J. Chem. Eng. Data **1995,** *40,* 531–546

Reviews

Vapor–Liquid Critical Properties of Elements and Compounds. 2. Normal Alkanes

Douglas Ambrose

University College London, 20 Gordon Street, London WC1H 0AJ, England

Constantine Tsonopoulos*

Exxon Research and Engineering Company, P.O. Box 101, Florham Park, New Jersey 07932

This is part 2 of a series of contributions by the critical properties group of the IUPAC Commission I.2 on Thermodynamics, Subcommittee on Thermodynamic Data. It presents all known experimental data for the critical constants of normal alkanes, the most extensively investigated class of organic compounds. Data are presented up to C_{24}, and recommendations are given along with uncertainties. Such uncertainties are relatively small for the first 10 normal alkanes, which are stable at the critical point, but are larger for the progressively more unstable C_{11}–C_{24} compounds. The critical temperatures have been converted to ITS-90.

Part 1 of this series is an introductory survey of the vapor–liquid critical point [95-amb/you]. Part 2 reviews the experimental data for normal alkanes, which were chosen for study first because of their importance in providing the framework on which depend many correlations of critical and other properties. These correlations are used for estimating properties that have not been measured (often because the compound is unstable at the critical point). Values are given for compounds up to tetracosane. Octadecane is probably the limiting compound for which critical properties are measurable by what may be called conventional techniques, but Nikitin et al. [93-nik/pav, 94-nik/pav] have introduced a method in which the substance under study is exposed to elevated temperatures only for a few milliseconds, and this has allowed them to obtain values for alkanes up to tetracosane. Table 1 contains the recommended values, and Table 2 contains the observed values, including for completeness those already collected in the reviews by Kobe and Lynn [53-kob/lyn] and by Kudchadker, Alani, and Zwolinski [68-kud/ala]. Those reviews contain more detailed discussions than are given here of some investigations completed before 1968. Critical properties are expressed in Tables 1 and 2 in K, MPa, and $g{\cdot}cm^{-3}$, but Table 2 also includes values in the original units (except where those units differ from the chosen SI units only by a power of 10) in order to simplify reconciliation of the present review with the source literature.

Temperatures

Temperatures are expressed as International Kelvin temperatures on ITS-90, and, as a general rule, the accuracy of each temperature is indicated by the number of figures given. Those values originally expressed as Celsius temperatures have been converted to Kelvin temperatures by addition of 273.15 K. Where the final figure of Celsius temperatures that are specified only to 0.1 K is 0.05, the figure has been omitted, and the temperatures have been rounded to an even single decimal.

Where necessary, temperatures have been adjusted by addition of the difference between the scale used for the measurement and ITS-90. Between 190.5 and 618 K, the approximate critical temperatures of methane and decane, the differences between ITS-90 and both IPTS-48 (identical in the range of present interest with ITS-27) and IPTS-68 are less than 0.05 K. No change, therefore, has been required for any temperature specified only to 0.1 K. No critical temperatures published before 1927 were of sufficient accuracy to require adjustment. In work published after 1927 in which temperatures are specified to 0.01 K, the scale used is that appropriate to the date of publication; the question of which scale was used only arises in the years immediately following adoption of the scale of 1968, when there were significant changes, but not all researchers had recalibrated thermometers.

The compounds above decane, which have critical temperatures greater than 620 K, are unstable at their critical temperatures, and the reported values are subject to larger errors than the differences arising from changes in the scale.

Selection of Best Values

For methane to butane the values recommended are those resulting from thermodynamic studies. The values of critical properties arising from such studies may be specified with more digits than would be warranted if the critical properties were being considered in isolation. The precision is required because the values of the critical properties are parameters in equations correlating the properties of the substance away from the critical point, and all of the figures given are, presumably, needed for correct evaluation of the equations. Where this occurs, the number of digits in the recommended values here has been limited without reference to the use of the values as parameters in the thermodynamic equations, for which the original publications should be consulted.

In choosing the recommended values for pentane and the higher members of the series, we have taken a middle value

