$\bar{V}$ = partial molal volume; partial volume, cu. ft./lb.-mole
$\underline{V}$ = total volume, cu. ft.
x = independent variable

Greek Letters

α, β = constants in recursion formula
δ_{jk} = Kronecker delta
$\sum$ = summation
Φ = orthonormal polynomial
ϕ = orthogonal polynomial
∂ = partial differential operator
$\int$ = integral

Subscripts

$1, 2, i \ldots n$ = indicate elements of series
j = component j
k = component k
m_i = change in state during which the weight of all components other than k remains constant
P = pressure, p.s.i.a.
T = thermodynamic temperature, °R.

Superscript

o = pure component

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Transport Properties of the Normal Paraffins at Attenuation

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The available experimental information for the paraffins concerning the temperature dependence of the thermal conductivity, viscosity, and the Chapman-Cowling diffusion coefficient is reviewed along with statistical mechanical predictions for polyatomic gases. The results are presented in analytical and tabular form with graphical representation of a few examples.

DURING the past decade there has been a significant increase in the quantity of viscosity (*3, 7, 8, 10, 11, 12, 28, 31, 32, 39, 46, 48, 49, 51, 53–57*), thermal conductivity (*6, 9, 10, 13, 19, 25, 27, 29, 30, 32–36, 38, 40, 51, 53*), and molecular transport (*20*) data concerning the lighter paraffin hydrocarbons in the gas phase. Furthermore, there has been a material increase in effort directed to the application of statistical mechanics to the prediction of such transport properties at attenuation. Values of these transport properties are of interest to industry in connection with the prediction of over-all transport in processing equipment. For this reason it appears desirable to review the available information and present it in a form suitable for engineering use.

In the application of statistical mechanical techniques, information concerning the equilibrium volumetric behavior of the systems concerned is necessary. A reasonable background of experimental data for volumetric behavior of a number of the lighter paraffin hydrocarbons is available (*2, 14–16, 24, 41, 42, 43, 45, 47, 52, 58*). The effects of pressure on the specific volume of the saturated gas and liquid phases were established graphically, together with the standard error of estimate of each of the sets of experimental data from the critically chosen values. Since much has been published concerning the volumetric behavior of the paraffin hydrocarbons, the results have not been included.

VISCOSITY

From available information concerning the effect of pressure upon the viscosity of the lighter hydrocarbons in the gas phase, the values of the rate of change of viscosity with respect to pressure have been established for each of the normal paraffin hydrocarbons from methane through *n*-decane at attenuation as a function of temperature. In Table I are presented the limiting values of this derivative together with smooth values of the viscosity based on measurements at a pressure near 1 atm. or dew point, whichever was the lower pressure (*3, 7, 8, 10, 11, 12, 28, 31, 32, 39, 46, 48, 49, 51, 53–57*). Information for the viscosity at attenuation has been included in Table I. The values at attenuation were calculated by statistical mechanical considerations based on the Lennard-Jones 6–12 potential (*20*). The data for atmospheric or dew point were established from the calculated values at attenuation and the effect of pressure upon the viscosity for each compound. The experimental data employed extrapolated to attenuation are depicted in Figure 1. The full curves were calculated as described in connection with Table I. Table II lists the range of conditions covered by each investigation as well as the standard error of estimate for each set of the experimental data employed. The over-all relative standard error of estimate as defined in a part of Table II for all of the data presented in Figure 1 is 0.026 fraction.

