



Reference Correlations of the Viscosity and Thermal Conductivity of Acetone from the Triple Point to High Temperatures and Pressures

Sofia G. Sotiriadou¹ · Eleftheria Ntonti¹ · Marc J. Assael¹ · Marcia L. Huber²

Received: 22 October 2024 / Accepted: 5 November 2024 / Published online: 4 December 2024
This is a U.S. Government work and not under copyright protection in the US; foreign copyright protection may apply 2025

Abstract

This paper presents new wide-ranging correlations for the viscosity and thermal conductivity of acetone (2-propanone or dimethyl ketone) based on critically evaluated experimental data. Both correlations are designed to be used with a Helmholtz-energy equation of state (EOS) that extends from the triple point to 550 K, at pressures up to 700 MPa. The viscosity correlation is valid from the triple point to 550 K and up to 162 MPa pressure, while the thermal conductivity is valid from the triple point to 550 K and 700 MPa. The estimated uncertainty (at a 95 % confidence level) for the viscosity varies from a low of 2 % for the low-pressure gas ($p < 0.5$ MPa) to 5.5 % for the liquid phase at pressures up to 162 MPa, and for thermal conductivity varies from a low of 3.5% for the low-pressure gas up to 6.2% for the thermal conductivity at pressures up to 700 MPa.

Keywords Acetone · Thermal conductivity · Transport properties · Viscosity

1 Introduction

Acetone or dimethyl ketone, also known as 2-propanone (IUPAC name), has the molecular formula of C_3H_6O . Acetone is a synthesized chemical that also exists naturally in the environment. It is a colorless, flammable liquid with a distinct smell and is miscible in water. The primary use of acetone is the production of plastics, fibers, pharmaceuticals, and other chemicals. In addition, acetone is used in the preparation of paper coatings, adhesives, heat-seal coatings, and is

✉ Marcia L. Huber
marcia.huber@nist.gov

¹ Laboratory of Thermophysical Properties and Environmental Processes, Chemical Engineering Department, Aristotle University, 54636 Thessaloniki, Greece

² Applied Chemicals and Materials Division, National Institute of Standards and Technology, 325 Broadway, Boulder, CO 80305, USA

also employed as a starting material in the synthesis of many compounds [1]. Despite its wide range of applications, we are unaware of any reference correlations for the viscosity or thermal conductivity of acetone. There is a preliminary corresponding-states model [2] implemented in the computer program REFPROP [3], as well as other models such as friction theory [4, 5] or entropy scaling [6, 7].

In a series of papers published over the last 10 years, we reported new reference correlations over extended temperature and pressure ranges, for the viscosity of some simple fluids [8–11], hydrocarbons [12–19], alcohols [20–23], and some refrigerants [24–28]. In the case of the thermal conductivity, we also reported new reference correlations over extended temperature and pressure ranges for some simple fluids [29–35], hydrocarbons [14, 15, 19, 36–43], alcohols [44, 45], and some refrigerants [26, 27, 46, 47]. In this paper, the methodology adopted in the aforementioned papers is extended to developing new reference correlations for the viscosity and thermal conductivity of acetone. Therefore, the goal of this work is to critically assess the available literature data, and provide wide-ranging correlations for the viscosity and thermal conductivity of acetone that are valid over gas, liquid, and supercritical states, and incorporate densities provided by the equation of state of Lemmon and Span [48].

The analysis we use is based on the best available experimental data. A prerequisite to the analysis is a critical assessment of the experimental data. Here we define two categories of experimental data: primary data, employed in the development of the correlation, and secondary data, used simply for comparison purposes. According to the recommendation adopted by the Subcommittee on Transport Properties (now known as The International Association for Transport Properties) of the International Union of Pure and Applied Chemistry, the primary data are identified by a well-established set of criteria [49]. These criteria have been successfully employed to establish standard reference values for the viscosity and thermal conductivity of fluids over wide ranges of conditions, with uncertainties in the range of 1 %. However, in many cases, such a narrow definition unacceptably limits the range of the data representation. Consequently, within the primary data set, it is also necessary to include results that extend over a wide range of conditions, albeit with a poorer accuracy, provided they are consistent with other more accurate data or with theory. In all cases, the accuracy claimed for the final recommended data must reflect the estimated uncertainty in the primary information.

The development of the correlation requires densities; Lemmon and Span [48] has published in 2006, an accurate, wide-ranging Helmholtz-energy equation of state valid from the triple point up to 550 K and 700 MPa. The uncertainties in the density are 0.1 % in the saturated liquid state between 280 and 310 K, 0.5 % in the liquid phase below 380 K, and 1 % everywhere else, including all states at pressures above 100 MPa. We use the EOS of Lemmon and Span [48] for all thermodynamic properties and also adopt their values for the critical point and triple point—the critical temperature, T_c , and the critical density, ρ_c , are 508.1 K and 272.971958 kg·m⁻³, respectively, and the triple-point temperature is 178.5 K [48].

2 The Viscosity Correlation

The viscosity η can be expressed [8–18, 20–28] as the sum of four independent contributions, as

$$\eta(\rho, T) = \eta_0(T) + \eta_1(T)\rho + \Delta\eta(\rho, T) + \Delta\eta_c(\rho, T), \quad (1)$$

where ρ is the molar density, T is the absolute temperature, and the first term, $\eta_0(T) = \eta(0, T)$, is the contribution to the viscosity in the dilute-gas limit, where only two-body molecular interactions occur. The linear-in-density term, $\eta_1(T)\rho$, known as the initial density dependence term, can be separately established with the development of the Rainwater–Friend theory [50–52] for the transport properties of moderately dense gases. The critical enhancement term, $\Delta\eta_c(\rho, T)$, arises from the long-range density fluctuations that occur in a fluid near its critical point, which contribute to divergence of the viscosity at the critical point. This term for viscosity is significant only in the region very near the critical point, as shown in Vesovic et al. [53] and Hendl et al. [54]. For CO_2 , Vesovic et al. [53] showed that the enhancement contributes greater than 1 % to the viscosity only in the small region bounded by $0.986 < T_r < 1.019$ and $0.642 < \rho_r < 1.283$ (where T_r and ρ_r denote the reduced temperature and density). Since data close to the critical point are unavailable for acetone, $\Delta\eta_c(\rho, T)$ will be set to zero in Eq. 1 and not discussed further. Finally, the term $\Delta\eta(\rho, T)$, the residual term, represents the contribution of all other effects to the viscosity of the fluid at elevated densities including many-body collisions, molecular-velocity correlations, and collisional transfer.

The identification of these four separate contributions to the viscosity and to transport properties in general is useful because it is possible in general, to some extent, to treat $\eta_0(T)$, and $\eta_1(T)$ theoretically. In addition, it is possible to derive information about both $\eta_0(T)$ and $\eta_1(T)$ from experiment. In contrast, there is little theoretical guidance concerning the residual contribution, $\Delta\eta(\rho, T)$, and therefore its evaluation is based entirely on an empirical equation obtained by fitting experimental data.

Table 1 summarizes, to the best of our knowledge, the experimental measurements of the viscosity of acetone reported in the literature. In relation to the selection of the primary data set of measurements at 0.1 MPa presented in Table 1, the same criteria adopted in our recent paper on the reference correlation of ethanol [21] and THF [139] were adopted. As already mentioned in the introduction, acetone is extensively employed in the chemical industry. In most cases, applications take place around room temperature and in atmospheric pressure, and thus, in recent literature, there is a very large number of papers that include a single measurement of the viscosity of acetone at these conditions with inadequate assessments of uncertainty. Therefore, we did not include in the primary data set such articles with a single viscosity measurement at room temperature or near it. Since we are also interested in low-uncertainty measurements, we also did not consider for the primary data set measurements with quoted uncertainty larger than 3 %. In conclusion, for viscosity measurements at 0.1 MPa to be included in the primary data set,

Table 1 Viscosity measurements of acetone

Investigators/reference	Publ. year	Technique employed	Purity ^b (%)	Uncertainty (%)	No. of data	Temperature range (K)	Pressure range (MPa)
<i>Primary data</i>							
Kerscher et al. [55]	2024	SLS, Cap	99.9	0.99–2.1	16	273–403	0.009–0.76
Han et al. [56]	2023	FBall	99.5	0.50	7	293–323	0.1
Mohammadi and Hamzehloo [57]	2019	Cap	99.8	0.37	5	298–318	0.1
Gowrisankar et al. [58]	2014	Cap	99.5	1.67	3	298–308	0.1
Wu et al. [59]	2014	Cap	99.9	0.50	3	303–323	0.1
Yang et al. [60]	2010	Cap	99.8	0.60	8	278–313	0.1
Rajagopal and Chemthilnath [61]	2010	Cap	99.5	2.67	3	298–308	0.1
Ren et al. [62]	2007	Cap	na	1.10	5	298–323	0.1
Chen and Tu [63]	2005	Cap	99.9	0.60	3	288–308	0.1
Gonzalez et al. [64]	2005	Cap	99.8	0.33	3	293–303	0.1
Peng et al. [65]	2002	Cap	99.6	0.80	3	288–308	0.1
Kimart et al. [66]	2002	Cap	99.95	0.65	3	293–303	0.1
Sun et al. [67]	1996	Cap	na	3.00	5	293–323	0.1
Prakash et al. [68]	1990	Cap	na	0.70	3	303–313	0.1
Bauer and Meerlender [69]	1984	Cap	99.5	0.10	6	293–298	0.1
Atoyán and Mamedov [70]	1976	FCyl	na	na	51	273–473	0.1–162
Hafez and Hartland [71]	1976	Cap	na	0.35	4	293–318	0.1
Terenteva et al. [72]	1973	na	na	na	6	223–273	0.1
Konobeév and Lyapin [73]	1970	Cap	na	2.0	2	293–313	0.1
Golubev [74, 75] ^a	1959	Cap	na	na	47	476–557	0.1–81
Howard and Pike [76]	1959	Cap	Pur	0.10	5	293–329	0.02–0.1
Ling and Van Winkler [77] ^a	1958	Cap	Reag	0.2–4	6	303–423	0.1–1.14

Table 1 (continued)

Investigators/reference	Publ. year	Technique employed	Purity ^b (%)	Uncertainty (%)	No. of data	Temperature range (K)	Pressure range (MPa)
Golubev and Petrov [75, 78] ^a	1953	Cap	na	na	6	373–673	0.1
Craven and Lambert [79] ^a	1951	OCyl	Pur	1.00	5	308–358	0.04–0.25
Lacher et al. [80]	1949	Cap	na	na	3	193–273	0.1
Titani [81] ^a	1933	Cap	Pur	na	7	392–580	0.1
Mitsukuri and Tonomura [82]	1927	Cap	na	na	13	181–273	0.1
<i>Secondary data</i>							
Trenzado et al. [83]	2019	Cap	99.0	0.40	6	293–303	0.1
Dueroh et al. [84]	2017	Cap	99.7	0.25	4	298–313	0.1
Gotmare et al. [85]	2017	Cap	na	4.35	3	295–305	0.1
Zhu et al. [86]	2016	Cap	na	na	1	298	0.1
Zavkovic et al. [87]	2014	RCyl	99.8	0.40	8	288–323	0.1
Tian et al. [88]	2008	Cap	Pur	0.40	1	298	0.1
Sih et al. [89]	2008	FCyl	99.5	na	4	298–313	0.1
Liu and Kiran [90]	2007	FCyl	99.5	4.00	20	323–398	7.5–35.3
Wang et al. [91]	2005	Cap	Pur	0.2	1	298	0.1
Jain and Singh [92]	2004	Cap	99.0	1.00	1	303	0.1
Agarwal and Singh [93]	2004	Cap	99.0	1.00	1	298	0.1
Govindarajan et al. [94]	2003	Cap	Hplc	na	5	293–313	0.1
Tsierkezos and Molinou [95]	1999	Cap	99.5	0.30	1	297	0.1
Lorenzi et al. [96]	1995	Cap	99.0	na	1	298	0.1
Petrino et al. [97]	1995	Cap	98.0	0.10	1	298	0.1
Liu and Luo [98]	1992	Cap	na	na	4	293–313	0.1
Skomorokhov and Dregalin [99]	1992	na	na	na	1	298	0.1

Table 1 (continued)

Investigators/reference	Publ. year	Technique employed	Purity ^b (%)	Uncertainty (%)	No. of data	Temperature range (K)	Pressure range (MPa)
Das and Jha [100]	1991	Cap	99.0	0.85	1	302	0.1
Zhang and Liu [101]	1991	FBod	99.5	2.00	21	298–339	0.1–29.5
Scumpe and Luehring [102]	1990	Cap	na	na	1	293	0.1
Mamagakis and Panayiotou [103]	1989	Cap	99.5	0.50	1	298	0.1
Wei and Rowley [104]	1984	Cap	na	0.40	1	298	0.1
Noda et al. [105]	1982	Cap	na	0.52	1	298	0.1
Yadava and Yadava [106]	1981	Cap	Spc	0.35	1	307	0.1
Chandak et al. [107]	1979	Cap	Anal	1.40	5	298–321	0.1
Kerchove and Vijlder [108]	1977	Cap	Pur	1.90	1	296	0.1
Campbell and Martzmark [109]	1973	na	na	na	1	298	0.1
Mato and Coca [110]	1972	FBall	na	na	5	288–308	0.1
Yakovlev [111]	1967	na	na	na	1	323	0.1
Kalidas and Laddha [112]	1964	CAP	na	na	1	303	0.1
Blank [113]	1963	na	na	na	1	298	0.1
Vilim and Rezabek [114]	1960	na	na	na	1	303	0.1
Toropov [115]	1956	na	na	na	2	293–313	0.1
Udovenko and Khomenko [116]	1956	na	na	na	3	298–323	0.1
Chang and Wilke [117]	1955	Cap	Pur	na	3	286–313	0.1
Karr et al. [118]	1951	Cap	na	0.20	1	298	0.1
Reynolds and Kraus [119]	1948	Cap	na	na	1	298	0.1
Treybal et al. [120]	1946	Cap	Reag	na	1	298	0.1
Staudinger and Jorder [121]	1942	na	na	na	2	293–313	0.1
Hughes and Hartley [122]	1933	na	Pur	na	1	298	0.1

Table 1 (continued)

Investigators/reference	Publ. year	Technique employed	Purity ^b (%)	Uncertainty (%)	No. of data	Temperature range (K)	Pressure range (MPa)
Bingham and Brown [123]	1932	na	Pur	na	3	283–303	0.1
Trew [124]	1932	Cap	Pur	na	1	298	0.1
Bridgman [125]	1926	FCyl	na	na	18	303–348	0.1–1176.8
McBain et al. [126]	1926	Cap	Pur	na	1	298	0.1
Lewis [127]	1925	Cap	Pur	na	1	298	0.1
Weissenberger and Piatti [128]	1925	Cap	na	na	1	293	0.1
Yajnik et al. [129]	1925	Cap	na	na	2	291–313	0.1
Weissenberger and Schuster [130]	1924	Cap	na	na	1	293	0.1
Kendall and Brakeley [131]	1921	RCyl	na	na	1	298	0.1
Bramley [132]	1916	Cap	na	na	2	283–293	0.1
Baker [133]	1913	Cap	na	na	3	273–298	0.1
Faust [134]	1912	Cap	na	na	13	260–315	0.1
Rappenecker [135] ^a	1910	Cap	na	na	2	373–485	0.1
Getman [136]	1908	Cap	na	na	1	298	0.1
Walden [137]	1906	Cap	na	na	2	273–298	0.1
Dunstan [138]	1904	Cap	na	na	1	293	0.1

Cap capillary; FBal falling ball, FBod falling body, FCyl falling cylinder, OCyl oscillating cylinder, RCyl rotating cylinder, SLS surface light scattering, anal analytical reagent grade, Hplc HPLC grade, Pur purified in the laboratory, Reag reagent grade, SPC spectroscopic grade, na not available

^aIncludes measurements in the vapor phase

- (1) must not be a single measurement at room temperature,
- (2) their quoted uncertainty must be not more than 3 %, and
- (3) the purity of the sample and the technique employed must be stated.

