(H_2–Ar)^{tr}$ of a ternary gas mixture on the mole fraction of Ne (a), He (b), CH_4 (c), and N_2 (d) in it at $p = 0.1$ MPa, $T_1 = 280$ K, and $T_2 = 800$ K: points, experiment; lines, calculation by formula (2).

which allowed us to determine the compositions of the mixture components in the hot and cold flasks and the difference between their mole fractions.

It should be noted that the TDC of a gas mixture can be calculated on the basis of experimental data by all the formulas presented in [5, 11, 13], i.e., with use of both the separation coefficient q_{ij} and the differences between the mole fractions of the ith and jth gases in the hot and cold flasks Δx_i^{mlt} and Δx_j^{mlt} :

$$\alpha_{Tij}^{mlt} = \frac{\ln q_{ij}}{\ln T_2/T_1} = \left(\frac{\Delta x_i^{mlt}}{x_i^{mlt}} - \frac{\Delta x_j^{mlt}}{x_j^{mlt}} \right) \Bigg/ \ln \frac{T_2}{T_1} . \tag{1}$$

The thermodiffusion constant of a gas mixture was determined in most cases by the value of Δx_i^{mlt} since this method gives higher accuracy as compared to the calculation of the TDC of the mixture with the use of its separation coefficient q_{ij}. At a reliability level $\alpha = 0.95$, the total experimental error in determining the TDC of a gas mixture was 4–6%.

The Results Obtained and Their Discussion. The behavior of the thermodiffusion constants of binary mixtures with ratios between the mole fractions of their components 0.25, 1.00, and 4.00, depending on the addition of a third component to them, was investigated with the use of the above-described setup. As a third component, we used gases with molecular
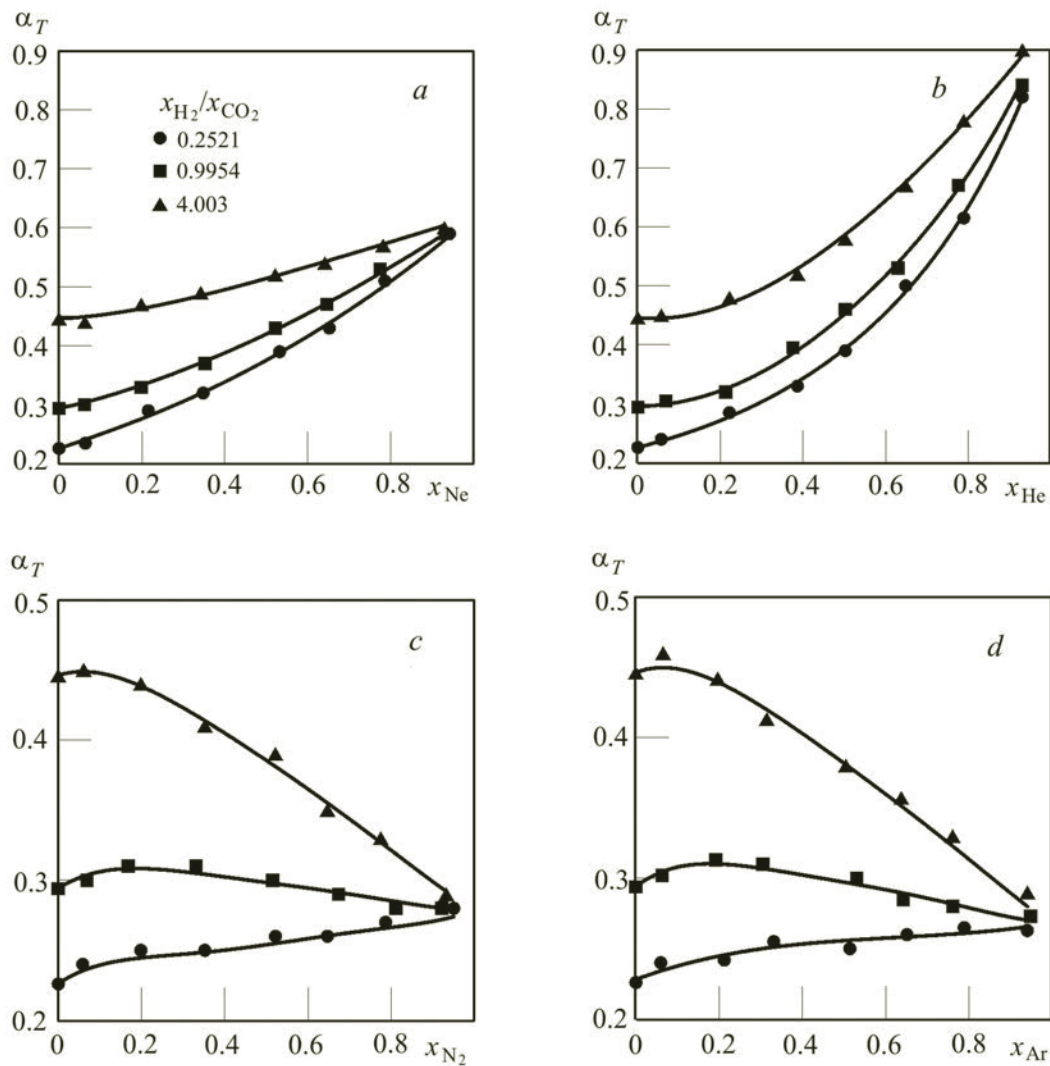
Fig. 2. Dependence of the thermodiffusion constant $\alpha_T(H_2- CO_2)^{tr}$ of a ternary gas mixture on the mole fraction of Ne (a), He (b), N_2 (c), and Ar (d) in it at $p = 0.1$ MPa, $T_1 = 280$ K, and $T_2 = 800$ K: points, experiment; lines, calculation by formula (2).