Table I. Viscosity of Normal Paraffins

Temp. °F.	Vapor Pressure, p.s.i.a.	$(d\eta/dP)_{T,P=0}$	Viscosity, Micropoises		
			Attenuation	Atmospheric	Dew point
		METHANE			
40	...	0.003[a]	104.10	104.14	...
70	...	0.006	108.65	108.74	...
100	...	0.011	115.20	115.36	...
130	...	0.015	120.68	120.89	...
160	...	0.019	126.17	126.44	...
190	...	0.021	131.65	131.96	...
220	...	0.024	137.25	137.61	...
250	...	0.028	142.82	143.27	...
280	...	0.032	148.24	148.71	...
		ETHANE			
40	385.0	0.004	88.00	88.05	...
70	558.3	0.008	92.88	93.00	...
100		0.014	97.77	97.97	...
130		0.018	103.08	103.35	...
160		0.023	107.39	107.73	...
190		0.027	112.27	112.66	...
220		0.031	117.18	117.64	...
250		0.037	122.12	122.66	...
280		0.042	126.99	127.60	...
		PROPANE			
40	79.0	0.004	76.37	76.43	...
70	125.1	0.010	80.64	80.79	...
100	188.7	0.016	84.91	85.15	...
130	273.5	0.022	89.30	89.62	...
160	383.8	0.027	93.71	94.11	...
190	524.8	0.032	97.87	98.34	...
220		0.038	102.03	102.59	...
250		0.044	106.17	106.82	...
280		0.051	110.31	111.06	...
		n-BUTANE			
40	17.7	0.005	68.76	68.83	...
70	31.3	0.012	72.74	72.91	...
100	51.5	0.019	76.72	76.99	...
130	80.6	0.025	80.91	81.28	...
160	120.6	0.031	85.11	85.57	...
190	173.3	0.038	89.23	89.79	...
220	241.2	0.045	93.15	93.81	...
250	327.7	0.052	97.19	97.96	...
280	436.0	0.060	101.24	102.13	...
		n-PENTANE			
40	4.3	0.006	64.00	...	64.02
70	8.6	0.013	67.95	...	68.06
100	15.7	0.021	71.90	72.21	...
130	25.8	0.028	75.74	76.15	...
160	42.5	0.036	79.58	80.10	...
190	64.0	0.043	83.44	84.07	...
220	94.9	0.052	87.31	88.07	...
250	134.5	0.060	91.15	92.04	...
280	186.6	0.070	95.00	96.02	...
		n-HEXANE			
40	1.11	0.006	59.73	...	59.73
70	2.46	0.014	63.27	...	63.28
100	4.95	0.024	66.91	...	67.03
130	9.16	0.032	70.57	...	70.86
160	15.82	0.040	74.24	74.83	...
190	25.76	0.049	78.12	78.84	...
220	39.87	0.059	82.00	82.86	...
250	59.24	0.067	85.51	86.49	...
280	84.93	0.078	89.01	90.16	...
		n-HEPTANE			
40	0.32	0.007	55.30	...	55.30
70	0.73	0.016	58.85	...	58.85
100	1.58	0.026	62.40	...	62.40
130	2.62	0.035	65.90	...	65.91
160	6.11	0.044	69.40	...	69.67
190	10.63	0.054	74.70	...	75.27
220	17.48	0.066	76.41	77.37	...
250	27.36	0.076	79.85	80.97	...
280	40.96	0.088	83.30	84.59	...
		n-OCTANE			
40	0.08	0.007	51.40	...	51.40
70	0.22	0.016	54.80	...	54.80
100	0.52	0.027	58.20	...	58.21
130	1.19	0.036	61.55	...	61.59
160	2.50	0.045	64.90	...	65.01
190	4.49	0.056	68.20	...	68.45
220	7.57	0.068	71.50	...	72.01
250	12.93	0.084	74.98	...	76.07
280	20.33	0.097	78.00	79.43	...
		n-NONANE			
40	0.006	0.008	48.00	...	48.00
70	0.044	0.019	51.09	...	51.10
100	0.179	0.031	54.19	...	54.20
130	0.438	0.042	57.29	...	57.30
160	0.961	0.052	60.40	...	60.45
190	1.92	0.065	63.50	...	63.62
220	3.57	0.079	66.61	...	66.89
250	6.23	0.092	69.80	...	70.37
280	10.28	0.108	73.00	...	74.11
		n-DECANE			
40	0.004	0.009	44.70	...	44.70
70	0.019	0.021	47.55	...	47.55
100	0.073	0.034	50.40	...	50.40
130	0.168	0.045	53.35	...	53.35
160	0.40	0.057	56.30	...	56.32
190	0.83	0.071	59.15	...	59.21
220	1.59	0.086	62.00	...	62.14
250	3.04	0.100	65.00	...	65.30
280	5.08	0.116	68.00	...	68.65