Regardless of the above three criteria, we did not include six more sets to the primary data: the measurements of Trenzado et al. [83], Duereh et al. [84], Zivkovich et al. [87], Zhang and Liu [101], and Chandak et al. [107], because they either showed systematic deviations from other data sets, or displayed large scatter. In addition, the 1926 measurements of Bridgman were also not included in the primary data set as they extend to pressures of up to 1176 MPa that are well outside the range of the present EOS correlation (700 MPa) and the measurements at 348 K showed deviation of about 20 % from other data at similar conditions. Finally, we very recently became aware of the new data of Kerscher et al. [55] that are suitable for inclusion in primary data but were not used in the development of the correlation since we were unaware of them during the correlation development. We have added them to the primary set and included them in the comparisons with primary data.

Figures 1 and 2 show the ranges of the primary measurements outlined in Table 1, and the phase may be seen as well.

As it can be seen from both figures, the primary measurements cover a wide range of conditions, i.e. the vapor and liquid phase, as well as the supercritical range.

2.1 The Viscosity Dilute-Gas Limit

The dilute-gas limit viscosity, $\eta_0(T)$ is a function only of temperature and can be analyzed independently of all other contributions in Eq. 1. According to the kinetic theory, the viscosity of a pure polyatomic gas may be related to an effective collision cross section, which contains all the dynamic and statistical information about the

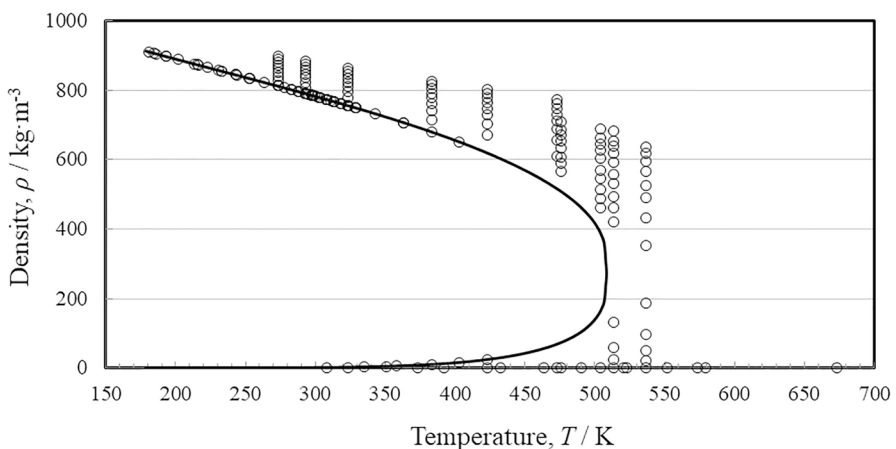


Fig. 1 Temperature–density ranges of the primary experimental viscosity data for acetone, (—) saturation curve

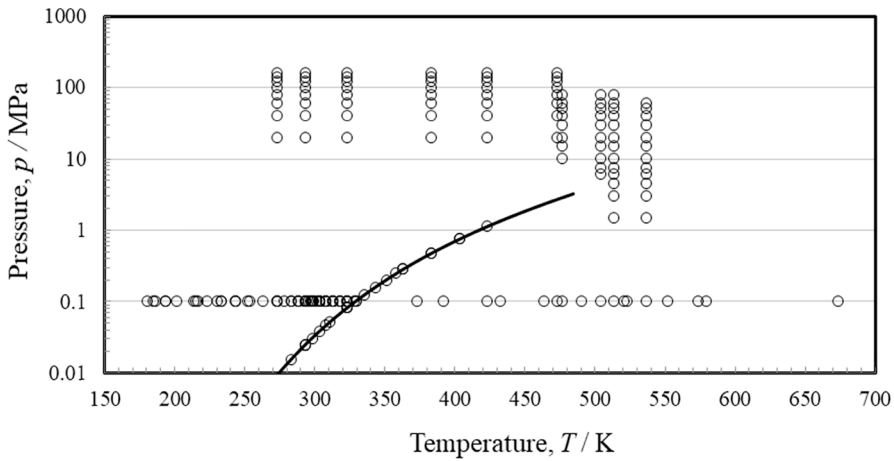


Fig. 2 Temperature–pressure ranges of the primary experimental viscosity data for acetone, (—) saturation curve

binary collision. For practical purposes, this relation is formally identical to that of monatomic gases and can be written as [140]

$$\eta_0(T) = 0.02669 \frac{\sqrt{MT}}{\sigma^2 \Omega^{(2,2)}} \tag{2}$$

where M (58.07914 g·mol⁻¹) is the molar mass [141], the collision diameter σ in nm is the smallest separation distance where the intermolecular potential function is equal to zero, T is the temperature in K, and the resulting viscosity is in $\mu\text{Pa s}$. $\Omega^{(2,2)}$ is a collision integral that depends upon the potential function.

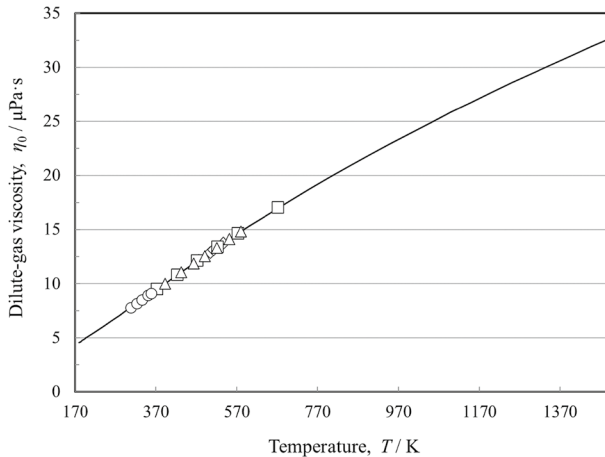
In the case of nonpolar gases, Neufeld et al. [142] developed an empirical correlation for the $\Omega^{(2,2)}$ collision integral for the Lennard–Jones (12–6) potential, as a function of the dimensionless temperature $T^* = T/(\varepsilon/k_B)$ (where k_B is Boltzmann’s constant and ε is the Lennard–Jones energy parameter), as

$$\begin{aligned} \Omega^{(2,2)}(T^*) = & 1.16145(T^*)^{-0.14874} + 0.52487 e^{-0.7732T^*} + 2.16178 e^{-2.43787T^*} \\ & - 6.435 \times 10^{-4}(T^*)^{0.14874} \sin [18.0323(T^*)^{-0.7683} - 7.27371]. \end{aligned} \tag{3}$$

Although acetone is polar, we found that this model is adequate for acetone as well. Equations 2 and 3 form a consistent scheme for the calculation of the dilute-gas limit viscosity as a function of the temperature, the only unknowns being the parameters σ and ε/k_B . These were calculated from the low-pressure vapor-phase measurements of Golubev [74], Golubev and Petrov [75, 78], Craven and Lambert [79], Titani [81], and are shown in Table 2. Figure 3 shows the gas-phase low-pressure data calculated using Eqs. 2 and 3, while their deviations from this scheme are shown in Fig. 4. The data are represented to within 1 %. The data of Craven and Lambert have an estimated uncertainty of 1 %, but the other data shown in Fig. 4 were not assigned uncertainties by their authors

Table 2 Parameters for acetone

Parameters	
M (g·mol ⁻¹)	58.07914
T_c (K)	508.1
ρ_c (kg·m ⁻³)	272.971958
ϵ/k_B (K)	432
σ (nm)	0.490

**Fig. 3** Dilute-gas viscosity, η_0 , as a function of the temperature: Golubev [74] (\diamond), Golubev and Petrov [75, 78] (\square), Craven and Lambert [79] (\circ), Titani [81] (\triangle)

and it is difficult to assign an estimated uncertainty to the dilute-gas correlation based on comparisons with experimental data. However, we will estimate the uncertainty of the dilute-gas correlation as 2 %.

For ease of use in calculations, η_0 values calculated from Eqs. 2 and 3 over the temperature range from the triple point to 1500 K were fitted using a commercial program [143] by a rational polynomial:

$$\eta_0(T_r) = \frac{0.931015 + 13.4773T_r - 6.84412T_r^2 + 3.30874T_r^3 + 4.78248T_r^4 - 1.45555T_r^5 + 0.149281T_r^6}{1.46335 - 1.36059T_r + T_r^2}, \quad (4)$$

where the units for η_0 are $\mu\text{Pa}\cdot\text{s}$, and the reduced temperature is $T_r = (T/T_c)$. Equation 4 reproduces the values calculated by Eqs. 2 and 3 to within 0.05 % up to 1500 K, and thus it will be employed hereafter.

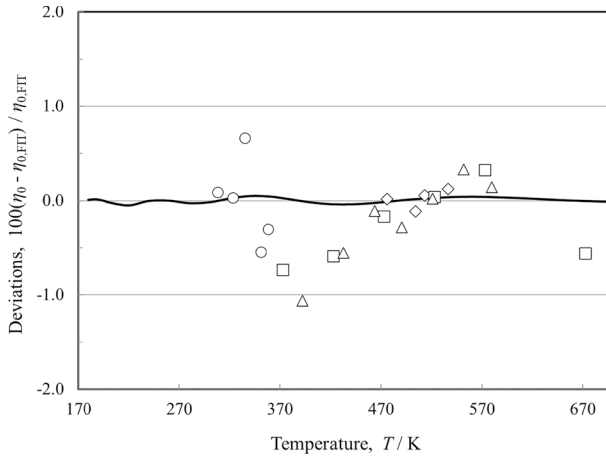


Fig. 4 Percentage dilute-gas viscosity deviations from the values obtained by the scheme of Eqs. 2 and 3. as a function of the temperature: Golubev [74] (\diamond), Golubev and Petrov [75, 78] (\square), Craven and Lambert [79] (\circ), Titani [81] (\triangle), and values calculated from Eq. 4 ($_$)

2.2 The Viscosity Initial-Density Dependence Term

The temperature dependence of the linear-in-density coefficient of the viscosity $\eta_1(T)$ in Eq. 1 is very large at subcritical temperatures and must be considered to obtain an accurate representation of the behavior of the viscosity in the vapor phase. It changes sign from positive to negative as the temperature decreases. Therefore, the viscosity along an isotherm should first decrease in the vapor phase and subsequently increase with increasing density [140]. Vogel et al.[144] have shown that fluids exhibit the same general behavior of the initial density dependence of viscosity, which can also be expressed by means of the second viscosity virial coefficient $B_\eta(T)$ in $\text{m}^3 \cdot \text{kg}^{-1}$, as

$$B_\eta(T) = \frac{\eta_1(T)}{\eta_0(T)}. \tag{5}$$

The second viscosity virial coefficient can be obtained according to the theory of Rainwater and Friend [50, 51] as a function of a reduced second viscosity virial coefficient, $B_\eta^*(T^*)$, as

$$B_\eta^*(T^*) = \frac{B_\eta(T)}{N_A \sigma^3}, \tag{6}$$

where [140]

$$B_\eta^*(T^*) = \sum_{i=0}^6 d_i(T^*)^{-0.25i} + d_7(T^*)^{-2.5} + d_8(T^*)^{-5.5}. \tag{7}$$

In the above equations, N_A is the Avogadro constant. The universal coefficients d_i from Ref. [140] are given in Table 3.

2.3 The Viscosity Residual Term

The residual viscosity term $\Delta\eta(\rho, T)$, represents the contribution of all other effects to the viscosity of the fluid at elevated densities including many-body collisions, molecular-velocity correlations, and collisional transfer. Because there is little theoretical guidance concerning this term, its evaluation here is based entirely on experimentally obtained data.

The procedure adopted during this analysis used symbolic regression software [145] to fit all the primary data to the residual viscosity. Symbolic regression is a type of genetic programming that allows the exploration of arbitrary functional forms to regress data. The functional form is obtained by use of a set of operators, parameters, and variables as building blocks. In the present work we restricted the operators to the set (+, -, *, /) and the operands (constant, T_r , ρ_r), with $T_r = T/T_c$ and $\rho_r = \rho/\rho_c$. In addition, we adopted a form suggested from the hard-sphere model employed by Assael et al. [146] $\Delta\eta(\rho_r, T_r) = (\rho_r^{2/3} T_r^{1/2}) F(\rho_r, T_r)$, where the symbolic regression method was used to determine the functional form for $F(\rho_r, T_r)$. For this task, the dilute-gas limit and the initial density dependence terms were calculated for each experimental point (employing Eqs. 4–7) and subtracted from the experimental viscosity to obtain the residual term. The final equation obtained was

$$\Delta\eta(\rho, T) = (\rho_r^{2/3} T_r^{1/2}) \left\{ f_0 \rho_r + \frac{f_1 + f_2 \rho_r + f_3 \rho_r^5 + f_4 T_r^2 \rho_r^8}{T_r + f_5 \rho_r} \right\}. \quad (8)$$

The coefficients are given in Table 3, and $\Delta\eta$ is in $\mu\text{Pa}\cdot\text{s}$.

Table 3 Coefficients for Eqs. 7 and 8

i	d_i (-), Eq. 7 [140]	f_i (-), Eq. 8
0	-0.195728810×10^2	$0.62435628350 \times 10^1$
1	0.219739990×10^3	$0.16610522013 \times 10^0$
2	-0.101532260×10^4	$0.89088278828 \times 10^1$
3	0.247101251×10^4	$0.16610522013 \times 10^0$
4	-0.337517170×10^4	$0.69857927082 \times 10^{-2}$
5	0.249165970×10^4	$-0.88521102246 \times 10^{-1}$
6	-0.787260860×10^3	
7	0.140854550×10^2	
8	-0.346641580×10^0	

2.4 Comparison with Data

The final correlation model consists of Eq. 1, and Eqs. 4–8 with the critical enhancement term set to zero. Table 4 summarizes comparisons of the primary data with the correlation, and Table 5 gives comparison for the secondary data. We define the percent deviation as $PCTDEV = 100(\eta_{exp} - \eta_{fit})/\eta_{fit}$, where η_{exp} is the experimental value of the viscosity and η_{fit} is the value calculated from the correlation. The average absolute percent deviation (AAD) is found with the expression $AAD = (\sum |PCTDEV|)/n$, where the summation is over all n points, the bias percent is found with the expression $BIAS = (\sum PCTDEV)/n$.