masses larger than the molecular mass of the light component of a mixture and smaller than the molecular mass of its heavy component. The following gas systems were investigated: H_2–Ar with an addition of He, CH_4, Ne, or N_2, H_2–CO_2 with an addition of He, CH_4, Ne, or Ar, H_2–N_2 with an addition of He or CH_4. The dependences of the TDC of the equimolar binary H_2–CO_2 and H_2–N_2 mixtures on the addition of CH_4 to them were taken from [11].

It was shown in [19] that the TDC of a ternary gas mixture having a definite composition can be calculated by the formula

$$\alpha_{Tij}^{tr} = \alpha_{Tij}^{bin} + x_k^{tr}\left(\alpha_{Tik}^{bin} - \alpha_{Tjk}^{bin} - \alpha_{Tij}^{bin}\right). \tag{2}$$

The TDC of a binary gas mixture α_{Tij}^{bin} should be determined from the conditions of equality of the ratios between the mole fractions of the mixture components ($x_{ij}^{bin} / x_{ji}^{bin} = x_i^{tr} / x_j^{tr}$) and correspondence of the temperatures T_1 and T_2 in the experiments with the binary and ternary mixtures. These constants can be calculated by the formula [11]

$$\alpha_{ij}^{bin} = \left(1 - \frac{K_{ij}}{2}\right)\frac{\sqrt{m_j} - \sqrt{m_i}}{x_{ij}^{bin}\sqrt{m_i} + x_{ji}^{bin}\sqrt{m_j}} \tag{3}$$
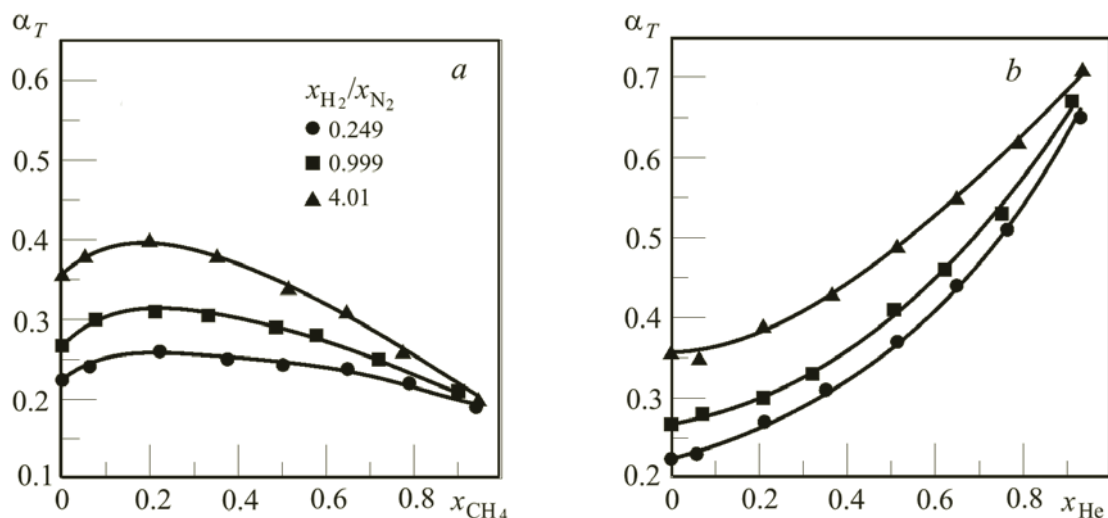
Fig. 3. Dependence of the thermodiffusion constant $\alpha_T(H_2–N_2)^{tr}$ of a ternary gas mixture on the mole fraction of Ne (a) and CH_4 (b) in it at $p = 0.1$ MPa, $T_1 = 280$ K, and $T_2 = 800$ K: points, experiment; lines, calculation by formula (2).