[a] Values of $d\eta/dP$ expressed in micropoises/p.s.i.a.

THERMAL CONDUCTIVITY

Values of the thermal conductivity as a function of temperature at atmospheric pressure and at attenuation were established graphically from available experimental data as a function of state (*6, 9, 10, 13, 19, 25, 27, 29, 30, 32–36, 38, 40, 51, 53*). The available experimental information concerning the thermal conductivity of the gaseous paraffin hydrocarbons at atmospheric pressure or at dew point is more limited than similar experimental data for the viscosity. Smooth values of thermal conductivity at attenuation and at atmospheric pressure or dew point, whichever is the lower pressure, together with the isothermal pressure derivative at attenuation are presented in Table III. The experimental thermal conductivity data presented in Figure 2 have been corrected to attenuation, utilizing the values of the isothermal pressure derivative presented in Table III. Table IV gives the relative values of the average error and of the standard error of estimate for each set of experimental data employed as well as the range of conditions to which it applies. As indicated in Table IV, the over-all relative standard error of estimate for all the data in Figure 2 is 0.020 fraction.

The thermal conductivity at attenuation, k_o, in the "ratio" shown as the ordinate of Figure 3 is an identical quantity to that depicted in Figure 2 and recorded in part of Table III. Experimental points in Figure 3 are shown for the normal paraffin hydrocarbons at temperatures between 13° and 340° F. Several monatomic and diatomic gases (*21*) of differing molecular weight are included to illustrate the effect of molecular structure. The full line of Figure 3 was calculated from the following semiempirical relation:

$$\frac{k_o - k_o^{(0)}}{k_o^{(0)}} = 0.3267 \left(\frac{C_{po}}{R} - \frac{5}{2}\right) \tag{1}$$

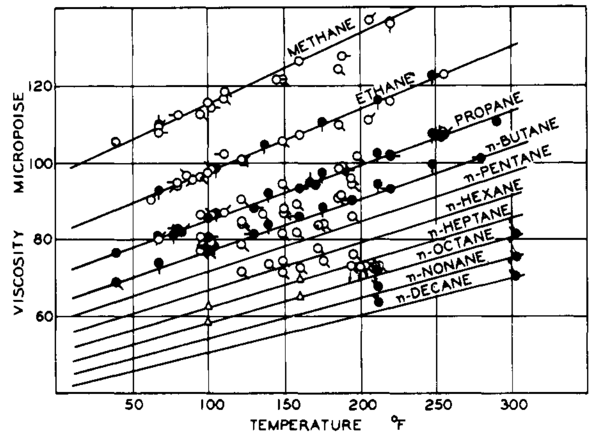

Figure 1. Viscosity of normal paraffins at attenuation

○ Carmichael (8)	○ Carmichael (11)	●- Sage (46)
○ Kestin (28)	-○ Svehla (53)	● Carmichael (12)
○ Trautz (57)	○ Senftleben (51)	● Titani (55)
○- Kuss (31)	● Carmichael (7)	-● Sage (49)
○ Lambert (32)	● Bicher (3)	● Melaven (39)
○ Sage (48)	● Trautz (56)	△ Carmichael (10)