The average absolute percentage deviation of the fit for the primary data is 2.01 %, with a bias of 0.55 %, while the estimated uncertainty of the correlation in the temperature range 181 K to 673 K and up to 162 MPa is 5.5 % (at the 95 % confidence level).

Table 4 Evaluation of the acetone viscosity correlation for the primary data

Investigators/reference	Year publ	AAD (%)	BIAS (%)
Kerscher et al. [55]	2024	1.71	− 0.17
Han et al. [56]	2023	0.95	− 0.71
Mohammadi and Hamzehloo [57]	2019	1.10	− 0.80
Gowrisankar et al. [58]	2014	1.59	− 0.34
Wu et al. [59]	2014	2.85	2.85
Yang et al. [60]	2010	3.39	3.39
Rajagopal and Chenthilnath [61]	2010	1.32	− 1.32
Ren et al. [62]	2007	0.62	0.50
Chen and Tu [63]	2005	2.52	− 2.52
Gonzalez et al. [64]	2005	1.33	− 1.33
Peng et al. [65]	2002	1.51	− 1.51
Kinart et al. [66]	2002	1.00	− 0.44
Sun et al. [67]	1996	0.74	0.74
Prakash et al. [68]	1990	0.96	− 0.96
Bauer and Meerlender [69]	1984	2.55	− 2.55
Atoyan and Mamedov [70]	1976	2.02	0.97
Hafez and Hartland [71]	1976	2.61	− 2.61
Terenteva et al. [72]	1973	3.32	3.20
Konobeev and Lyapin [73]	1970	0.68	0.64
Golubev [74, 75]	1959	2.22	0.48
Howard and Pike [76]	1959	2.19	− 2.19
Ling and Van Winkler [77]	1958	2.91	1.14
Golubev and Petrov [75, 78]	1953	0.30	− 0.19
Craven and Lambert [79]	1951	1.26	1.26
Lacher et al. [80]	1949	4.87	4.80
Titani [81]	1933	0.28	− 0.15
Mitsukuri and Tonomura [82]	1927	2.15	1.36
Total		2.01	0.55

Table 5 Evaluation of the acetone viscosity correlation for the secondary data

Investigators/reference	Year publ	AAD (%)	BIAS (%)
Trenzado et al. [83]	2019	6.67	6.67
Duereh et al. [84]	2017	12.45	- 12.45
Gotmare et al. [85]	2017	6.83	1.59
Zhu et al. [86]	2016	0.26	- 0.26
Zivkovic et al. [87]	2014	4.98	4.59
Tian et al. [88]	2008	0.71	0.71
Sih et al. [89]	2008	0.92	0.18
Liu and Kiran [90]	2007	11.25	11.25
Wang et al. [91]	2005	2.00	2.00
Jain and Singh [92]	2004	1.32	- 1.32
Agarwal and Singh [93]	2004	0.71	0.71
Govindarajan et al. [94]	2003	9.52	9.52
Tsierkezos and Molinou [95]	1999	3.66	3.66
Lorenzi et al. [96]	1995	1.58	- 1.58
Petrino et al. [97]	1995	23.66	23.66
Liu and Luo [98]	1992	1.63	- 1.63
Skomorokhov and Dregalin [99]	1992	0.71	0.71
Das and Jha [100]	1991	98.78	98.78
Zhang and Liu [101]	1991	8.69	8.52
Scumpe and Luehring [102]	1990	0.64	0.64
Mamagakos and Panayiotou [103]	1989	2.31	- 2.31
Wei and Rowley [104]	1984	2.31	- 2.31
Noda et al. [105]	1982	2.85	- 2.85
Yadava and Yadava [106]	1981	2.05	2.05
Chandak et al. [107]	1979	8.57	- 8.57
Kerchove and Vijlder [108]	1977	2.00	- 2.00
Campbell and Martzmark [109]	1973	2.71	- 2.71
Mato and Coca [110]	1972	1.19	0.28
Yakovlev [111]	1967	0.93	- 0.93
Kalidas and Laddha [112]	1964	1.72	- 1.72
Blank [113]	1963	0.59	- 0.59
Vilim and Rezabek [114]	1960	0.18	- 0.18
Toropov [115]	1956	1.74	- 1.74
Udoenko and Khomenko [116]	1956	5.53	5.53
Chang and Wilke [117]	1955	0.96	- 0.49
Karr et al. [118]	1951	3.50	- 3.50
Reynolds and Kraus [119]	1948	1.88	- 1.88
Treybal et al. [120]	1946	2.96	2.96
Staudinger and Jorder [121]	1942	1.18	0.63
Hughes and Hartley [122]	1933	0.92	- 0.92
Bingham and Brown [123]	1932	0.64	- 0.64
Trew [124]	1932	1.57	- 1.57

Table 5 (continued)

Investigators/reference	Year publ	AAD (%)	BIAS (%)
Bridgman [125]	1926	26.86	3.53
McBain et al. [126]	1926	1.91	− 1.91
Lewis [127]	1925	1.72	− 1.72
Weissenberger and Piatti [128]	1925	10.80	− 10.80
Yajnik et al. [129]	1925	6.09	6.09
Weissenberger and Schuster [130]	1924	13.80	13.80
Kendall and Brakeley [131]	1921	1.08	− 1.08
Bramley [132]	1916	0.41	− 0.20
Baker [133]	1913	0.87	0.77
Faust [134]	1912	4.52	− 1.68
Rappenecker [135]	1910	0.75	0.29
Getman [136]	1908	0.83	0.83
Walden [137]	1906	1.22	0.73
Dunstan [138]	1904	3.88	− 3.88

As indicated in Fig. 2, there still are data gaps for the liquid below 273 K at higher pressures, all temperatures for pressures above 163 MPa, and the compressed vapor above 537 K; additional data in this region would be helpful to assess uncertainties in that region. Also, as pointed out by Kerscher et al. [55] there is a large amount of scatter in the data that exceeds the stated uncertainties of the data that there is no clear explanation for. This contributes to the large uncertainty of our correlation.

Figure 5 shows the relative deviations of the primary viscosity data of acetone from the values calculated by Eqs. 1, 4–8, as a function of temperature, while Figs. 6 and 7 show the same deviations but as a function of the pressure and the density.

Finally, Fig. 8 shows a plot of the viscosity of acetone as a function of the temperature for different pressures. The plot demonstrates the physically reasonable extrapolation behavior at pressures higher than 162 MPa, and at temperatures that exceed the 673 K limit of the current measurements and the 550 K limit of the EOS. However, acetone is subject to thermal decomposition at high temperatures [147–149] and our correlation does not take this into account.

3 The Thermal Conductivity Correlation

In a very similar fashion to that described for the expression of viscosity in Sect. 2, the thermal conductivity λ is expressed as the sum of three independent contributions, as

$$\lambda(\rho, T) = \lambda_0(T) + \Delta\lambda(\rho, T) + \Delta\lambda_c(\rho, T) \quad (9)$$

where ρ is the density, T is the temperature, and the first term, $\lambda_0(T) = \lambda(0, T)$, is the contribution to the thermal conductivity in the dilute-gas limit, where only two-body molecular interactions occur. The final term, $\Delta\lambda_c(\rho, T)$, the critical enhancement,

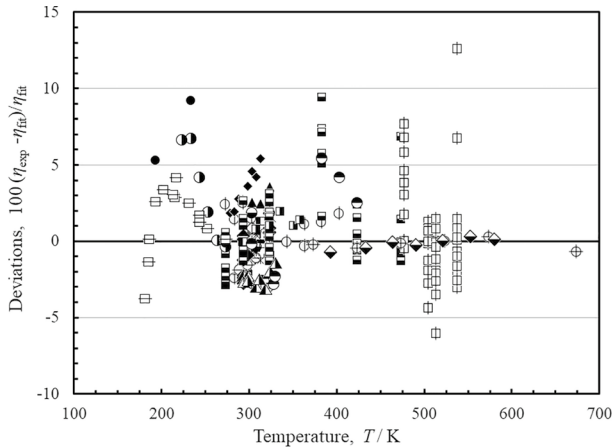


Fig. 5 Relative deviations of the viscosity of the primary experimental data of acetone from the values calculated by the present model, Eqs. 1, 4–8, as a function of temperature: Kerscher et al. [55] (\oplus), Han et al. [56] (\blacksquare), Mohammadi and Hamzehloo [57] (\boxplus), Gowrisankar et al. [58] (\ominus), Wu et al. [59] (\blacktriangle), Yang et al. [60] (\blacklozenge), Rajagopal and Chentilnath [61] (\square), Ren et al. [62] (\times), Chen and Tu [63] ($+$), Gonzalez et al. [64] (\odot), Peng et al. [65] (\ominus), Kinart et al. [66] (\blacklozenge), Sun et al. [67] (\blacklozenge), Prakash et al. [68] (\times), Bauer and Meerlender [69] (\blacklozenge), Atoyán and Mamedov [70] (\boxplus), Hafez and Hartland [71] (\blacktriangle), Terenteva et al. [72] (\odot), Konobeev and Lyapin [73] (\boxplus), Golubev [74, 75] (\boxplus), Howard and Pike [76] (\blacktriangle), Ling and Van Winkler [77] (\odot), Golubev and Petrov [75, 78] (\oplus), Craven and Lambert [79] (\boxplus), Lacher et al. [80] (\bullet), Titani [81] (\blacklozenge), Mitsukuri and Tonomura [82] (\boxplus)

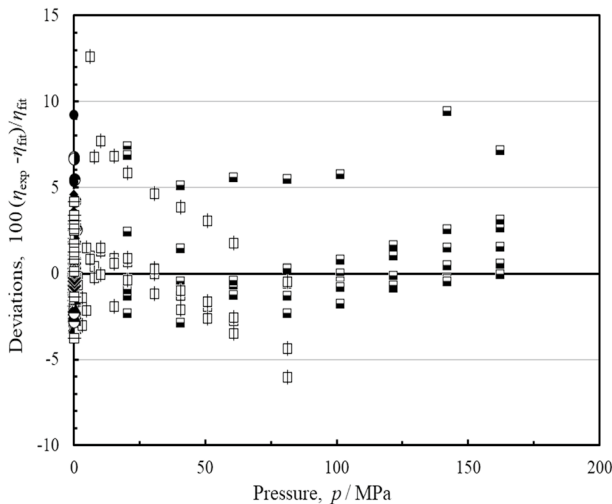


Fig. 6 Relative deviations of the viscosity of the primary experimental data of acetone from the values calculated by the present model, Eqs. 1, 4–8, as a function of pressure: Kerscher et al. [55] (\oplus), Han et al. [56] (\blacksquare), Mohammadi and Hamzehloo [57] (\boxplus), Gowrisankar et al. [58] (\ominus), Wu et al. [59] (\blacktriangle), Yang et al. [60] (\blacklozenge), Rajagopal and Chentilnath [61] (\square), Ren et al. [62] (\times), Chen and Tu [63] ($+$), Gonzalez et al. [64] (\odot), Peng et al. [65] (\ominus), Kinart et al. [66] (\blacklozenge), Sun et al. [67] (\blacklozenge), Prakash et al. [68] (\times), Bauer and Meerlender [69] (\blacklozenge), Atoyán and Mamedov [70] (\boxplus), Hafez and Hartland [71] (\blacktriangle), Terenteva et al. [72] (\odot), Konobeev and Lyapin [73] (\boxplus), Golubev [74, 75] (\boxplus), Howard and Pike [76] (\blacktriangle), Ling and Van Winkler [77] (\odot), Golubev and Petrov [75, 78] (\oplus), Craven and Lambert [79] (\boxplus), Lacher et al. [80] (\bullet), Titani [81] (\blacklozenge), Mitsukuri and Tonomura [82] (\boxplus)

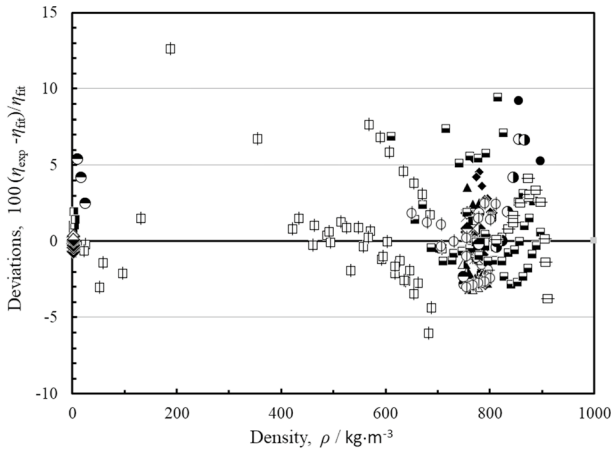


Fig. 7 Relative deviations of the viscosity of the primary experimental data of acetone from the values calculated by the present model, Eqs. 1, 4–8, as a function of density: Kerscher et al. [55] (\diamond), Han et al. [56] (\blacksquare), Mohammadi and Hamzehloo [57] (\square), Gowrisankar et al. [58] (\ominus), Wu et al. [59] (\blacktriangle), Yang et al. [60] (\blacklozenge), Rajagopal and Chentilnath [61] (\square), Ren et al. [62] (\times), Chen and Tu [63] ($+$), Gonzalez et al. [64] (\odot), Peng et al. [65] (\ominus), Kinart et al. [66] (\odot), Sun et al. [67] (\odot), Prakash et al. [68] (\times), Bauer and Mehlender [69] (\odot), Atoyan and Mamedov [70] (\square), Hafez and Hartland [71] (\blacktriangle), Terenteva et al. [72] (\odot), Konobeev and Lyapin [73] (\square), Golubev [74, 75] (\square), Howard and Pike [76] (\blacktriangle), Ling and Van Winkler [77] (\odot), Golubev and Petrov [75, 78] (\oplus), Craven and Lambert [79] (\square), Lacher et al. [80] (\bullet), Titani [81] (\odot), Mitsukuri and Tonomura [82] (\square)

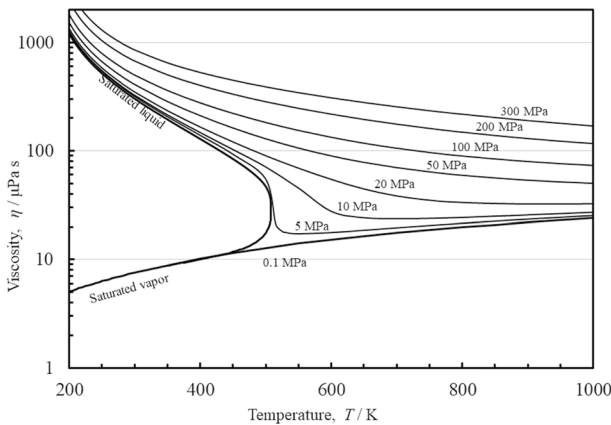


Fig. 8 Viscosity of acetone as a function of the temperature for different pressures

arises from the long-range density fluctuations that occur in a fluid near its critical point, which contribute to divergence of the thermal conductivity at the critical point. Finally, the term $\Delta\lambda(\rho, T)$, the residual property, represents the contribution of all other effects to the thermal conductivity of the fluid at elevated densities.