on condition that the values of K_{ij} are determined at equal temperatures of the cold and hot regions of the gases in the binary and ternary systems or on the condition that α_{Tij}^{bin} is independent of the temperature within the measurement error in the temperature range being considered. The values of K_{ij} for the binary gas mixtures being considered are presented in [11, 13, 20].

The results of measurements of Δx_i^{tr}, necessary for calculating the TDC of gas mixtures, are given in Tables 1–3. The values of Δx_i^{tr} for the system $H_2–CH_4–Ar$ at a ratio between the mole fractions of its H_2 and Ar components $x(H_2)/x(Ar)$ = 0.998 were taken from [13]. Figures 1–3 show the thermodiffusion coefficients calculated by formula (1) on the basis of the data presented in Tables 1–3. It is seen from these figures that the addition of a third gas to a binary mixture differently influences the TDC of the two initial gases and that the TDC of some mixtures depends substantially on the ratio between their mixture components.

Figure 1 shows the dependence of the TDC of the $H_2–Ar$ mixture of different compositions on the addition of four gases to it. The addition of He or Ne to a $H_2–Ar$ mixture causes its TDC to increase, and the addition of CH_4 or N_2 to it leads to a decrease in its TDC, excepting at small mole fractions of an additive. The addition of He or Ne to a $H_2–Ar$ mixture has a larger effect on its TDC in the case where the content of Ar is larger than the content of H_2, and the effect of the addition of CH_4 or N_2 to this mixture is larger in the case where the content of H_2 is larger than the content of Ar in it.

Figure 2 shows the dependence of the TDC of the $H_2–CO_2$ mixture of different compositions on the addition of He, Ne, N_2, or Ar to it. The influence of the addition of He or Ne to this mixture on the value of $\alpha_T(H_2–CO_2)^{tr}$ is identical to that of the $H_2–Ar$ mixture. The influence of the addition of N_2 to a $H_2–CO_2$ mixture on its TDC depends substantially on the initial composition of the mixture. In the case where the content of CO_2 in this mixture comprises 80%, its TDC increases, and the TDC of the mixture containing 50 or 20% of CO_2 decreases on addition of one of the above identical elements to it. An analogous dependence of the TDC of the $H_2–CO_2$ mixture on the addition of CO to it was detected in [13]. The addition of Ar to the $H_2–CO_2$ mixture containing 80% of CO_2 practically has no influence on the value of $\alpha_T(H_2–CO_2)^{tr}$ within the measurement error, while the addition of this element to the $H_2–CO_2$ mixture of other compositions decreases its TDC.

Figure 3 presents the dependence of the TDC of the $H_2–N_2$ mixture of different compositions on the addition of He and CH_4 to it. It is seen that the behavior of the TDC of this gas system depending on the addition of He or CH_4 to it is identical to that of the $H_2–Ar$ and $H_2–CO_2$ gas systems.