The empirical coefficient in Equation 1 compares within 8% of the value of 0.354 reported by Hirschfelder (*22*). Values of the isobaric heat capacity at attenuation (*1*) at several temperatures for each of the hydrocarbons were used in these calculations. A reference thermal conductivity, $k_o^{(0)}$, also involved in the ratio shown as the ordinate of Figure 3 was evaluated from the viscosity at attenuation by statistical mechanical considerations in accordance with the following equation:

$$k_o^{(0)} = \frac{15R}{4M} \eta_o \tag{2}$$

If desired, the thermal conductivity at attenuation may be calculated from the heat capacity and the viscosity in the following way:

$$k_o = \left[0.3267 \left(\frac{C_{po}}{R} - \frac{5}{2}\right) + 1\right] \frac{15}{4} \frac{R}{M} \eta_o \tag{3}$$

The relative standard error of estimate of all the experimental data shown in Figure 3 and Table III from Equation 3 is 0.032 fraction.

BINARY MIXTURES

The experimental background for the transport properties of the hydrocarbons in binary mixtures involving similar or dissimilar components is limited. A brief statement concerning the present status follows.

Viscosity and Thermal Conductivity. Recent measurements (*10*) have been made of the viscosity and thermal conductivity of the binary gas mixture of *n*-heptane and nitrogen near attenuation and illustrate the complexities of the behavior for systems of widely differing molecules. Mixing rules based on Chapman-Cowling analysis (*23*) can be empiricized to represent adequately the limited available experimental data

Table II. Range of Conditions for Viscosity

	Range of Data						
	Temp., ° F.				Deviation		
Hydrocarbon	Lower	Upper	Pressure,[a] p.s.i.a. max.	No. of States	Av.[b]	Standard[c]	Ref.
Methane	40	220	19	18	0.014	0.020	(*8, 28, 31, 32, 48, 53, 57*)
Ethane	63	256	34	23	0.010	0.014	(*11, 32, 51, 53, 57*)
Propane	40	290	50	34	0.014	0.019	(*3, 7, 32, 46, 51, 53, 56, 57*)
n-Butane	32	280	60	26	0.024	0.028	(*12, 32, 49, 51, 55*)
n-Pentane	122	195	0	6	0.034	0.038	(*32*)
n-Hexane	122	172	0	4	0.021	0.025	(*32*)
n-Heptane	100	303	0.8	8	0.034	0.042	(*10, 32, 39*)
n-Octane	100	304	0.3	9	0.038	0.047	(*10, 32, 39*)
n-Nonane	212	303	0.3	2	0.058	. . .[d]	(*39*)
n-Decane[e]							
Over-all					0.012	0.026	

[a] Data from near attenuation to indicated maximum.

[b] Average deviation defined by:

$$s = \left\{\sum_1^N (\eta_e - \eta_p)/\eta_e\right\}/N$$

[c] Standard error of estimate defined by:

$$\sigma = \left\{\sum_1^N [(\eta_e - \eta_p)/\eta_p]^2/(N-1)\right\}^{1/2}$$

[d] Two experimental points. No standard error of estimate calculated.

[e] Extrapolated.

Table III. Thermal Conductivity of Normal Paraffins[a]