Table 6 summarizes, to the best of our knowledge, the experimental measurements of the thermal conductivity of acetone reported in the literature. Following

Table 6 Thermal conductivity measurements of acetone

Investigators/reference	Publ. year	Technique employed	Purity (%)	Uncertainty (%)	No. of data	Temperature range (K)	Pressure range (MPa)
<i>Primary data</i>							
Fujii et al. [159]	1997	STHW	na	2.0	2	293–299	0.1
Qun-Fang et al. [160]	1991	THW	99.5	0.7	6	253–303	0.1
Madzhidov [153]	1984	TCal	na	2.5	120	288–573	0.1–49
Frurip et al. [161] ^a	1978	HW	99.5	1.0	75	340–378	0.02–0.16
Madzhidov and Khalilov [162] ^a	1978	TCal	na	na	27	340–572	0.1
Takizawa et al. [163]	1978	THW	na	1.5	3	273–293	0.1
Mallan et al. [164]	1972	THW	na	1.3	10	298–384	0.1
Filippov [165]	1968	PP	na	3.0	5	288–323	0.1
Mianna et al. [166] ^a	1968	HW	na	na	8	308–474	0.1
Mukhamedzyanov and Usmanov [167]	1968	HF	na	1.5	8	277–307	0.1
Rastorguev and Nemzer [168]	1968	CC	na	1.5	4	293–323	0.1
Tufeu et al. [169]	1968	CC	na	1.5	6	277–326	0.1
Geller et al. [170]	1965	CC	na	1.0	4	293–323	0.1
Jobst [171]	1964	THW	Pur	2.0	4	177–274	0.1
Vines and Bennett [172] ^a	1954	2HW	na	1.0	4	351–434	0.1
Vines [173] ^a	1953	2HW	na	0.35	6	338–388	0.1
Riedel [150]	1951	CSp	na	1.0	1	193	0.1
Riedel [174]	1951	PP	na	1.0	6	233–323	0.1
Lambert et al. [151] ^a	1950	2HW	Pur	na	27	339–358	0.003–0.08
Bridgman [152]	1923	CC	Pur	na	22	303–348	0.1–1177
<i>Secondary data</i>							
Gross et al. [175]	1992	THD	na	na	1	293	0.02

Table 6 (continued)

Investigators/reference	Publ. year	Technique employed	Purity (%)	Uncertainty (%)	No. of data	Temperature range (K)	Pressure range (MPa)
Baroncini et al. [176]	1984	HW	na	na	2	298–323	0.1
Wang et al. [177]	1984	TTh	na	2.0	1	298	0.1
Parkinson [178]	1974	THW	Anal	0.25	1	273	0.1
Akhundon and Glymanov [179]	1969	CC	na	na	1	298	0.1
Jamieson and Hastings [180]	1969	HW	na	3.0	1	273	0.1
Perry and Jangda [181]	1968	HW	na	na	6	299–318	0.1
Jamieson and Tudhope [182]	1964	HW	na	5.0	2	273–298	0.1
Amirkhanov and Adamov [154]	1963	CC	na	2.0	2	298–303	0.1
Scheffy and Johnson [183]	1961	SSTF	na	10–15	9	356–509	0.23–4.8
El'darov [184]	1960	Cal	na	na	1	298	0.1
Frontas'ev and Gusakov [185]	1959	OPT	na	0.5	1	293	0.1
Hildenbrand and Happe [155]	1957	CC	na	3.0	1	303	0.1
Abas-Zade [156] ^a	1954	HW	na	na	11	273–505	0.01–4.4
Mason [186]	1954	CC	Reag	5.4	8	292–313	0.1
Baxter et al. [157]	1953	CC	na	2.0	2	303–312	0.1
van der Held and van Drunen [158]	1949	THW	na	2.0	1	289	0.1
Vargafuk [187]	1949	HW	na	na	1	303	0.1
Hutchinson [188]	1945	HW	na	na	1	291	0.1
Riedel [189]	1940	PP	na	1.0	1	293	0.1
Eucken [190] ^a	1913	HW	na	na	1	373	0.1
Moser [191]	1913	HW	na	30–50	4	273–457	0.009–2.1
Goldschmidt [192]	1911	HW	na	na	1	273	0.1

Cal, calorimeter, TCal, twin calorimeter, CC concentric cylinders, CSp concentric spheres, OPT optical, PP parallel plate, STHW short transient hot wire; HF, hot filament; HW, hot wire; THW, transient hot wire; 2HW, 2 hot wires, anal analytical reagent grade; Pur purified in the laboratory; Reag reagent grade, na not available

^aIncludes measurements in the vapor phase

the discussion on the selection of the viscosity primary data set of measurements at 0.1 MPa presented in Table 1, the same criteria were employed for the thermal conductivity. Therefore, we did not include in the primary data set such articles with a single thermal-conductivity measurement at room temperature or near it. Since we are also interested in low-uncertainty measurements, we also did not consider for the primary data set measurements with quoted uncertainty larger than 3 %. In conclusion, for the thermal-conductivity measurements to be included in the primary data set,

- (1) must not be a single measurement at, or about, room temperature and 0.1 MPa,
- (2) their quoted uncertainty must not be more than 3 %, and
- (3) the purity of the sample and the technique employed must be stated.

However as thermal conductivity is not very affected by small impurities, here we did include measurements with unstated purity. Additionally, in order to extend the range of the correlation we included in the primary data set, the single measurement of Riedel [150] performed at 193 K, the vapor measurements of Lambert et al. [151], as well as the high-pressure measurements of Bridgman [152].

We also note that we did not include in the primary data set,

- (a) the 4.9 MPa isobar of Madzhidov [153], as it is showed very large deviations, probably attributed to the fact that it is very near the critical pressure and the temperature was not measured accurately enough, and
- (b) the measurements of Amirkhanov and Adamov [154], Hildenbrand and Happe [155], Abas-Zade [156], Baxter et al. [157], and van der Held and van Drunen [158], as they showed systematic deviations of approximately 10, 40, – 30, 10 and 20 % respectively, from all other sets.

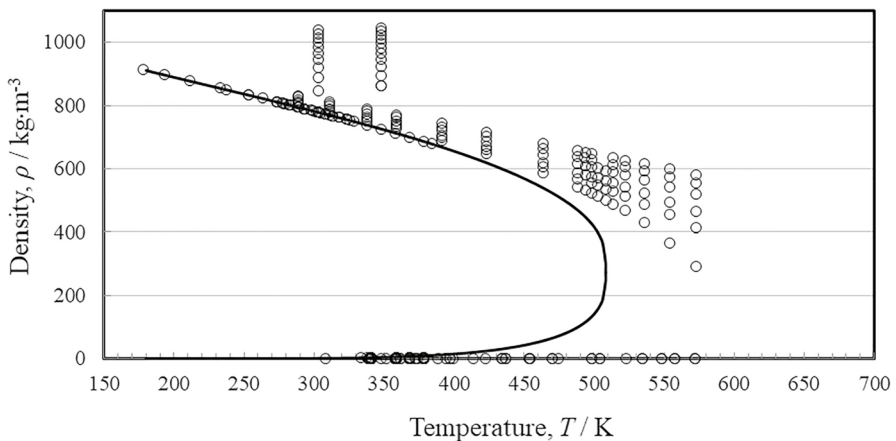


Fig. 9 Temperature–density ranges of the primary experimental thermal conductivity data for acetone, (—) saturation curve

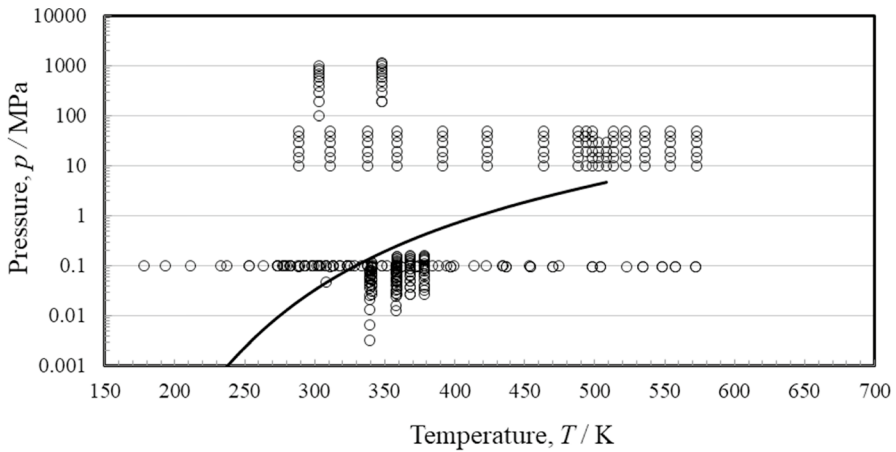


Fig. 10 Temperature–pressure ranges of the primary experimental thermal conductivity data for acetone, (—) saturation curve

Figures 9 and 10 show the ranges of the primary measurements outlined in Table 6, and the phase may be seen as well. The development of the correlation requires densities. As already discussed in the case of the viscosity correlation, we employed the Helmholtz-energy equation of state of Lemmon and Span [48].

3.1 The Thermal Conductivity Dilute-Gas Limit

To extrapolate the temperature range of the measurements, a theoretically based scheme was used to correlate the dilute-gas limit thermal conductivity, $\lambda_o(T)$, over a wide temperature range. The traditional kinetic approach for thermal conductivity results in an expression involving three generalized cross sections [193, 194]. However, it is possible to derive an equivalent kinetic theory expression for thermal conductivity by making use of the approach of Thijssse et al. [195] and Millat et al. [196], where one considers an expansion in terms of total energy, rather than separating translational from internal energy as is done traditionally. In this case, the dilute-gas limit thermal conductivity, $\lambda_o(T)$ ($\text{mW}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$), of a polyatomic gas can be shown to be inversely proportional to a single generalized cross section [193–196], $S(10E)$ (nm^2), as

$$\lambda_o(T) = 1000 \frac{5k_B^2(1+r^2)T}{2m\langle v \rangle_o S(10E)} f_\lambda, \tag{10}$$

where k_B is the Boltzmann constant ($1.380649 \times 10^{-23} \text{ J}\cdot\text{K}^{-1}$ [197]), T (K) is the absolute temperature, f_λ (–) is the dimensionless higher-order correction factor, m (kg) is the molecular mass of acetone [$(0.05807914/6.02214076 \times 10^{23}) \text{ kg}$], and $\langle v \rangle_o = 4\sqrt{k_B T/\pi m}$ (m/s) is the average relative thermal speed. The quantity r^2 is defined by $r^2 = 2C_{\text{int}}^o/5k_B$, where C_{int}^o is the contribution of both the rotational, C_{rot}^o , and the vibrational, C_{vib}^o , degrees of freedom to the isochoric ideal-gas heat capacity C_v^o .

Classical trajectory calculations [198–200] confirm that for most molecules studied, the higher-order thermal-conductivity correction factor is near unity. One can take advantage of this finding to define the effective generalized cross section S_λ ($=S(10E)/f_\lambda$) (nm^2), and rewrite Eq. 10 for the dilute-gas limit thermal conductivity of acetone, $\lambda_0(T)$ ($\text{mW}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$), as

$$\lambda_0(T) = 0.07320228 \frac{(C_p^o/k_B)\sqrt{T}}{S_\lambda}. \quad (11)$$

The ideal-gas isobaric heat capacity, C_p^o ($=C_{\text{int}}^o + 2.5 k_B$) in (J/K), can be obtained from Lemmon and Span [48] with the dimensionless ratio C_p/k_B expressed as

$$\frac{C_p^o}{k_B} = 4 + \sum_{k=1}^3 \nu_k \left(\frac{u_k}{T}\right)^2 \frac{\exp(u_k/T)}{[\exp(u_k/T) - 1]^2}, \quad (12)$$

where the values of the coefficients ν_k and u_k are: $\nu_1 = 3.7072$, $\nu_2 = 7.0675$, $\nu_3 = 11.012$, and $u_1 = 310$ K, $u_2 = 3480$ K, $u_3 = 1576$ K.

It has been previously noted [196], and confirmed [194] for smaller molecules, that the cross section $S(10E)$ exhibits an almost linear dependence on the inverse temperature. Hence, in order to develop the correlation, we have fitted the effective cross section S_λ (nm^2), obtained from the low-density data of Frurip et al. [161], Madzhidov and Khalilov [162], Manna et al. [166], Vines and Bennet [172], Vines [173], and Lambert et al. [151], shown in Table 6, by means of Eqs. 11 and 12, to a linear fit in inverse temperature, resulting in the following expression,

$$S_\lambda = 0.2356 + \frac{232.51}{T}. \quad (13)$$

Equations 11–13 form a consistent set of equations for the calculation of the dilute-gas limit thermal conductivity of acetone.

The values of the dilute-gas limit thermal conductivity, $\lambda_0(T)$ in $\text{mW}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$, obtained by the scheme of Eqs. 11–13, were fitted as a function of the reduced temperature $T_r = T/T_c$ for ease of use to the following equation:

$$\lambda_0(T) = \frac{-5.98797 + 46.9565T_r - 149.748T_r^2 + 241.207T_r^3 - 43.1278T_r^4 + 3.52029T_r^5}{-0.614176 + 2.57584T_r + T_r^2}. \quad (14)$$

Values calculated by Eq. 14 do not deviate from the values calculated by the scheme of Eqs. 11–13 by more than 0.1 % over the temperature range from the triple point to 1500 K. Equation 14 is hence employed in the calculations that will follow.

Figure 11 shows the dilute-gas thermal conductivity as a function of temperature, while Fig. 12 shows their deviations from the values obtained by the scheme of Eqs. 11–13. The selected data are represented within the uncertainty of the data. No obvious systematic trends are observed. Therefore, based on the aforementioned discussion, Eqs. 11–13 or Eq. 14 represent the dilute-gas limit thermal conductivity to within 3.5 % at the 95 % confidence level.