The experimental data obtained give no way of making an unambiguous conclusion on the behavior of the TDC of a gas mixture depending on the mass of an additive in it. To make this conclusion, it is necessary to perform a more comprehensive analysis with the use of kinetic notions on the structure of a substance.

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TABLE 1. Change in the Mole Fractions of the Components of the H$_2$–Ar Gas Mixture Depending on the Mole Fraction of an Additive at Temperatures $T_1 = 280$ K and $T_2 = 800$ K and Pressure $p = 0.1$ MPa

$x_2^{tr} \cdot 10^2$	$\Delta x_1^{tr} \cdot 10^2$	$\Delta x_2^{tr} \cdot 10^2$	$\Delta x_3^{tr} \cdot 10^2$	$x_2^{tr} \cdot 10^2$	$\Delta x_1^{tr} \cdot 10^2$	$\Delta x_2^{tr} \cdot 10^2$	$\Delta x_3^{tr} \cdot 10^2$	$x_2^{tr} \cdot 10^2$	$\Delta x_1^{tr} \cdot 10^2$	$\Delta x_2^{tr} \cdot 10^2$	$\Delta x_3^{tr} \cdot 10^2$
$x_{H2}/x_{Ar} = 0.251$				$x_{H2}/x_{Ar} = 0.998$				$x_{H2}/x_{Ar} = 3.99$			
x_{He}											
0.00	4.55	0.00	−4.55	0.00	8.23	0.00	−8.23	0.00	6.89	0.00	−6.89
5.79	4.22	1.20	−5.42	6.91	7.53	0.57	−8.10	7.53	6.59	−0.25	−6.34
23.46	3.18	4.29	−7.47	16.78	6.61	1.52	−8.13	20.13	6.04	−0.31	−5.73
36.13	2.41	6.09	−8.50	33.12	5.06	2.85	−7.91	31.44	5.43	−0.22	−5.21
52.13	1.76	7.69	−9.45	51.50	3.61	4.02	−7.63	51.12	4.29	0.14	−4.43
63.16	1.21	7.90	−9.11	67.32	2.39	4.38	−6.77	63.78	3.39	0.33	−3.72
78.39	0.62	6.92	−7.54	81.14	1.35	3.56	−4.91	76.12	2.34	0.41	−2.75
94.53	0.14	2.55	−2.69	92.15	0.52	1.93	−2.45	94.48	0.64	0.16	−0.80
x_{CH4}											
0.00	4.55	0.00	−4.55	0.00	8.23	0.00	−8.23	0.00	6.89	0.00	−6.89
6.03	4.59	−0.08	−4.51	7.41	9.41	−1.68	−7.43	7.08	9.49	−3.34	−6.15
24.71	3.64	0.48	−4.12	23.12	8.26	−2.62	−5.64	19.45	10.75	−5.91	−4.84
37.15	2.86	0.92	−3.78	37.84	6.76	−2.26	−4.50	33.10	9.99	−6.48	−3.51
52.09	1.98	1.17	−3.15	52.19	4.92	−1.77	−3.15	51.45	7.54	−5.30	−2.24
65.35	1.41	1.20	−2.61	68.08	3.06	−1.05	−2.01	62.12	5.70	−4.22	−1.48
78.90	0.73	0.99	−1.72	75.17	2.39	−0.74	−1.65	73.14	3.99	−2.99	−1.00
93.67	0.18	0.34	−0.52	92.88	0.58	−0.15	−0.43	93.70	0.86	−0.72	−0.14
x_{Ne}											
0.00	4.55	0.00	−4.55	0.00	8.23	0.00	−8.23	0.00	6.89	0.00	−6.89
6.12	4.27	0.38	−4.65	5.64	8.05	−0.46	−7.59	6.94	7.50	−1.39	−6.11
23.46	3.79	1.20	−4.99	24.04	7.56	−1.28	−6.28	21.15	8.36	−3.51	−4.85
36.13	3.19	1.74	−4.93	36.13	6.92	−1.44	−5.48	35.50	8.51	−4.65	−3.86
50.97	2.67	2.19	−4.86	50.97	5.72	−1.27	−4.45	53.92	7.56	−4.95	−2.61
63.16	1.98	2.28	−4.26	66.05	4.30	−0.98	−3.32	65.18	6.35	−4.43	−1.92
78.39	1.29	1.95	−3.24	77.45	3.12	−0.71	−2.41	78.60	4.40	−3.33	−1.07
94.21	0.32	0.74	−1.06	92.78	1.03	−0.19	−0.84	94.57	1.24	−1.00	−0.24
x_{N2}											
0.00	4.55	0.00	−4.55	0.00	8.23	0.00	−8.23	0.00	6.89	0.00	−6.89
5.87	4.43	0.06	−4.49	6.35	8.48	−0.98	−7.50	6.21	8.17	−1.99	−6.18
22.13	3.60	0.39	−3.99	22.08	7.61	−1.95	−5.66	21.15	8.96	−4.48	−4.48
36.13	2.90	0.52	−3.42	34.64	6.58	−2.17	−4.41	33.46	8.55	−5.16	−3.39
51.24	2.28	0.44	−2.72	49.86	5.25	−2.13	−3.12	53.92	6.73	−4.87	−1.86
62.54	1.73	0.42	−2.15	61.08	4.15	−1.96	−2.19	64.31	5.44	−4.25	−1.19
77.45	0.95	0.21	−1.16	75.15	2.68	−1.51	−1.17	77.02	3.68	−3.05	−0.63
94.21	0.27	0.06	−0.33	91.87	0.85	−0.56	−0.29	93.57	1.12	−0.99	−0.13