0021-9568/95/1740-0531$09.00/0

Table 1. Recommended Values of Critical Properties of *n*-Alkanes

	molar mass M/g·mol^{-1}	T_c/K^a	(±)	p_c/MPa	(±)	ϱ_c/g·cm^{-3}	(±)	V_c/cm^3·mol^{-1}	Z_c^b
methane	16.043	190.564	(0.015)	4.599	(0.003)	0.1627	(0.0005)	98.60	0.286
ethane	30.070	305.32	(0.04)	4.872	(0.01)	0.2066	(0.003)	145.5	0.279
propane	44.097	369.83	(0.1)	4.248	(0.01)	0.220	(0.003)	200	0.277
butane	58.123	425.12	(0.1)	3.796	(0.01)	0.228	(0.003)	255	0.274
pentane	72.150	469.7	(0.2)	3.370	(0.02)	0.232	(0.003)	311	0.268
hexane	86.177	507.6	(0.2)	3.025	(0.02)	0.234	(0.003)	368	0.264
heptane	100.204	540.2	(0.3)	2.74	(0.03)	0.234	(0.003)	428	0.261
octane	114.231	568.7	(0.3)	2.49	(0.03)	0.232	(0.003)	492	0.259
nonane	128.258	594.6	(0.6)	2.29	(0.05)	0.231	(0.005)	555	0.257
decane	142.285	617.7	(0.6)	2.11	(0.05)	0.228	(0.005)	624	0.256
undecane	156.312	639	(1)	1.98	(0.1)	0.227	(0.01)	689	0.257
dodecane	170.338	658	(1)	1.82	(0.1)	0.226	(0.01)	754	0.251
tridecane	184.365	675	(1)	1.68	(0.1)	0.224	(0.01)	823	0.246
tetradecane	198.392	693	(2)	1.57	(0.2)	0.222	(0.02)	894	0.244
pentadecane	212.419	708	(2)	1.48	(0.2)	0.220	(0.02)	966	0.243
hexadecane	226.446	723	(2)	1.40	(0.2)	0.219	(0.02)	1034	0.241
heptadecane	240.473	736	(2)	1.34	(0.2)	0.218	(0.02)	1103	0.242
octadecane	254.500	747	(3)	1.29	(0.2)	0.214	(0.03)	1189	0.247
nonadecane	268.527	755	(8)	1.16	(0.2)				
eicosane	282.553	768	(8)	1.07	(0.2)				
heneicosane	296.580	778	(8)	1.03	(0.2)				
docosane	310.607	786	(8)	0.98	(0.2)				
tricosane	324.634	790	(8)	0.92	(0.2)				
tetracosane	338.661	800	(8)	0.87	(0.2)				

[a] Temperatures are expressed on ITS-90, but it should be noted that only for methane is the estimated uncertainty less than the difference between ITS-90 and earlier scales. [b] $Z_c = p_c V_c / RT_c$, where R = 8.31451 Pa·m^3·mol^{-1}·K^{-1}.

from those given by what appear to be the most reliable investigators (taking into account the general record of the laboratory concerned). Although the most recent work is not necessarily the most accurate, there have been such advances in instrumentation and control equipment since 1960 that, if it can be assumed that equal care has been taken in two investigations, post-1960 should be more accurate than pre-1960. At least two measurements fall within the uncertainties stated for all properties of all the compounds considered here, except for the critical densities of undecane upward and the critical temperatures and pressures of compounds higher than octadecane. In these instances, the recommended values are those from a single investigation.

Uncertainties. Uncertainties given in this paper have not been obtained by statistical analysis; those in Table 2 are generally those given by authors or have been inferred from related work, and those in Table 1 have been allocated by consideration of the ranges of values given by those investigators assessed as the most reliable. Uncertainties in Table 1 have also been allocated for each compound in the light of its position in the series; that is, it is assumed that the uncertainties for the higher members will be greater than those for the lower ones, because the lower members have been the subject of more thorough investigations, because the simpler compounds are generally available in greater purity than the higher members, and because the higher members are unstable at their critical points (in the time required by conventional measurement techniques).

Methane. The investigations listed in Table 2 up to and including that by Jones and Rowlinson [63-jon/row] were reviewed by Kobe and Lynn [53-kob/lyn] and Kudchadker et al. [68-kud/ala]. The work prior to 1968 has been superseded by the subsequent investigations listed in Table 2, which have been carried out with samples of determined purity and with modern refined instrumentation. They have yielded results in close agreement with one another.

Kleinrahm and Wagner [86-kle/wag] measured the orthobaric densities of methane from the triple point, T_{68} = 90.685 K, to 0.02 K below the critical temperature by a buoyancy method in a newly designed apparatus that appears to be capable of yielding results of very high accuracy. The measurements were made at 5 K intervals, reducing to 0.03 K in the critical region, and vapor pressures were measured at the same time. Great care was taken in the measurements and, for example, away from the critical region, 3 h was allowed for the system to reach equilibrium after each change in conditions, while in the critical region 24 h was allowed. The critical temperature and critical density were then determined from the density measurements in the range T_{68} = 186 K to T_{68} = 190.53 K by fitting to the values for the liquid and vapor the equation

$$(\varrho/\varrho_c) - 1 = N_1(1 - T/T_c) \pm N_2(1 - T/T_c)^\beta$$

where ϱ is the density, T is the temperature, the subscript c refers to the critical state, and the coefficients N_1 and N_2 and exponent β were obtained by a nonlinear least-squares method. The final value of the critical density was determined from the rectilinear diameter. Complementary measurements of density in the critical region were made by Kleinrahm, Duschek, and Wagner [86-kle/dus].

The critical pressure was obtained from the following optimized equation fitted to the vapor pressure measurements:

$$\ln(p/p_c) = (n_1\tau + n_2\tau^{1.5} + n_3\tau^2 + n_4\tau^{4.5})/T_r$$

Here $\tau = (1 - T_r)$ and $T_r = T/T_c$.