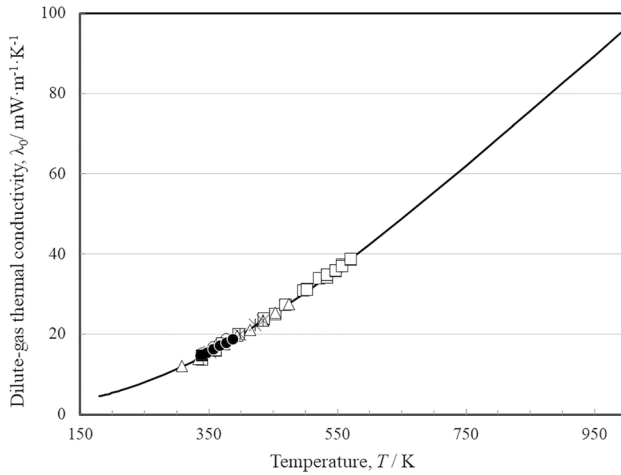


Fig. 11 Dilute-gas thermal conductivity as a function of the temperature: Frurip et al. [161] (○), Madzhidov and Khalilov [162] (□), Manna et al. [166] (△), Vines and Bennet [172] (✕), Vines [173] (●), Lambert et al. [151] (■), values calculated by Eq. 14 (—)

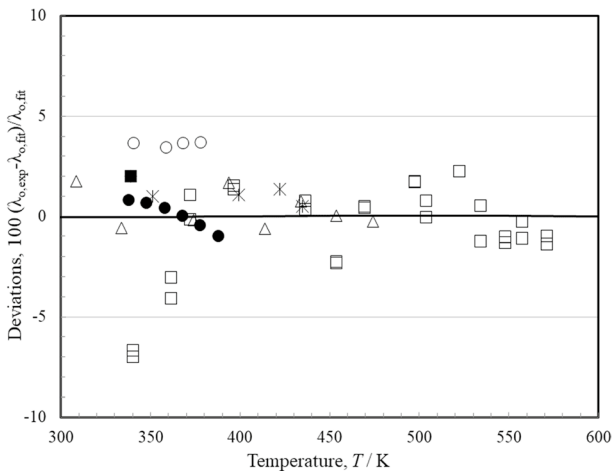


Fig. 12 Dilute-gas thermal conductivity deviations from the values obtained by the scheme of Eqs. 11–13, as a function of the temperature: Frurip et al. [161] (○), Madzhidov and Khalilov [162] (□), Manna et al. [166] (△), Vines and Bennet [172] (✕), Vines [173] (●), Lambert et al. [151] (■)

3.2 The Thermal Conductivity Residual Term

The thermal conductivities of pure fluids exhibit an enhancement over a large range of densities and temperatures around the critical point and become infinite at the critical point. This behavior can be described by models that produce a smooth crossover from the singular behavior of the thermal conductivity

Table 7 Coefficients of Eq. 15 for the residual thermal conductivity of acetone

i	$B_{1,i}$ (mW·m ⁻¹ ·K ⁻¹)	$B_{2,i}$ (mW·m ⁻¹ ·K ⁻¹)
1	1.49900120×10^2	-5.98846154×10^1
2	-2.23191952×10^2	1.17823591×10^2
3	1.30528948×10^2	-7.07635055×10^1
4	-2.90922187×10^1	1.49380192×10^1
5	2.14538883×10^0	$-5.06124251 \times 10^{-1}$

asymptotically close to the critical point to the residual values far away from the critical point [201–203]. The density-dependent terms for thermal conductivity can be grouped according to Eq. 9 as $[\Delta\lambda(\rho, T) + \Delta\lambda_c(\rho, T)]$. To assess the critical enhancement theoretically, we need to evaluate, in addition to the dilute-gas thermal conductivity, the residual thermal-conductivity contribution. The model, containing a residual contribution and an estimated critical enhancement, was fit to the primary data while maintaining the values of the dilute-gas thermal-conductivity data already obtained (Eq. 14). We used the ODRPACK [204] program to fit the data. The density values employed were obtained by the equation of state of Lemmon and Span [48]. The primary data were weighted in inverse proportion to the square of their uncertainty.

The residual thermal conductivity, $\Delta\lambda$, in mW·m⁻¹·K⁻¹, was represented with a polynomial in temperature and density:

$$\Delta\lambda(\rho, T) = \sum_{i=1}^5 (B_{1,i} + B_{2,i}(T/T_c)) (\rho/\rho_c)^i. \quad (15)$$

Coefficients $B_{1,i}$ and $B_{2,i}$ are shown in Table 7.

3.3 The Thermal Conductivity Critical Enhancement Term

The theoretically based crossover model proposed by Olchowy and Sengers [201–203] is complex and requires solution of a quartic system of equations in terms of complex variables. A simplified crossover model has also been proposed by Olchowy and Sengers [205]. The critical enhancement of the thermal conductivity from this simplified model is given by

$$\Delta\lambda_c = \frac{\rho_c R_D k_B T}{6\pi\bar{\eta}\xi} (\bar{\Omega} - \bar{\Omega}_0), \quad (16)$$

with

$$\bar{\Omega} = \frac{2}{\pi} \left[\left(\frac{c_p - c_v}{c_p} \right) \arctan(\bar{q}_D \xi) + \frac{c_v}{c_p} \bar{q}_D \xi \right] \quad (17)$$

and

$$\bar{\Omega}_0 = \frac{2}{\pi} \left[1 - \exp \left(- \frac{1}{(\bar{q}_D \xi)^{-1} + (\bar{q}_D \xi \rho_c / \rho)^2 / 3} \right) \right]. \quad (18)$$

In Eqs. 16–18, SI units are used, and k_B is the Boltzmann constant, $\bar{\eta}$ (Pa·s) is the viscosity, and c_p and c_v ($\text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$) are the isobaric and isochoric specific heat obtained from the equation of state. The correlation length ξ (m) is given by

$$\xi = \xi_0 \left(\frac{p_c \rho}{\Gamma \rho_c^2} \right)^{\nu/\gamma} \left[\left. \frac{\partial \rho(T, \rho)}{\partial p} \right|_T - \left(\frac{T_{\text{ref}}}{T} \right) \left. \frac{\partial \rho(T_{\text{ref}}, \rho)}{\partial p} \right|_T \right]^{\nu/\gamma}. \quad (19)$$

The regression process fits the residual term and the enhancement simultaneously with the dilute–gas contribution as calculated with Eq. 14 to obtain the coefficients $B_{1,i}$ and $B_{2,i}$ in Eq. 15, and any parameters needed in the critical enhancement term. When there are no critical-region data available, as is the case for acetone, one can compute the critical enhancement with estimated parameters using the model of Perkins et al. [206]. The model requires the universal amplitude, $R_D = 1.02$ (–), and the universal critical exponents, $\nu = 0.63$ and $\gamma = 1.239$, and the system–dependent amplitudes Γ and ξ_0 . For this work, we adopted the values $\Gamma = 0.052$ (–), $\xi_0 = 0.196 \times 10^{-9}$ m, using the universal representation of the critical enhancement of the thermal conductivity by Perkins et al. [206]. To estimate the effective cut-off wavelength \bar{q}_D^{-1} (m), we used the method of Perkins et al. [206], and the value obtained is 5.86×10^{-10} m. The viscosity required for Eq. 16 was calculated with the correlation developed earlier in this work. The reference temperature T_{ref} , far above the critical temperature where the critical enhancement is negligible, was calculated by $T_{\text{ref}} = (3/2) T_c$ [53], which for acetone is 762.15 K. Thus, the present critical enhancement calculation is consistent with the equation of state of Lemmon and Span [48] and should provide reasonable estimates of the thermal conductivity critical enhancement, although the uncertainty is larger in this area.

3.4 Comparison with Data

Table 8 summarizes comparisons of the primary data with the correlation, while Table 9 gives comparison for the secondary data. We estimate the uncertainty (at the 95 % confidence level) for the thermal conductivity from the triple–point temperature to 573 K at pressures up to 1177 MPa, to be 6.2 %. Uncertainties in the critical region are much larger, since the thermal conductivity approaches infinity at the critical point and is very sensitive to small changes in density. In addition, the EOS of Lemmon and Span [48] has a maximum temperature of 550 K and a pressure limit of 700 MPa, but comparisons with data indicate that the thermal conductivity correlation is valid up to 573 K and 1177 MPa using extrapolated densities from the EOS.

Figure 13 shows the percentage deviations of all primary thermal–conductivity data from the values calculated by Eqs. 9, 14–19, as a function of temperature.

Table 8 Evaluation of the acetone thermal-conductivity correlation for the primary data

Investigators/reference	Publ. year	AAD (%)	BIAS (%)
Fujii et al. [159]	1997	0.65	− 0.65
Qun-Fang et al. [160]	1991	2.45	− 2.45
Madzhidov [153]	1984	2.96	1.51
Frurip et al. [161]	1978	2.88	2.88
Madzhidov and Khalilov [162]	1978	2.43	− 2.32
Takizawa et al. [163]	1978	3.60	3.60
Mallan et al. [164]	1972	2.21	− 1.91
Filippov [165]	1968	4.62	4.62
Manna et al. [166]	1968	3.04	− 3.04
Mukhamedzyanov and Usmanov [167]	1968	1.01	1.01
Rastorguev and Nemzer [168]	1968	0.77	− 0.38
Tufeu et al. [169]	1968	5.15	5.15
Geller et al. [170]	1965	0.93	− 0.70
Jobst [171]	1964	5.83	− 5.83
Vines and Bennett [172]	1954	2.46	− 2.46
Vines [173]	1953	4.61	− 4.61
Riedel [150]	1951	3.58	3.58
Riedel [174]	1951	1.38	1.27
Lambert et al. [151]	1950	2.00	2.00
Bridgman [152]	1923	3.80	1.90
Total		2.84	1.12

Figures 14 and 15 show the same deviations but as a function of pressure and density, respectively.

Examining Fig. 13 (and similarly Fig. 14), one can notice that the measurements cover successfully a wide temperature and pressure range. In any case, the deviations are within the uncertainty of the current correlation (Fig. 15).

Figure 16 shows a plot of the thermal conductivity of acetone as a function of the temperature for different pressures. The plot demonstrates the physically reasonable extrapolation behavior outside of the range of validity of the EOS at pressures higher than 700 MPa and at temperatures that exceed the 550 K recommended upper temperature limit of the EOS. Finally, Fig. 17 shows the thermal conductivity as a function of density including temperatures with significant critical enhancement as calculated by the present correlation.

Table 9 Evaluation of the acetone thermal–conductivity correlation for the secondary data

Investigators/reference	Publ. year	AAD (%)	BIAS (%)
Gross et al. [175]	1992	1.61	1.61
Baroncini et al. [176]	1984	2.23	2.23
Wang et al. [177]	1984	2.33	2.33
Parkinson [178]	1974	1.85	1.85
Akhundon and Glymanov [179]	1969	6.85	6.85
Jamieson and Hastings [180]	1969	2.51	2.51
Perry and Jangda [181]	1968	2.64	2.64
Jamieson and Tudhope [182]	1964	5.58	5.58
Amirkhanov and Adamov [154]	1963	8.00	8.00
Scheffy and Johnson [183]	1961	30.31	19.13
El'darov [184]	1960	11.59	– 11.59
Frontas'ev and Gusakov [185]	1959	1.76	1.76
Hildenbrand and Happe [155]	1957	44.03	44.03
Abas-Zade [156]	1954	35.40	– 28.57
Mason [186]	1954	1.11	0.23
Baxter et al. [157]	1953	11.21	11.21
van der Held an van Drunen [158]	1949	17.93	17.93
Vargaftik [187]	1949	7.14	7.14
Hutchinson [188]	1945	6.50	6.50
Riedel [189]	1940	0.80	0.80
Eucken [190]	1913	17.85	– 17.85
Moser [191]	1913	47.30	47.30
Goldschmidt [192]	1911	6.06	6.06

4 Recommended Values and Computer-Program Verification

4.1 Recommended Values

In Table 10, viscosity and thermal conductivity values are given along the saturation boundary, calculated from the present proposed correlation between 200 K and 500 K, while in Table 11, viscosity and thermal conductivity values are given for temperatures between 200 and 500 K and at selected pressures. Saturation density values for selected temperatures, as well as the density values for the selected temperature and pressure are obtained from the equation of state of Lemmon and Span [48]. The values in the Table 11 are calculated from the given temperatures and densities according to Eqs. 1, 4–8 for viscosity and Eqs. 9, 14–19 for thermal conductivity.

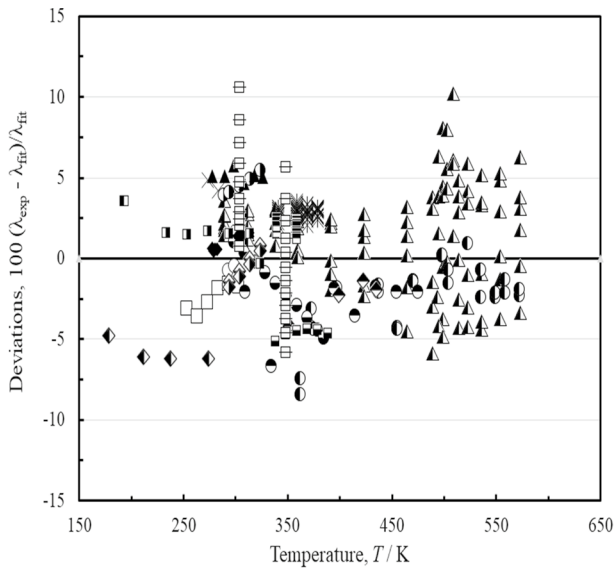


Fig. 13 Percentage deviations of primary thermal conductivity experimental data of acetone from the values calculated by the present model, Eqs. 9, 14–19, as a function of temperature: Fujii et al. [159] (○), Qun-Fang et al. [160] (□), Madzhidov [153] (◻), Frurip et al. [161] (▲), Madzhidov and Khalilov [162] (×), Takizawa et al. [163] (×), Mallan et al. [164] (●), Filippov [165] (◐), Manna et al. [166] (◑), Mukhamedzyanov and Usmanov [167] (◒), Rastorguev and Nemzer [168] (◆), Tufeu et al. [169] (▲), Geller et al. [170] (◊), Jobst [171] (◊), Vines and Bennett [172] (◊), Vines [173] (◊), Riedel [150] (◑), Riedel [174] (◑), Lambert et al. [151] (◑), Bridgman [152] (◑)

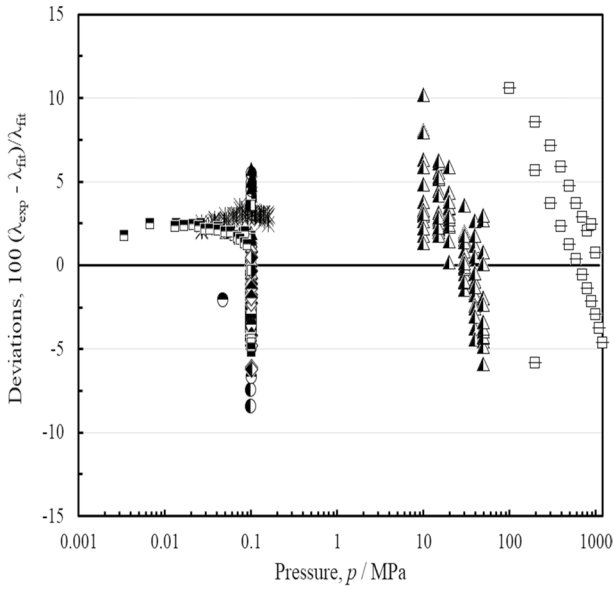


Fig. 14 Percentage deviations of primary thermal conductivity experimental data of acetone from the values calculated by the present model, Eqs. 9, 14–19, as a function of pressure: Fujii et al. [159] (○), Qun-Fang et al. [160] (□), Madzhidov [153] (○), Frurip et al. [161] (▲), Madzhidov and Khalilov [162] (*), Takizawa et al. [163] (×), Mallan et al. [164] (◐), Filippov [165] (◑), Manna et al. [166] (◒), Mukhamedzyanov and Usmanov [167] (◔), Rastorguev and Nemzer [168] (◕), Tufeu et al. [169] (▲), Geller et al. [170] (▲), Jobst [171] (◖), Vines and Bennett [172] (◗), Vines [173] (◘), Riedel [150] (◙), Riedel [174] (◚), Lambert et al. [151] (◛), Bridgman [152] (◜)