TABLE 2. Change in the Mole Fractions of the Components of the H_2–CO_2 Gas Mixture Depending on the Mole Fraction of an Additive at Temperatures $T_1 = 280$ K and $T_2 = 800$ K and Pressure $p = 0.1$ MPa

$x_2^{tr} \cdot 10^2$	$\Delta x_1^{tr} \cdot 10^2$	$\Delta x_2^{tr} \cdot 10^2$	$\Delta x_3^{tr} \cdot 10^2$	$x_2^{tr} \cdot 10^2$	$\Delta x_1^{tr} \cdot 10^2$	$\Delta x_2^{tr} \cdot 10^2$	$\Delta x_3^{tr} \cdot 10^2$	$x_2^{tr} \cdot 10^2$	$\Delta x_1^{tr} \cdot 10^2$	$\Delta x_2^{tr} \cdot 10^2$	$\Delta x_3^{tr} \cdot 10^2$
$x_{H2}/x_{CO2} = 0.2521$				$x_{H2}/x_{CO2} = 0.9954$				$x_{H2}/x_{CO2} = 4.003$			
x_{He}											
0.00	3.76	0.00	−3.76	0.00	7.67	0.00	−7.67	0.00	7.54	0.00	−7.54
5.68	3.45	1.19	−4.64	6.78	7.12	0.64	−7.76	5.68	7.18	−0.10	−7.08
22.18	2.81	4.42	−7.23	21.24	5.73	2.18	−7.91	22.18	6.12	0.00	−6.12
38.64	2.00	7.15	−9.15	37.49	4.46	3.76	−8.22	38.64	5.16	0.35	−5.51
50.23	1.67	8.42	−10.09	50.23	3.59	4.76	−8.35	50.23	4.46	0.63	−5.09
64.87	1.05	9.09	−10.14	63.00	2.64	5.25	−7.89	64.87	3.28	0.84	−4.12
78.91	0.65	7.80	−8.45	77.57	1.54	4.67	−6.21	78.91	2.16	0.78	−2.94
93.09	0.22	3.83	−4.05	93.05	0.49	2.15	−2.64	93.09	0.74	0.38	−1.12
x_{Ne}											
0.00	3.76	0.00	−3.76	0.00	7.67	0.00	−7.67	0.00	7.54	0.00	−7.54
6.34	3.75	0.48	−4.23	6.11	7.75	−0.37	−7.38	6.24	8.02	−1.25	−6.77
21.54	3.33	1.59	−4.92	19.84	7.45	−0.77	−6.68	19.84	8.73	−3.15	−5.58
34.78	3.05	2.65	−5.70	35.23	6.79	−0.73	−6.06	34.21	8.82	−4.25	−4.57
53.21	2.30	3.49	−5.79	52.17	5.53	−0.38	−5.15	52.17	7.84	−4.51	−3.33
65.23	1.89	3.56	−5.45	64.67	4.48	−0.13	−4.35	64.15	6.61	−4.11	−2.50
78.61	1.16	3.01	−4.17	77.49	3.08	0.09	−3.17	78.21	4.51	−2.98	−1.53
94.21	0.31	1.11	−1.42	93.24	1.02	0.13	−1.15	92.99	1.64	−1.10	−0.54
x_{N2}											
0.00	3.76	0.00	−3.76	0.00	7.67	0.00	−7.67	0.00	7.54	0.00	−7.54
5.87	3.82	−0.16	−3.66	6.91	8.08	−1.17	−6.91	6.11	8.74	−2.04	−6.70
19.84	3.37	−0.08	−3.29	16.78	7.64	−1.98	−5.66	19.84	9.40	−4.39	−5.01
35.23	2.75	0.02	−2.77	33.12	6.59	−2.38	−4.21	35.23	8.67	−5.26	−3.41
52.17	2.06	0.14	−2.20	51.50	4.90	−2.31	−2.59	52.17	7.04	−4.92	−2.12
64.67	1.56	0.19	−1.75	67.32	3.37	−1.84	−1.53	64.67	5.43	−4.20	−1.23
78.64	0.93	0.25	−1.18	81.14	2.04	−1.19	−0.85	77.49	3.64	−3.05	−0.59
95.02	0.19	0.08	−0.27	92.15	0.87	−0.51	−0.36	93.24	1.18	−1.04	−0.14
x_{Ar}											
0.00	3.76	0.00	−3.76	0.00	7.67	0.00	−7.67	0.00	7.54	0.00	−7.54
5.97	3.79	−0.39	−3.40	6.35	8.23	−1.39	−6.84	6.54	8.99	−2.49	−6.50
21.23	3.48	−0.81	−2.67	19.17	7.90	−2.76	−5.14	19.67	10.06	−5.12	−4.94
33.16	3.03	−0.89	−2.14	30.54	7.29	−3.37	−3.92	31.44	9.78	−6.12	−3.66
51.42	2.22	−0.98	−1.24	53.08	5.33	−3.42	−1.91	50.46	8.14	−6.29	−1.85
65.14	1.76	−0.93	−0.83	64.27	4.28	−3.02	−1.26	63.78	6.49	−5.42	−1.07
78.91	1.03	−0.64	−0.39	76.12	2.97	−2.35	−0.62	76.12	4.57	−4.06	−0.51
94.06	0.33	−0.23	−0.10	94.87	0.69	−0.59	−0.10	94.07	1.26	−1.21	−0.05

TABLE 3. Change in the Mole Fractions of the Components of the H$_2$–N$_2$ Gas Mixture Depending on the Mole Fraction of an Additive at Temperatures $T_1 = 280$ K and $T_2 = 800$ K and Pressure $p = 0.1$ MPa