Temp., ° F.	Vapor Pressure, p.s.i.a.	Thermal Conductivity, B.t.u./(Sec.)(Ft.)(° F.)		
		Attenuation	Atmospheric	Dew point
		METHANE		
		$(dk/dP)_{T,P=0} = 0.0016 \times 10^{-6}$[b]		
40	...	4.917×10^{-6}	4.942×10^{-6}	...
70	...	5.275	5.296	...
100	...	5.633	5.650	...
130	...	5.994	6.014	...
160	...	6.356	6.378	...
190	...	6.724	6.745	...
220	...	7.128	7.144	...
250	...	7.531	7.548	...
280	...	7.947	7.968	...
		ETHANE		
		$(dk/dP)_{T,P=0} = 0.0018 \times 10^{-6}$[b]		
40	385.0	3.008×10^{-6}	3.038×10^{-6}	...
70	558.3	3.323	3.353	...
100	...	3.639	3.667	...
130	...	4.003	4.033	...
160	...	4.367	4.394	...
190	...	4.714	4.742	...
220	...	5.061	5.083	...
250	...	5.404	5.426	...
280	...	5.748	5.771	...
		PROPANE		
		$(dk/dP)_{T,P=0} = 0.0021 \times 10^{-6}$[b]		
40	79.0	2.492×10^{-6}	2.517×10^{-6}	...
70	125.1	2.799	2.818	...
100	188.7	3.106	3.119	...
130	273.5	3.439	3.457	...
160	383.8	3.772	3.794	...
190	524.8	4.115	4.137	...
220		4.458	4.480	...
250		4.815	4.835	...
280		5.180	5.207	...
		n-BUTANE		
		$(dk/dP)_{T,P=0} = 0.0024 \times 10^{-6}$[b]		
40	17.7	2.217×10^{-6}	2.253×10^{-6}	...
70	31.3	2.483	2.519	...
100	51.5	2.750	2.786	...
130	80.6	3.017	3.054	...
160	120.6	3.306	3.342	...
190	173.3	3.661	3.697	...
220	241.2	4.022	4.056	...
250	327.7	4.479	4.511	...
280	436.0	4.911	4.951	...
		n-PENTANE		
		$(dk/dP)_{T,P=0} = 0.0026 \times 10^{-6}$[b]		
40	4.4	2.000×10^{-6}	...	2.011×10^{-6}
70	8.6	2.236	...	2.261
100	15.7	2.472	2.511×10^{-6}	...
130	25.8	2.764	2.806	...
160	42.5	3.056	3.106	...
190	64.0	3.369	3.414	...
220	94.9	3.683	3.722	...
250	134.5	4.061	4.099	...
280	186.6	4.414	4.460	...
		n-HEXANE		
		$(dk/dP)_{T,P=0} = 0.0029 \times 10^{-6}$[b]		
40	1.17	1.844×10^{-6}	...	1.847×10^{-6}
70	2.46	2.061	...	2.070
100	4.95	2.278	...	2.294
130	9.16	2.520	...	2.548
160	15.82	2.778	2.817×10^{-6}	...
190	25.76	3.069	3.108	...
220	39.87	3.361	3.400	...
250	59.24	3.711	3.760	...
280	84.93	4.042	4.088	...
		n-HEPTANE		
		$(dk/dP)_{T,P=0} = 0.0031 \times 10^{-6}$[b]		
40	0.32	1.722×10^{-6}	...	1.722×10^{-6}
70	0.73	1.919	...	1.923
100	1.58	2.117	...	2.125
130	2.62	2.325	...	2.336
160	6.11	2.550	...	2.567
190	10.63	2.803	...	2.830
220	17.48	3.056	3.094×10^{-6}	...
250	27.36	3.364	3.409	...
280	40.96	3.650	3.707	...
		n-OCTANE		
		$(dk/dP)_{T,P=0} = 0.0034 \times 10^{-6}$[b]		
40	0.08	1.630×10^{-6}	...	1.630×10^{-6}
70	0.22	1.805	...	1.807
100	0.52	1.980	...	1.983
130	1.19	2.184	...	2.185
160	2.50	2.389	...	2.397
190	4.49	2.601	...	2.620
220	7.57	2.814	...	2.844
250	12.93	3.063	...	3.107
280	20.33	3.298	3.360×10^{-6}	...
		n-NONANE		
		$(dk/dP)_{T,P=0} = 0.0036 \times 10^{-6}$[b]		
40	0.006	1.533×10^{-6}	...	1.533×10^{-6}
70	0.044	1.800	...	1.800
100	0.179	1.867	...	1.867
130	0.438	2.045	...	2.044
160	0.961	2.225	...	2.228
190	1.92	2.415	...	2.421
220	3.57	2.600	...	2.614
250	6.23	2.825	...	2.845
280	10.28	3.034	...	3.058
		n-DECANE		
		$(dk/dP)_{T,P=0} = 0.0039 \times 10^{-6}$[b]		
40	0.004	1.464×10^{-6}	...	1.464×10^{-6}
70	0.019	1.618	...	1.618
100	0.073	1.772	...	1.772
130	0.168	1.932	...	1.933
160	0.40	2.092	...	2.094
190	0.83	2.250	...	2.261
220	1.59	2.408	...	2.419
250	3.04	2.596	...	2.611
280	5.08	2.754	...	2.785