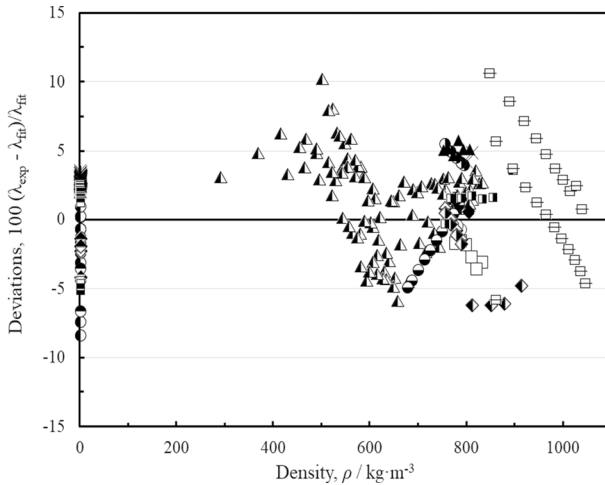


Fig. 15 Percentage deviations of primary thermal conductivity experimental data of acetone from the values calculated by the present model, Eqs. 9, 14–19, as a function of density: Fujii et al. [159] (○), Qun-Fang et al. [160] (□), Madzhidov [153] (△), Frurip et al. [161] (*), Madzhidov and Khalilov [162] (◐), Takizawa et al. [163] (×), Mallan et al. [164] (◑), Filippov [165] (◒), Manna et al. [166] (◓), Mukhamedzyanov and Usmanov [167] (◔), Rastorguev and Nemzer [168] (◕), Tufeu et al. [169] (▲), Geller et al. [170] (◖), Jobst [171] (◗), Vines and Bennett [172] (◘), Vines [173] (◙), Riedel [150] (◚), Riedel [174] (◛), Lambert et al. [151] (◜), Bridgman [152] (◝)

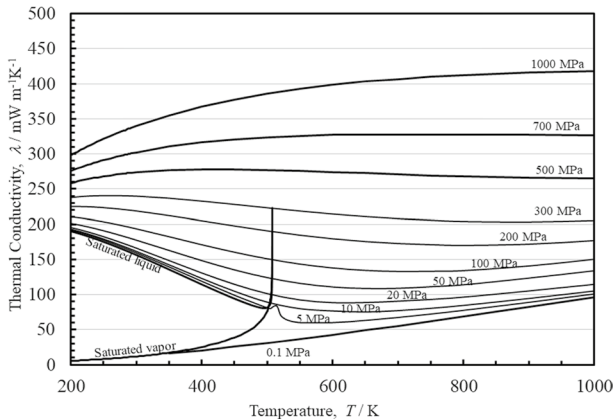


Fig. 16 The thermal conductivity of acetone as a function of temperature at different pressures

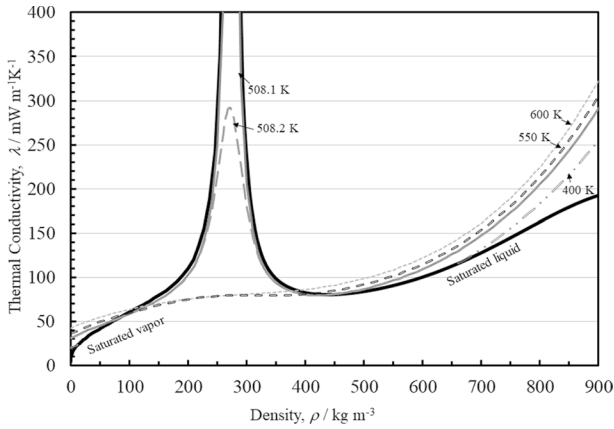


Fig. 17 The thermal conductivity of acetone as a function of density at different temperatures

Table 10 Viscosity and thermal conductivity values of acetone along the saturation boundary, calculated by the present scheme

T (K)	ρ_{liq} ($\text{kg}\cdot\text{m}^{-3}$)	ρ_{vap} ($\text{kg}\cdot\text{m}^{-3}$)	η_{liq} ($\mu\text{Pa}\cdot\text{s}$)	η_{vap} ($\mu\text{Pa}\cdot\text{s}$)	λ_{liq} ($\text{mW}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$)	λ_{vap} ($\text{mW}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$)
200	890.00	0.0011958	1210.0	5.0601	190.32672	5.4126
250	836.94	0.066908	519.91	6.3065	175.22129	8.0366
300	782.56	0.79564	304.24	7.5569	156.45214	11.640
350	723.73	4.2492	195.29	8.7753	135.71839	16.963
400	655.92	14.830	128.94	10.030	114.42260	25.267
450	569.42	42.672	84.230	11.750	94.072925	38.962
500	415.91	142.06	47.038	17.523	80.942348	76.217

Densities are calculated with the EOS of Lemmon and Span [48]

Table 11 Viscosity and thermal conductivity values of acetone at selected temperatures and pressures, calculated by the present scheme

p (MPa)	T (K)	ρ (kg·m ⁻³)	η (μPa·s)	λ (mW·m ⁻¹ ·K ⁻¹)
0.1	200	890.05	1210.6	190.35
	250	837.01	520.20	175.26
	300	782.63	304.40	156.49
	350	2.0741	8.8431	16.102
	400	1.7836	10.192	20.514
	450	1.5730	11.515	25.473
	500	1.4097	12.808	30.882
10	200	894.99	1269.6	192.70
	250	843.79	548.95	178.70
	300	792.27	326.34	161.30
	350	738.10	214.74	142.24
	400	678.56	147.27	122.98
	450	609.30	102.57	104.85
	500	521.16	70.885	89.487
50	200	912.57	1505.5	201.17
	250	866.91	659.27	190.78
	300	822.95	407.75	177.41
	350	779.55	284.01	162.83
	400	736.06	210.10	148.36
	450	692.19	161.73	135.16
	500	648.01	128.71	124.16
100	200	930.88	1800.7	210.19
	250	889.75	789.95	203.25
	300	851.25	501.41	193.39
	350	814.43	361.40	182.20
	400	778.81	277.72	170.85
	450	744.18	222.18	160.21
	500	710.54	183.14	150.90
150	200	946.49	2101.5	218.07
	250	908.56	916.90	213.96
	300	873.65	591.01	206.84
	350	840.80	434.83	198.21
	400	809.52	341.64	189.09
	450	779.57	279.28	180.24
	500	750.84	234.71	172.20
200	200	960.21	2411.3	225.15
	250	924.72	1042.2	223.49
	300	892.41	678.56	218.71
	350	862.31	506.45	212.21
	400	833.93	404.11	204.96
	450	806.97	335.41	197.63
	500	781.28	285.82	190.72

4.2 Computer-Program Verification

For checking computer implementations of the correlation, the following points may be used for the given T , ρ conditions: $T=300$ K, $\rho=0$ kg·m⁻³, $\eta=7.6011$ μPa·s, and $\lambda=11.306$ mW·m⁻¹·K⁻¹, while for $T=300$ K, $\rho=785.0$ kg m⁻³, $\eta=309.65$ μPa·s, and $\lambda=157.66$ mW·m⁻¹·K⁻¹ (for this point there is a very small contribution of 0.09 mW·m⁻¹·K⁻¹ to λ from the critical enhancement term).

5 Conclusions

New, wide-ranging correlations for the viscosity and thermal conductivity of acetone based on critically evaluated experimental data were presented. Both correlations are designed to be used with an equation of state [48] that extends from the triple-point temperature (178.5 K) to 550 K, at pressures up to 700 MPa. The EOS has good extrapolation behavior and we have used it slightly outside of its recommended temperature range for our correlations. The viscosity correlation is valid from the triple point to 580 K and up to 162 MPa pressure, while the thermal conductivity is valid from the triple point to 573 K and 700 MPa pressure (1177 MPa if extrapolated densities are employed). The estimated expanded uncertainty (at a 95 % confidence level) for the viscosity is 2 % for the low-density gas (pressures below 0.5 MPa), and 5.5 % over the rest of the range of application. For thermal conductivity, the expanded uncertainty is estimated to be 3.5 % for the low-density gas and 6.2 % over the rest of the range.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10765-024-03465-6>.

Author Contributions All authors contributed equally to the research, preparation, and review of this manuscript.

Funding This study was partially supported by the National Institute of Standards and Technology.

Data Availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors declare no competing interests. Marc J. Assael is the Editor-in-Chief and Marcia L. Huber is on the Editorial Advisory Board of the International Journal of Thermophysics.

References

1. In <https://pubchem.ncbi.nlm.nih.gov/compound/Acetone>. last accessed June 2024
2. M.L. Huber, Models for the Viscosity, Thermal Conductivity, and Surface Tension of Selected Pure Fluids as Implemented in REFPROP v10.0, NISTIR 8209 (2018). <https://doi.org/10.6028/NIST.IR.8209>

3. E.W. Lemmon, I.H. Bell, M.L. Huber, M.O. McLinden, REFPROP, NIST Standard Reference Database 23, Version 10.0, NIST, Standard Reference Data Program, Gaithersburg, MD (2018). <https://doi.org/10.18434/T4/1502528>
4. S.E. Quiñones-Cisneros, U.K. Deiters, *J. Phys. Chem. B* **110**(25), 12820 (2006). <https://doi.org/10.1021/jp0618577>
5. S.E. Quiñones-Cisneros, S. Pollak, K.A.G. Schmidt, *J. Chem. Eng. Data* **66**(11), 4215 (2021). <https://doi.org/10.1021/acs.jced.1c00400>
6. X.X. Yang, D.C. Kim, E.F. May, I.H. Bell, *Ind. Eng. Chem. Res.* **60**(35), 13052 (2021). <https://doi.org/10.1021/acs.iecr.1c02154>
7. X.X. Yang, X. Xiao, M. Thol, M. Richter, I.H. Bell, *Int. J. Thermophys.* **43**(12), 183 (2022). <https://doi.org/10.1007/s10765-022-03096-9>
8. D. Velliadou, K. Tasidou, K.D. Antoniadis, M.J. Assael, R.A. Perkins, M.L. Huber, *Int. J. Thermophys.* **42**, 74 (2021). <https://doi.org/10.1007/s10765-021-02818-9>
9. M.L. Huber, R.A. Perkins, A. Laesecke, D.G. Friend, J.V. Sengers, M.J. Assael, I.N. Metaxa, E. Vogel, R. Mares, K. Miyagawa, *J. Phys. Chem. Ref. Data* **38**, 101 (2009). <https://doi.org/10.1063/1.3088050>
10. S.A. Monogenidou, M.J. Assael, M.L. Huber, *J. Phys. Chem. Ref. Data* **47**, 023102 (2018). <https://doi.org/10.1063/1.5036724>
11. M.J. Assael, S.A. Monogenidou, M.L. Huber, R.A. Perkins, J.V. Sengers, *J. Phys. Chem. Ref. Data* **50**, 033102 (2021). <https://doi.org/10.1063/5.0048711>
12. E.K. Michailidou, M.J. Assael, M.L. Huber, R.A. Perkins, *J. Phys. Chem. Ref. Data* **42**, 033104 (2013). <https://doi.org/10.1063/1.4818980>
13. E.K. Michailidou, M.J. Assael, M.L. Huber, I.M. Abdulagatov, R.A. Perkins, *J. Phys. Chem. Ref. Data* **43**, 023103 (2014). <https://doi.org/10.1063/1.4875930>
14. M.J. Assael, T.B. Papalas, M.L. Huber, *J. Phys. Chem. Ref. Data* **46**, 033103 (2017). <https://doi.org/10.1063/1.4996885>
15. S.A. Monogenidou, M.J. Assael, M.L. Huber, *J. Phys. Chem. Ref. Data* **47**, 013103 (2018). <https://doi.org/10.1063/1.5021459>
16. S. Avgeri, M.J. Assael, M.L. Huber, R.A. Perkins, *J. Phys. Chem. Ref. Data* **43**, 033103 (2014). <https://doi.org/10.1063/1.4892935>
17. S. Avgeri, M.J. Assael, M.L. Huber, R.A. Perkins, *J. Phys. Chem. Ref. Data* **44**, 033101 (2015). <https://doi.org/10.1063/1.4926955>
18. K. Tasidou, M.L. Huber, M.J. Assael, *J. Phys. Chem. Ref. Data* **48**, 043101 (2019). <https://doi.org/10.1063/1.5128321>
19. S. Sotiriadou, E. Ntonti, D. Velliadou, M.J. Assael, M.L. Huber, *Int. J. Thermophys.* **44**, 108 (2023). <https://doi.org/10.1007/s10765-023-03217-y>
20. E.A. Sykioti, M.J. Assael, M.L. Huber, R.A. Perkins, *J. Phys. Chem. Ref. Data* **42**, 043101 (2013). <https://doi.org/10.1063/1.4829449>
21. S. Sotiriadou, E. Ntonti, D. Velliadou, K.D. Antoniadis, M.J. Assael, M.L. Huber, *Int. J. Thermophys.* **40**, 44 (2023) [Erratum: *Int. J. Thermophys.* **44**, 46 (2023)]. <https://doi.org/10.1007/s10765-022-03149-z>
22. M. Mebellis, D. Velliadou, M.J. Assael, M.L. Huber, *Int. J. Thermophys.* **42**, 116 (2021). <https://doi.org/10.1007/s10765-021-02867-0>
23. D. Velliadou, K.D. Antoniadis, M.J. Assael, M.L. Huber, *Int. J. Thermophys.* **43**, 42 (2022). <https://doi.org/10.1007/s10765-021-02970-2>
24. M.L. Huber, M.J. Assael, *Int. J. Refrig.* **71**, 39 (2016). <https://doi.org/10.1016/j.ijrefrig.2016.08.007>
25. D. Velliadou, M.J. Assael, M.L. Huber, *Int. J. Thermophys.* **43**, 105 (2022). <https://doi.org/10.1007/s10765-022-03029-6>
26. C.M. Tsolakidou, M.J. Assael, M.L. Huber, R.A. Perkins, *J. Phys. Chem. Ref. Data* **46**, 023103 (2017). <https://doi.org/10.1063/1.4983027>
27. R.A. Perkins, M.L. Huber, M.J. Assael, *J. Chem. Eng. Data* **61**, 3286 (2016). <https://doi.org/10.1021/acs.jced.6b00350>
28. D. Velliadou, K.D. Antoniadis, M.J. Assael, M.L. Huber, *Int. J. Thermophys.* **43**, 129 (2022). <https://doi.org/10.1007/s10765-022-03050-9>
29. D. Velliadou, K.D. Antoniadis, M.J. Assael, M.L. Huber, *Int. J. Thermophys.* **42**, 51 (2021). <https://doi.org/10.1007/s10765-021-02803-2>