$x_2^{tr} \cdot 10^2$	$\Delta x_1^{tr} \cdot 10^2$	$\Delta x_2^{tr} \cdot 10^2$	$\Delta x_3^{tr} \cdot 10^2$	$x_2^{tr} \cdot 10^2$	$\Delta x_1^{tr} \cdot 10^2$	$\Delta x_2^{tr} \cdot 10^2$	$\Delta x_3^{tr} \cdot 10^2$	$x_2^{tr} \cdot 10^2$	$\Delta x_1^{tr} \cdot 10^2$	$\Delta x_2^{tr} \cdot 10^2$	$\Delta x_3^{tr} \cdot 10^2$
$x_{H2}/x_{N2} = 0.249$				$x_{H2}/x_{N2} = 0.999$				$x_{H2}/x_{N2} = 4.01$			
x_{He}											
0.00	3.73	0.00	−3.73	0.00	7.05	0.00	−7.05	0.00	5.95	0.00	−5.95
5.79	3.52	1.12	−4.64	7.04	6.41	0.56	−6.97	6.38	5.72	−0.15	−5.57
21.19	2.78	3.68	−6.46	20.94	5.42	1.73	−7.15	20.94	5.34	−0.24	−5.10
35.16	2.23	5.73	−7.96	32.09	4.64	2.64	−7.28	36.59	4.69	−0.15	−4.54
51.36	1.60	7.12	−8.72	50.63	3.31	3.76	−7.07	51.36	3.94	0.03	−3.97
64.87	1.11	7.51	−8.62	62.13	2.57	4.06	−6.63	64.87	3.18	0.15	−3.33
76.34	0.72	6.57	−7.29	75.09	1.75	3.66	−5.41	78.91	2.06	0.20	−2.26
92.98	0.24	2.93	−3.17	91.07	0.62	1.92	−2.54	93.46	0.73	0.10	−0.83
x_{CH4}											
0.00	3.73	0.00	−3.73	0.00	7.05	0.00	−7.05	0.00	5.95	0.00	−5.95
6.24	3.92	0.01	−3.93	7.56	7.98	−1.62	−6.36	5.17	8.05	−2.60	−5.45
22.18	3.24	0.52	−3.76	21.13	7.84	−2.63	−5.21	19.84	10.24	−6.08	−4.16
37.56	2.49	0.68	−3.17	33.24	6.80	−2.63	−4.17	35.23	9.40	−6.63	−2.77
50.19	1.91	0.61	−2.52	48.59	5.13	−2.30	−2.83	51.46	7.32	−5.66	−1.66
64.87	1.27	0.38	−1.65	57.76	4.06	−2.08	−1.98	64.67	5.26	−4.26	−1.00
78.91	0.77	0.14	−0.91	71.91	2.61	−1.45	−1.16	77.49	3.24	−2.76	−0.48
94.08	0.21	0.01	−0.22	90.05	0.87	−0.61	−0.26	94.67	0.72	−0.67	−0.05

Conclusions. A method is proposed for calculating the TDC of a binary mixture depending on the addition of a third component, whose molecular mass is larger than the molecular mass of the light component of the mixture but smaller than the molecular mass of its heavy component, to it. Gas systems containing H$_2$, He, CH$_4$, Ne, N$_2$, Ar, and CO$_2$ were investigated. The results of calculations of the TDC of these mixtures by the semiempirical formula proposed earlier were compared with the results of experiments carried out with the use of a modified two-flask apparatus at temperatures $T_1 = 280$ K and $T_2 = 800$ K of the cold and hot flasks, respectively, and a pressure $p = 0.1$ MPa. The method proposed for determining the thermodiffusion coefficients of ternary and binary gas mixtures can be used for calculating and generalization of their thermodynamic parameters in an unexplored region.

NOTATION

K_{ij}, empirical coefficient for the molecules of the kinds i and j in a binary gas mixture; m_i, mass of the jth gas molecules; p, pressure, MPa; q_{ij}, separation coefficient of a gas mixture; T_1 and T_2, temperatures of the cold and hot regions of a gas, K; V_1 and V_2, volumes of the hot and cold flasks, m^3; x_{ij}^{bin}, mole fraction of the ith component of the i–j binary mixture prior to its separation; x_i^{mlt}, mole fraction of the ith component in a multicomponent mixture prior to its separation; x_i^{tr}, mole fraction of the ith component in a ternary gas mixture prior to its separation; x_{Ti}^{mlt}, mole fraction of the ith component in a multicomponent mixture at a temperature T; $x(a)$, mole fraction of the gas a in a mixture; Δx_{ij}^{bin}, change in the mole fraction

of the ith component in the binary i–j mixture; $\Delta x_i^{\mathrm{mlt}}$, change in the mole fraction of the ith component in a multicomponent mixture; $\alpha_{Tij}^{\mathrm{bin}}$, thermodiffusion constant of the i–j gas mixture; $\alpha_{Tij}^{\mathrm{mlt}}$, thermodiffusion constant of the ith and jth components of a ternary gas mixture; $\alpha_T(a$–$b)^{\mathrm{tr}}$, thermodiffusion constant of the gases a and b in a ternary gas mixture. Subscripts: bin, binary; mlt, multicomponent; tr, ternary; i and j, mixture components.

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