[a] Smooth values based upon experimental data.

[b] Values of (dk/dP) expressed in [B.t.u./(sec.)(ft.)(° F.)]/p.s.i.a.

(*20*). Further generalizations can be made when additional experimental data are available for systems of two or more dissimilar components.

Diffusion Coefficients. Data for molecular transport in binary mixtures containing at least one normal paraffin hydrocarbon are meager. The available experimental information near atmospheric pressure (*5*, *17*, *18*, *26*, *44*, *50*) concerning the symmetric Chapman-Cowling diffusion coefficient (*4*, *37*) is shown in Figure

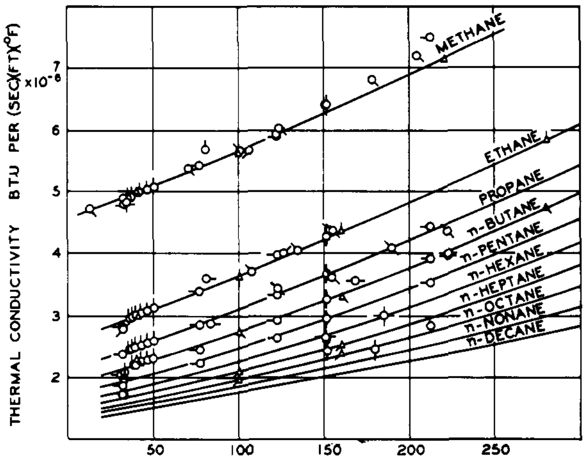

Figure 2. Thermal conductivity of normal paraffins at attenuation

○ Moser (*40*)	○ Lenoir (*35*)	○ Leng (*34*)
○ Mann (*38*)	○ Senftleben (*51*)	○ Lambert (*33*)
○ Keyes (*29*)	○ Lenoir (*36*)	△ Carmichael (*9*)
○ Svehla (*53*)	○ Lambert (*32*)	△ Carmichael (*6*)
○ Johnston (*25*)	○ Eucken (*19*)	△ Carmichael (*13*)
○ Kannuluik (*27*)	○ Kramer (*30*)	△ Carmichael (*10*)

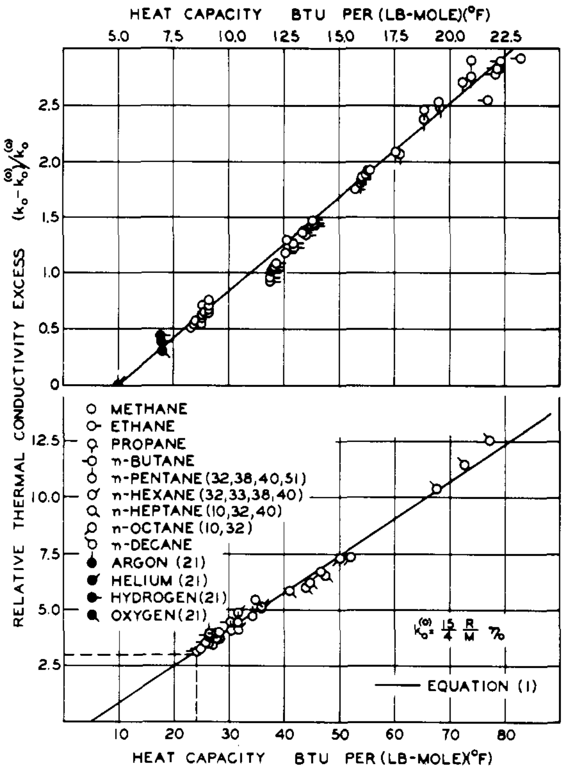

Figure 3. Thermal conductivity excess

○ Methane (*9,19,25,27,29,32,35,36,38,51,53*)
○ Ethane (*6,19,29,32,34,36,38,51,53*)
○ Propane (*32,34,38,51,53*)
○ n-Butane (*30,32,38,51*)