30. M.J. Assael, J.A.M. Assael, M.L. Huber, R.A. Perkins, Y. Takata, J. Phys. Chem. Ref. Data **40**, 033101 (2011). <https://doi.org/10.1063/1.3606499>
31. M.L. Huber, R.A. Perkins, D.G. Friend, J.V. Sengers, M.J. Assael, I.N. Metaxa, K. Miyagawa, R. Hellmann, E. Vogel, J. Phys. Chem. Ref. Data **41**, 033102 (2012). <https://doi.org/10.1063/1.4738955>
32. M.L. Huber, R.A. Perkins, M.J. Assael, S.A. Monogenidou, R. Hellmann, J.V. Sengers, J. Phys. Chem. Ref. Data **51**, 013102 (2022). <https://doi.org/10.1063/5.0084222>
33. M.L. Huber, E.A. Sykioti, M.J. Assael, R.A. Perkins, J. Phys. Chem. Ref. Data **45**, 013102 (2016). <https://doi.org/10.1063/1.4940892>
34. S.A. Monogenidou, M.J. Assael, M.L. Huber, J. Phys. Chem. Ref. Data **47**, 043101 (2018). <https://doi.org/10.1063/1.5053087>
35. M.J. Assael, I.A. Koini, K.D. Antoniadis, M.L. Huber, I.M. Abdulgatov, R.A. Perkins, J. Phys. Chem. Ref. Data **41**, 023104 (2012) [Erratum: J. Phys. Chem. Ref. Data **43**, 039901 (2014)]. <https://doi.org/10.1063/1.4708620>
36. C.-M. Vassiliou, M.J. Assael, M.L. Huber, R.A. Perkins, J. Phys. Chem. Ref. Data **44**, 033102 (2015). <https://doi.org/10.1063/1.4927095>
37. M.J. Assael, S.K. Mylona, C.A. Tsiglifi, M.L. Huber, R.A. Perkins, J. Phys. Chem. Ref. Data **42**, 013106 (2013). <https://doi.org/10.1063/1.4793335>
38. M.J. Assael, I. Bogdanou, S.K. Mylona, M.L. Huber, R.A. Perkins, V. Vesovic, J. Phys. Chem. Ref. Data **42**, 023101 (2013). <https://doi.org/10.1063/1.4794091>
39. M.J. Assael, A. Koutian, M.L. Huber, R.A. Perkins, J. Phys. Chem. Ref. Data **45**, 033104 (2016). <https://doi.org/10.1063/1.4958984>
40. M.J. Assael, E.K. Michailidou, M.L. Huber, R.A. Perkins, J. Phys. Chem. Ref. Data **41**, 043102 (2012). <https://doi.org/10.1063/1.4755781>
41. S.K. Mylona, K.D. Antoniadis, M.J. Assael, M.L. Huber, R.A. Perkins, J. Phys. Chem. Ref. Data **43**, 0431041 (2014). <https://doi.org/10.1063/1.4901166>
42. A. Koutian, M.J. Assael, M.L. Huber, R.A. Perkins, J. Phys. Chem. Ref. Data **46**, 013102 (2016). <https://doi.org/10.1063/1.4974325>
43. S.G. Sotiriadou, E. Ntonti, M.J. Assael, M.L. Huber, Int. J. Thermophys. **45**, 87 (2024). <https://doi.org/10.1007/s10765-024-03378-4>
44. M.J. Assael, E.A. Sykioti, M.L. Huber, R.A. Perkins, J. Phys. Chem. Ref. Data **42**, 023102 (2013). <https://doi.org/10.1063/1.4797368>
45. M. Mebellis, D. Velliadou, M.J. Assael, K.D. Antoniadis, M.L. Huber, Int. J. Thermophys. **42**, 151 (2021). <https://doi.org/10.1007/s10765-021-02904-y>
46. R.A. Perkins, M.L. Huber, M.J. Assael, J. Chem. Eng. Data **62**, 2659 (2017). <https://doi.org/10.1021/acs.jced.7b00106>
47. R.A. Perkins, M.L. Huber, M.J. Assael, Int. J. Thermophys. **43**, 12 (2021). <https://doi.org/10.1007/s10765-021-02941-7>
48. E.W. Lemmon, R. Span, J. Chem. Eng. Data **51**, 785 (2006). <https://doi.org/10.1021/je050186n>
49. M.J. Assael, A.E. Kalyva, S.A. Monogenidou, M.L. Huber, R.A. Perkins, D.G. Friend, E.F. May, J. Phys. Chem. Ref. Data **47**, 021501 (2018). <https://doi.org/10.1063/1.5036625>
50. D.G. Friend, J.C. Rainwater, Chem. Phys. Lett. **107**, 590 (1984). [https://doi.org/10.1016/S0009-2614\(84\)85163-5](https://doi.org/10.1016/S0009-2614(84)85163-5)
51. J.C. Rainwater, D.G. Friend, Phys. Rev. A **36**, 4062 (1987). <https://doi.org/10.1103/physreva.36.4062>
52. E. Bich, E. Vogel, in *Transport Properties of Fluids. Their Correlation, Prediction and Estimation* (Cambridge University Press, Cambridge, 1996)
53. V. Vesovic, W.A. Wakeham, G.A. Olchow, J.V. Sengers, J.T.R. Watson, J. Millat, J. Phys. Chem. Ref. Data **19**, 763 (1990). <https://doi.org/10.1063/1.555875>
54. S. Hendl, J. Millat, E. Vogel, V. Vesovic, W.A. Wakeham, J. Luettmer-Strathmann, J.V. Sengers, M.J. Assael, Int. J. Thermophys. **15**, 1 (1994). <https://doi.org/10.1007/BF01439245>
55. M. Kerscher, L.M. Braun, J.H. Jander, M.H. Rausch, T.M. Koller, P. Wasserscheid, A.P. Fröba, Int. J. Thermophys. **45**(1), 8 (2023). <https://doi.org/10.1007/s10765-023-03294-z>
56. J. Han, M. Li, H. Wang, Y. Zhang, J. Tian, X. Yang, J. Chem. Thermodyn. **176**, 106923 (2023). <https://doi.org/10.1016/j.jct.2022.106923>
57. M.D. Mohammadi, M. Hamzehloo, Fluid Phase Equilib. **483**, 14 (2019). <https://doi.org/10.1016/j.fluid.2018.10.024>

58. M. Gowrisankar, P. Venkateswarlu, K. Siva Kumar, S. Sivarambabu, J. Ind. Eng. Chem. (Amsterdam, Neth.) **20**, 405 (2014). <https://doi.org/10.1016/j.jiec.2013.04.035>
59. J.Y. Wu, Y.P. Chen, C.S. Su, J. Taiwan Inst. Chem. Eng. **45**, 2205 (2014). <https://doi.org/10.1016/j.jtice.2014.04.012>
60. L. Yang, T.L. Luo, H.L. Lian, G.J. Liu, J. Chem. Eng. Data **55**, 1364 (2010). <https://doi.org/10.1021/je900535d>
61. K. Rajagopal, S. Chenthilnath, J. Chem. Thermodyn. **42**, 675 (2010). <https://doi.org/10.1016/j.jct.2009.12.008>
62. Y. Ren, S. Xia, P. Ma, Shiyou Huagong **36**, 267 (2007)
63. H.-W. Chen, C.-H. Tu, J. Chem. Eng. Data **50**, 1262 (2005). <https://doi.org/10.1021/je050010l>
64. B. Gonzalez, A. Dominguez, J. Tojo, J. Chem. Eng. Data **50**, 1462 (2005). <https://doi.org/10.1021/je050110r>
65. I.H. Peng, C.H. Tu, J. Chem. Eng. Data **47**, 1457 (2002). <https://doi.org/10.1021/je020077y>
66. C.M. Kinart, W.J. Kinart, A. Cwiklinska, J. Chem. Eng. Data **47**, 76 (2002). <https://doi.org/10.1021/je010213j>
67. L.Q. Sun, M.S. Zhu, L.Z. Han, Z.-Z. Lin, J. Chem. Eng. Data **41**, 292 (1996). <https://doi.org/10.1021/je9502096>
68. S. Prakash, S. Srivastava, R. Singh, Acustica **71**, 236 (1990)
69. H. Bauer, G. Meerlender, Rheol. Acta **23**, 514 (1984). <https://doi.org/10.1007/BF01329284>
70. V.A. Atoyan, I.A. Mamedov, Zh. Fiz. Khim. **50**, 2976 (1976)
71. M. Hafez, S. Hartland, J. Chem. Eng. Data **21**, 179 (1976). <https://doi.org/10.1021/je60069a011>
72. A.A. Terent'eva, B.S. Krumgal'z, Y.I. Gerzhberg, Zh. Prikl. Khim. **46**, 1143 (1973)
73. B.I. Konobeev, V.V. Lyapin, Zh. Prikl. Khim. **43**, 803 (1970)
74. I.F. Golubev, *Viscosity of Gases and Gas Mixtures. A Handbook*, 1959, Transl. by R. Kondor, Ed. D. Slutzkin (Keter Press, Jerusalem, 1970)
75. I.F. Golubev, V.A. Petrov, Trudy Gosud. Nauch-Issl. Proekt. Inst. Azot. Prom. **2**, 5 (1953)
76. K.S. Howard, F.P. Pike, J. Chem. Eng. Data **4**, 331 (1959). <https://doi.org/10.1021/je60004a013>
77. T.D. Ling, M. Van Winkle, Ind. Eng. Chem. Chem. Eng. Data Ser. **3**, 88 (1958). <https://doi.org/10.1021/i460003a018>
78. I.F. Golubev, V.A. Petrov, Trudy Gosud. Nauch-Issl. Proekt. Inst. Azot. Prom. **1**, 7 (1953)
79. P.M. Craven, J.D. Lambert, Proc. R. Soc. A (Lond.) **205**, 439 (1951). <https://doi.org/10.1098/rspa.1951.0039>
80. J.R. Lacher, C.H. Walden, J.D. Park, J. Am. Chem. Soc. **71**, 3026 (1949). <https://doi.org/10.1021/ja01177a024>
81. T. Titani, Bull. Chem. Soc. Jpn. **8**, 255 (1933)
82. S. Mitsukuri, T. Tonomura, Chem. Inst. **3**, 155 (1927)
83. J.L. Trenzado, A. Gutierrez, R. Alcalde, M. Atilhan, S. Aparicio, J. Mol. Liq. **294**, 111632 (2019). <https://doi.org/10.1016/j.molliq.2019.111632>
84. A. Duereh, Y. Sato, J.R.L. Smith, H. Inomata, F. Pichierri, J. Phys. Chem. B **121**, 6033 (2017). <https://doi.org/10.1021/acs.jpcc.7b03446>
85. A.G. Gotmare, A.S. Burghate, S.A. Wadhwal, Phys. Chem. Indian J. **12**, 1 (2017)
86. X. Zhu, H. Zhang, Y. Xu, J. Mol. Liq. **213**, 139 (2016). <https://doi.org/10.1016/j.molliq.2015.11.008>
87. E.M. Zivkovic, M.L. Kijevcanin, I.R. Radovic, S.P. Serbanovic, Chem. Ind. Chem. Eng. Q. **20**, 441 (2014). <https://doi.org/10.2298/CICEQ130305026Z>
88. Y. Tian, X. Wang, J. Wang, J. Chem. Eng. Data **53**, 2056 (2008). <https://doi.org/10.1021/je8001128>
89. R. Sih, M. Armenti, R. Mammucari, F. Dehghani, N.R. Foster, J. Supercrit. Fluids **43**, 460 (2008). <https://doi.org/10.1016/j.supflu.2007.08.001>
90. K. Liu, E. Kiran, Ind. Eng. Chem. Res. **46**, 5453 (2007). <https://doi.org/10.1021/ie070274w>
91. J. Wang, A. Zhu, K. Zhuo, J. Solution Chem. **34**, 585 (2005). <https://doi.org/10.1007/s10953-005-5594-7>
92. P. Jain, M. Singh, J. Chem. Eng. Data **49**, 1214 (2004). <https://doi.org/10.1021/je034204h>
93. D. Agarwal, M. Singh, J. Chem. Eng. Data **49**, 1218 (2004). <https://doi.org/10.1021/je034203p>
94. S. Govindarajan, V. Kannappan, M.D. Naresh, K. Venkataboopathy, B. Lokanadam, J. Mol. Liq. **107**, 289 (2003). [https://doi.org/10.1016/S0167-7322\(03\)00156-9](https://doi.org/10.1016/S0167-7322(03)00156-9)
95. N.G. Tsierkezos, I.E. Molinou, J. Chem. Eng. Data **44**, 955 (1999). <https://doi.org/10.1021/je990059p>

96. L.D. Lorenzi, M. Fermeiglia, G. Torriano, *J. Chem. Eng. Data* **40**, 1172 (1995). <https://doi.org/10.1021/JE00022A003>
97. P.J. Petrino, Y.H. Gaston-Bonhomme, J.-L. Chevalier, *J. Chem. Eng. Data* **40**, 136 (1995). <https://doi.org/10.1021/je00017a031>
98. H. Liu, Z. Luo, *Huaxue Gongcheng* **20**, 65 (1992)
99. V.I. Skomorokhov, A.F. Dregalin, *Russ. J. Phys. Chem. A* **11**, 1569 (1992)
100. A.K. Das, B.L. Jha, *J. Mol. Liq.* **50**, 155 (1991). [https://doi.org/10.1016/0167-7322\(91\)80043-4](https://doi.org/10.1016/0167-7322(91)80043-4)
101. J. Zhang, H. Liu, *Huagong Xuebao* **42**, 269 (1991)
102. A. Schumpe, P. Luehring, *J. Chem. Eng. Data* **35**, 24 (1990). <https://doi.org/10.1021/je00059a007>
103. N. Mamagakis, C. Panayiotou, *Z. Phys. Chem. (Munich)* **162**, 57 (1989)
104. I.C. Wei, R.L. Rowley, *J. Chem. Eng. Data* **29**, 336 (1984). <https://doi.org/10.1021/je00037a033>
105. K. Noda, M. Ohashi, K. Ishida, *J. Chem. Eng. Data* **27**, 326 (1982). <https://doi.org/10.1021/je00029a028>
106. R.R. Yadava, S.S. Yadava, *Indian J. Chem. Sect. A Inorg. Phys. Theor. Anal.* **20**, 221 (1981)
107. B.S. Chandak, G.D. Nageshwar, P.S. Mene, *J. Chem. Eng. Data* **24**, 267 (1979). <https://doi.org/10.1021/je60083a026>
108. F.V. Kerchove, M. De Vijlder, *J. Chem. Eng. Data* **22**, 333 (1977). <https://doi.org/10.1021/JE60074A005>
109. R.H. Campbell, E.M. Kartzmark, *J. Chem. Thermodyn.* **5**, 163 (1973). [https://doi.org/10.1016/S0021-9614\(73\)80076-X](https://doi.org/10.1016/S0021-9614(73)80076-X)
110. F. Mato, J. Coca, *An. Quim.* **68**, 1043 (1972)
111. V.F. Yakovlev, *Russ. J. Phys. Chem.* **41**, 1619 (1967)
112. R. Kalidas, G.S. Laddha, *J. Chem. Eng. Data* **9**, 142 (1964). <https://doi.org/10.1021/je60020a048>
113. M.G. Blank, *Ukr. Khm. Zh.* **29**, 1009 (1963)
114. O. Vilim, A. Rezabek, *Chem. Prum.* **10**, 533 (1960)
115. A.P. Toropov, *J. Gen. Chem. USSR* **26**, 1453 (1956)
116. V.V. Udovenko, H. Chomenko, *Zh. Obshch. Khim.* **26**, 3639 (1956)
117. P. Chang, C.R. Wilke, *J. Phys. Chem.* **59**, 592 (1955). <https://doi.org/10.1021/j150529a005>
118. A.E. Karr, W.M. Bowes, E.G. Scheibel, *Anal. Chem.* **23**, 459 (1951). <https://doi.org/10.1021/ac60051a019>
119. M.B. Reynolds, C.A. Kraus, *J. Am. Chem. Soc.* **70**, 1709 (1948). <https://doi.org/10.1021/ja01185a012>
120. R.E. Treybal, L.D. Weber, J.F. Daley, *Ind. Eng. Chem.* **38**, 817 (1946). <https://doi.org/10.1021/IE50440A021>
121. H. Staudinger, H. Joerder, *J. Prakt. Chem.* **160**, 166 (1942)
122. O.L. Hughes, H. Hartley, *Philos. Mag.* **15**, 610 (1933). <https://doi.org/10.1080/14786443309462210>
123. E.C. Bingham, D.F. Brown, *J. Rheol.* **3**, 95 (1932). <https://doi.org/10.1122/1.2116447>
124. V.C.G. Trew, *Trans. Faraday Soc.* **28**, 509 (1932). <https://doi.org/10.1039/TF9322800509>
125. P.W. Bridgman, *Proc. Am. Acad. Arts Sci.* **61**, 57 (1926). <https://doi.org/10.2307/20026138>
126. J.W. McBain, C.E. Harvey, L.E. Smith, *J. Phys. Chem.* **30**, 312 (1926). <https://doi.org/10.1021/j150261a004>
127. J.R. Lewis, *J. Am. Chem. Soc.* **47**, 626 (1925). <https://doi.org/10.1021/ja01680a007>
128. G. Weissenberger, L. Piatti, *Monatsh. Chem.* **45**, 187 (1925)
129. N.A. Yajnik, M.D. Bhalla, R.C. Talwar, M.A. Soofi, *Z. Phys. Chem. Stoechiom. Verwandtschaftsl.* **118**, 305 (1925)
130. G. Weissenberger, F. Schuster, *Monatsh. Chem.* **45**, 413 (1924)
131. J. Kendall, E. Brakeley, *J. Am. Chem. Soc.* **43**, 1826 (1921). <https://doi.org/10.1021/ja01441a009>
132. A. Bramley, *J. Chem. Soc. Trans.* **109**, 10 (1916). <https://doi.org/10.1039/CT9160900010>
133. F. Baker, *J. Chem. Soc.* **103**, 1653 (1913). <https://doi.org/10.1039/CT9130301653>
134. O. Faust, *Z. Phys. Chem. Stoechiom. Verwandtschaftsl.* **79**, 97 (1912)
135. K. Rappenecker, *Z. Phys. Chem. Stoechiom. Verwandtschaftsl.* **72**, 695 (1910)
136. F.H. Getman, *J. Am. Chem. Soc.* **30**, 1077 (1908). <https://doi.org/10.1021/ja01949a004>
137. P. Walden, *Z. Phys.* **55**, 207 (1906). <https://doi.org/10.1515/zpch-1906-5511>
138. A.E. Dunstan, *J. Chem. Soc.* **85**, 817 (1904). <https://doi.org/10.1039/CT9048500817>
139. S.G. Sotiriadou, E. Ntonti, M.J. Assael, K.D. Antoniadis, M.L. Huber, *Int. J. Thermophys.* **45**, 123 (2024). <https://doi.org/10.1007/s10765-024-03415-2>

140. E Vogel, C. Küchenmeister, E Bich, A. Laesecke, J. Phys. Chem. Ref. Data **27**, 947 (1998). <https://doi.org/10.1063/1.556025>
141. M.E. Wieser, M. Berglund, Pure Appl. Chem. **81**(11), 2131 (2009). <https://doi.org/10.1351/PAC-REP-09-08-03>
142. P.D. Neufeld, A.R. Janzen, R.A. Aziz, J. Chem. Phys. **57**, 1100 (1972). <https://doi.org/10.1063/1.1678363>
143. FindGraph, v2.611, UNIPHIZ Lab, 2002–2015, Certain equipment, instruments, software, or materials are identified in this paper in order to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement of any product or service by NIST, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose
144. E. Vogel, E. Bich, R. Nimz, Physica A **139**, 188 (1986). [https://doi.org/10.1016/0378-4371\(86\)90012-9](https://doi.org/10.1016/0378-4371(86)90012-9)
145. EUREQA Formulize v.098.1 (Nutron Inc., Cambridge)
146. M.J. Assael, J.H. Dymond, M. Papadaki, P.M. Patterson, Int. J. Thermophys. **13**, 269 (1992). <https://doi.org/10.1007/BF00504436>
147. J.R.E. Smith, C.N. Hinshelwood, Proc. R. Soc. A (London) **183**(992), 33 (1944). <https://doi.org/10.1098/rspa.1944.0019>
148. J.G. Davoud, C.N. Hinshelwood, Nature **144**, 909 (1939). <https://doi.org/10.1038/144909a0>
149. A.O. Allen, J. Am. Chem. Soc. **58**(6), 865 (1936). <https://doi.org/10.1021/ja01297a501>
150. L. Riedel, Chem.-Ing.-Tech. **23**, 321 (1951)
151. J.D. Lambert, E.N. Staines, S.D. Woods, Proc. R. Soc. Lond. A **200**, 262 (1950). <https://doi.org/10.1098/rspa.1950.0016>
152. P.W. Bridgman, Proc. Am. Acad. Arts Sci. **59**, 141 (1923). <https://doi.org/10.2307/20026073>
153. K. Madzhidov, J. Eng. Phys. **47**, 933 (1984). <https://doi.org/10.1007/BF00869697>
154. K.I. Amirkhanov, A.P. Adamov, Teploenergetika **10**, 77 (1963)
155. D.L. Hildenbrand, J.A. Happe, J. Phys. Chem. **61**, 1415 (1957). <https://doi.org/10.1021/j150556a035>
156. A.K. Abas-Zade, Dokl. Akad. Nauk SSSR **99**, 227 (1954)
157. S. Baxter, H.A. Vodden, S. Davies, J. Appl. Chem. (Lond.) **3**, 477 (1953)
158. E.F.M. van der Held, F.G. van Drunen, Physica **15**, 865 (1949). [https://doi.org/10.1016/0031-8914\(49\)90129-9](https://doi.org/10.1016/0031-8914(49)90129-9)
159. M. Fujii, X. Zhang, N. Imaishi, S. Fujiwara, T. Sakamoto, Int. J. Thermophys. **18**, 327 (1997). <https://doi.org/10.1007/BF02575164>
160. L. Qun-Fang, L. Ruisen, N. Dan-Yan, H. Yu-Chun, J. Chem. Eng. Data **42**, 971 (1997). <https://doi.org/10.1021/je960351m>
161. D.J. Frurip, L.A. Curtiss, M. Blander, J. Phys. Chem. **82**, 2555 (1978). <https://doi.org/10.1021/j100513a004>
162. K. Madzhidov, M. Khalilov, Russ. J. Phys. Chem. **52**, 310 (1978)
163. S. Takizawa, H. Murata, A. Nagashima, Bull. JSME **21**, 273 (1978)
164. G.M. Mallan, M.S. Michaelian, F.J. Lockhart, J. Chem. Eng. Data **17**, 412 (1972). <https://doi.org/10.1021/je60055a028>
165. L.P. Filippov, Int. J. Heat Mass Transf. **11**, 331 (1968). [https://doi.org/10.1016/0017-9310\(68\)90161-0](https://doi.org/10.1016/0017-9310(68)90161-0)
166. A. Manna, A. Gupta, B.H. Srivastava, J. Phys. A: Gen. Phys. **2**, 272 (1968). <https://doi.org/10.1088/0305-4470/1/2/313>
167. G.K. Mukhamedzyanov, A.G. Usmanov, Tr. Kazan. Khim. Tekhnol. Inst. **37**, 52 (1968)
168. Y.L. Rastorguev, V.G. Nemzer, Teploenergetika **15**, 78 (1968)
169. R. Tufeu, B. LeNeindre, P. Bury, P. Johannin, Rev. Gen. Therm. **7**, 365 (1968)
170. Z.I. Geller, Y.L. Rastorguev, Y.A. Ganiev, Izv. Vyssh. Uchebn. Zaved. Neft Gaz **8**, 79 (1965)
171. W. Jobst, Int. J. Heat Mass Transf. **7**, 725 (1964). [https://doi.org/10.1016/0017-9310\(64\)90003-1](https://doi.org/10.1016/0017-9310(64)90003-1)
172. R.G. Vines, L.A. Bennett, J. Chem. Phys. **22**, 360 (1954). <https://doi.org/10.1063/1.1740075>
173. R.G. Vines, Aust. J. Chem. **6**, 1 (1953). <https://doi.org/10.1071/CH9530001>
174. L. Riedel, Chem.-Ing.-Tech. **23**, 465 (1951)
175. U. Gross, Y.W. Song, E. Hahne, Fluid Phase Equilib. **76**, 273 (1992). [https://doi.org/10.1016/0378-3812\(92\)85094-O](https://doi.org/10.1016/0378-3812(92)85094-O)
176. C. Baroncini, G. Latini, P. Pierpaoli, Int. J. Thermophys. **5**, 387 (1984). <https://doi.org/10.1007/BF00500868>

177. C. Wang, C. Guo, M. Yang, L. Ma, X. Lu, J. Chem. Ind. Eng. (China) **3**, 274 (1984)
178. W. Parkinson, Thermal Conductivity of Binary Liquid Mixtures, PhD thesis (University of Southern California, Los Angeles, 1974)
179. T.S. Akhundov, A.A. Glymanov, Izv. Vyssh. Uchebn. Zaved. Priborostr. **12**, 119 (1969)
180. D.T. Jamieson, E.H. Hastings, The thermal conductivity of binary liquid mixtures, in *Proc. 8th Thermal Cond. Conference*. ed. by C.Y. Ho, R.E. Taylor (Plenum, New York, 1969), pp.631–641
181. M.G. Perry, H.A.S. Jangda, The thermal conductivity of various organic liquid/water mixtures, in *Proc. of Symp. Phys. Prop. of Liq. and Gas* (NEL, East Kilbride, 1968)
182. D.T. Jamieson, J.S. Tudhope, J. Inst. Pet. **50**, 150 (1964)
183. W.J. Scheffy, E.F. Johnson, J. Chem. Eng. Data **6**, 245 (1961). <https://doi.org/10.1021/je60010a019>
184. F.G. El'Darov, Zh. Fiz. Chim. **34**, 1205 (1960)
185. V.P. Frontas'ev, M.Y. Gusakov, Zh. Tekh. Fiz. **29**, 1277 (1959)
186. H.L. Mason, Trans. Am. Soc. Mech. Eng. **76**, 817 (1954). <https://doi.org/10.1115/1.4014979>
187. N.B. Vargaftik, Izv. Vses. Teplotekhn. Inst. **18**, 6 (1949)
188. E. Hutchinson, Trans. Faraday Soc. **41**, 87 (1945). <https://doi.org/10.1039/TF9454100087>
189. L. Riedel, Forsch. Ing. Wes. **11**, 340 (1940)
190. A. Eucken, Phys. Z. **14**, 324 (1913)
191. E. Moser, About the thermal conductivity of gases and vapors at higher temperatures, Ph.D. Thesis (Friedrich-Wilhelms University, Berlin, 1913)
192. R. Goldschmidt, Phys. Z. **12**, 417 (1911)
193. R. Hellmann, E. Bich, E. Vogel, V. Vesovic, J. Chem. Eng. Data **57**, 1312 (2012). <https://doi.org/10.1021/je3000926>
194. F.R.W. McCourt, J.J.M. Beenakker, W.E. Köhler, I. Kučšer, *Nonequilibrium Phenomena in Polyatomic Gases* (Clarendon Press, Oxford, 1990)
195. B.J. Thijssse, G.W. Thooft, D.A. Coombe, H.F.P. Knaap, J.J.M. Beenakker, Physica A **98**, 307 (1979). [https://doi.org/10.1016/0378-4371\(79\)90181-x](https://doi.org/10.1016/0378-4371(79)90181-x)
196. J. Millat, V. Vesovic, W.A. Wakeham, Physica A **148**, 153 (1988). [https://doi.org/10.1016/0378-4371\(88\)90139-2](https://doi.org/10.1016/0378-4371(88)90139-2)
197. E. Tiesinga, P.J. Mohr, D.B. Newell, B.N. Taylor, J. Phys. Chem. Ref. Data **50**, 033105 (2021). <https://doi.org/10.1063/5.0064853>
198. S. Bock, E. Bich, E. Vogel, A.S. Dickinson, V. Vesovic, J. Chem. Phys. **120**, 7987 (2004). <https://doi.org/10.1063/1.1687312>
199. R. Hellmann, E. Bich, E. Vogel, A.S. Dickinson, V. Vesovic, J. Chem. Phys. **130**, 124309 (2009). <https://doi.org/10.1063/1.3098317>
200. R. Hellmann, E. Bich, E. Vogel, V. Vesovic, Phys. Chem. Chem. Phys. **13**, 13749 (2011). <https://doi.org/10.1039/C1CP20873J>
201. G.A. Olchowy, J.V. Sengers, Phys. Rev. Lett. **61**, 15 (1988). <https://doi.org/10.1103/PhysRevLett.61.15>
202. R. Mostert, H.R. van den Berg, P.S. van der Gulik, J.V. Sengers, J. Chem. Phys. **92**, 5454 (1990). <https://doi.org/10.1063/1.458523>
203. R.A. Perkins, H.M. Roder, D.G. Friend, C.A. Nieto de Castro, Physica A **173**, 332 (1991). [https://doi.org/10.1016/0378-4371\(91\)90368-M](https://doi.org/10.1016/0378-4371(91)90368-M)
204. P.T. Boggs, R.H. Byrd, J.E. Rogers, R.B. Schnabel, ODRPACK, *Software for Orthogonal Distance Regression*, NISTIR 4834, v2.013 (National Institute of Standards and Technology, Gaithersburg, 1992)
205. G.A. Olchowy, J.V. Sengers, Int. J. Thermophys. **10**, 417 (1989). <https://doi.org/10.1007/BF01133538>
206. R.A. Perkins, J.V. Sengers, I.M. Abdulagatov, M.L. Huber, Int. J. Thermophys. **34**, 191 (2013). <https://doi.org/10.1007/s10765-013-1409-z>