Table IV. Range of Conditions for Thermal Conductivity

Hydrocarbon	Range of Data Temp., ° F. Lower	 Upper	 Pressure,[a] p.s.i.a. Max.	No. of States	Deviation Av.[b]	 Standard[c]	Ref.
Methane	13	220	18	26	0.012	0.017	(*9, 19, 25, 27, 29, 32, 35, 36, 38, 51, 53*)
Ethane	32	280	18	21	0.013	0.020	(*6, 19, 29, 32, 34, 36, 38, 51, 53*)
Propane	32	222	15	16	0.009	0.013	(*32, 34, 38, 51, 53*)
n-Butane	32	280	17	17	0.014	0.021	(*13, 30, 32, 38, 51*)
n-Pentane	32	212	4	7	0.021	0.032	(*32, 38, 40, 51*)
n-Hexane	32	185	7	5	0.035	0.054	(*32, 33, 38, 40*)
n-Heptane	32	212	0.4	5	0.015	0.025	(*10, 32, 40*)
n-Octane	100	178	0.1	3	0.007	0.010	(*10, 32*)
n-Nonane[d]							
n-Decane[d]							
Over-all					0.012	0.020	

[a] Data from near attenuation to indicated maximum.

[b] Average deviation defined by:

$$s = \left\{\sum_{1}^{N} |(k_e - k_p)/k_e|\right\}/N$$

[c] Standard error of estimate defined by:

$$\sigma = \left\{\sum_{1}^{N} [(k_e - k_p)/k_e]^2/(N - 1)\right\}^{1/2}$$

[d] Extrapolated.

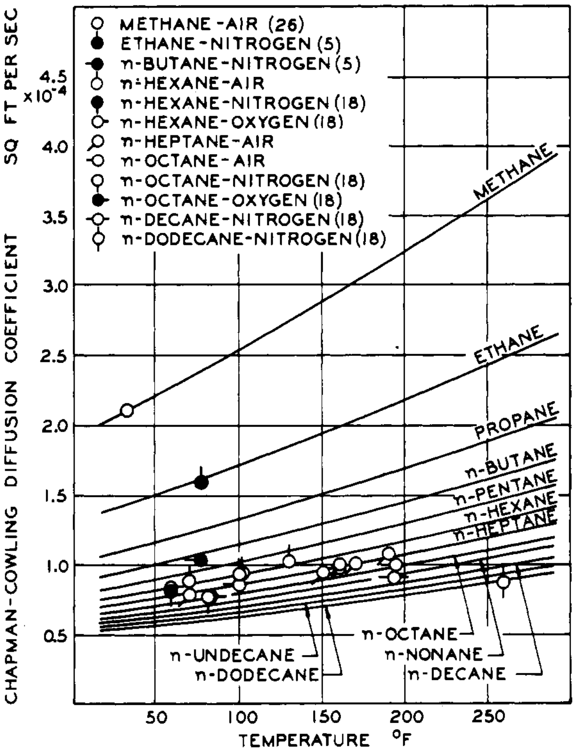

Figure 4. Chapman-Cowling diffusion coefficients for binary systems at 1 atm.

○ *n*-Hexane–air (*44,50*)
○ *n*-Heptane–air (*44,50*)
○ *n*-Octane–air (*44*)

4. The solid curves were predicted from statistical mechanical considerations supplemented by empirical mixing rules for the Lennard-Jones 6–12 potential binary interaction parameters (*23*). The Chapman-Cowling diffusion coefficient has been assumed to be independent of composition. Since insufficient experimental information appears available to permit the latter effect to be taken into account, any influence of composition has been neglected. However, such a simplification may not be justified. There are depicted in Table V the Chapman-Cowling diffusion coefficient and the standard error of estimate from the available experimental data for each of several gaseous binary systems containing a normal paraffin (*5, 17, 18, 26, 44, 50*). Diffusion coefficients for binary mixtures involving a normal paraffin hydrocarbon and an inorganic diatomic gas have been difficult to predict by conventional statistical mechanical methods (*20, 23*). The available theories do not appear sufficiently complete to permit the independent prediction of the numerical values of the diffusion coefficients without recourse to experiment.

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Table V. Chapman-Cowling Diffusion Coefficient for Binary Systems at Atmospheric Pressure[a]

System	Temp., ° F.	Chapman-Cowling Diffusion Coefficient, Sq. Ft./Sec.	Ref.
Methane–air	32	182.09 $\times 10^{-4}$	Jost (*26*)
Ethane–nitrogen	77	137.50	Boyd (*5*)
n-Butane–nitrogen	77	89.19	Boyd (*5*)
n-Hexane–air	70	86.44	Schlinger (*50*)
	100	90.72	Schlinger (*50*)
	100	92.80	Reamer (*44*)
	130	100.40	Schlinger (*50*)
n-Hexane–nitrogen	59	70.328	Cummings (*18*)
n-Hexane–oxygen	59	69.956	Cummings (*18*)
n-Heptane–air	70	76.46	Schlinger (*50*)
	100	83.36	Schlinger (*50*)
	150	93.64	Reamer (*44*)
	160	98.70	Schlinger (*50*)
	160	98.18	Reamer (*44*)
	170	100.95	Reamer (*44*)
	190	106.07	Schlinger (*50*)
n-Octane–air	195	100.27	Reamer (*44*)
n-Octane–nitrogen	86	65.961	Cummings (*18*)
n-Octane–oxygen	86	65.50	Cummings (*18*)
n-Decane–nitrogen	194	78.13	Cummings (*18*)
n-Dodecane–nitrogen	259	75.53	Cummings (*18*)
Av. deviation[b]		0.014	
Standard deviation[c]		0.017	

[a] Atmospheric pressure taken to be 14.696 p.s.i.a.

[b] Average deviation defined by:

$$s = \left\{\sum_{1}^{N} [(D_{Ckje} - D_{Ckjp})/D_{Ckje}]\right\}/N$$

[c] Standard error of estimate defined by:

$$\sigma = \left\{\sum_{1}^{N} [(D_{Ckje} - D_{Ckjp})/D_{Ckje}]^2/(N-1)\right\}^{1/2}$$

NOMENCLATURE

C_{P_o} = isobaric heat capacity at attenuation, B.t.u./(lb. mole) (° F.)
d = differential operator
D_{Ckj} = Chapman-Cowling diffusion coefficient, sq.ft./sec.
k = thermal conductivity, B.t.u./(sec.) (ft.) (° F.)
k_o = thermal conductivity at attenuation, B.t.u./(sec.) (ft.) (° F.)
$k_o^{(0)}$ = configurational thermal conductivity at attenuation, B.t.u./(sec.) (ft.) (° F.)
M = molecular weight, lb./lb.-mole
N = number of points
P = pressure, p.s.i.a.
R = universal gas constant, B.t.u./(lb.-mole) (° R.)
s = average deviation defined in Tables II and IV
η = viscosity, micropoises
η_0 = viscosity at attenuation, micropoises
Σ = summation operator
σ = standard error of estimate defined in Tables II, IV, and V

Subscripts

e = experimental
T = at constant temperature
P = at constant pressure
p = predicted

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