A considerable part of the paper by Kleinrahm and Wagner is devoted to discussion of the discrepancies between their measurements of vapor pressure and density and those of earlier work that had appeared to be of high accuracy. As far as the subject of this review is concerned, however, there is no discrepancy as the results of the various investigations considered converge on the critical point; the critical density and critical pressure lie in the middle of the range of previously published values, and the critical temperature is only 0.004 K lower than the value selected by Angus et al. [78-ang/arm], who made their selection on the basis of a thorough study of the thermodynamic properties of methane from investigations published up to 1978. Similar studies have been made by Younglove and Ely [87-you/ely] before publication of the results by Kleinrahm and Wagner, and by Friend, Ely, and Ingham [89-fri/ely] subsequent to publication of the results by Kleinrahm and Wagner, which were generally heavily emphasized to define the phase boundary. Friend, Ely, and Ingham, who presented equations for the thermophysical properties of methane, reported that in the development of the equations they allowed the critical parameters to vary but did not find any alternative set of values that improved the quality of fit significantly. Similar comment was made by Kurumov, Olchowy, and Sengers [88-kur/olc], who developed a scaled equation of state for the critical region. Both sets of authors adopted the values by Kleinrahm and Wagner without change except that they assigned larger estimates of uncertainty to the values of critical pressure and critical density. More recently, Setzmann and Wagner [91-set/wag] have published another equation of state using the critical values given by Kleinrahm and Wagner. Those values are recommended here.

Ethane. Table 2 includes some entries in the period covered by 53-kob/lyn and 68-kud/ala that were omitted from those reviews. Since that period the most comprehensive and accurate study has been the $p-V-T$ study by Douslin and Harrison [73-dou/har], who used a Beattie-type apparatus. The sample was purified by GLC and had a stated purity of 99.999 mole %. Younglove and Ely [87-you/ely], and subsequently Friend, Ingham, and Ely [91-fri/ing], have presented tables of thermophysical properties for ethane derived from an equation of state for which they adopted the values of the critical properties by Douslin and Harrison. The values recommended here are based on those tabulated by Friend, Ingham, and Ely. Douslin and Harrison identified the critical point from analysis of the plots of isotherms, and there is very close agreement between their results and the values found by Brunner [88-bru], who identified the critical point visually. Brunner's earlier values [85-bru, 87-bru] are higher, but his temperature and pressure are in step, and it is possible that the differences arise from uncertainty in identification of the critical state. Sliwinski [69-sli] obtained his value of the critical temperature, which is also exactly that recommended, by simultaneous measurement of the dielectric constant of liquid and vapor phases. Tanneberger [59-tan] obtained a value of critical temperature very close to the recommended value by a study using ultrasound. Ethane, therefore, provides an example where closely similar values of critical temperature have been obtained by a wide variety of methods. With the uncertainties given, there is no serious disagreement with the majority of the determination made since 1970.

Propane. Thomas and Harrison [82-tho/har] made a $p-V-T$ study of propane in a Beattie-type apparatus. The sample was purchased with a reported purity of 99.993%; treatment by the authors to remove propene and nitrogen gave a sample of 99.998% purity as assessed by GLC. Younglove and Ely [87-you/ely] have presented tables of thermophysical properties derived from a 32-term BWR equation of state for several alkanes, and one may assume they used the values by Thomas and Harrison as starting values for their computations; they also appear to have taken account of the higher value found for the critical density by Beattie, Poffenberger, and Hadlock [35-bea/pof], an early work of high quality, and by Kreglewski and Kay [69-kre/kay]. Within the uncertainties given, there is good agreement between values obtained by visual and by $p-V-T$ methods, and the critical temperature found by Sliwinski [69-sli] from dielectric constant measurement is also close to the other values. The values recommended here, based on those tabulated by Younglove and Ely, lie in the middle of the range of results obtained since 1935.

Butane. Younglove and Ely [87-you/ely] have presented tables of thermophysical properties derived from a 32-term BWR equation of state for several alkanes. They appear to have adopted the values given by Beattie, Simard, and Su [39-bea/sim] for critical temperature and pressure as starting values for their computations, along with the somewhat higher values obtained by later investigators for the critical density. The values recommended here are based on those tabulated by Younglove and Ely; they are in very close agreement with the values for critical temperature and pressure obtained by Connolly [62-con], by Kratzke, Spillner, and Müller [82-kra/spi], and by Brunner [88-bru].

Pentane. Kratzke [85-kra] reviewed the work on the critical properties of pentane. The range of published critical temperatures exceeds the range of individually estimated uncertainties, and it is necessary to make a choice from those published. Kratzke adopted the value chosen by Kudchadker, Alani, and Zwolinski [68-kud/ala], and the critical pressure is that arising at the critical temperature from the equation fitted to the vapor pressures measured by Kratzke, Müller, Bohn, and Kohlen [85-kra/mul]. For critical density there is fair agreement between results obtained by the various investigators, except for that by Beattie, Levine, and Douslin [51-bea/lev]. Kratzke presented an argument, based on the principle of corresponding states and comparison with lower n-alkanes from ethane to butane, to favor a value close to those found by most other investigators, and this value was used as a parameter in the equation representing the liquid density measured in the range 237–439 K by Kratzke et al. A plot of the critical temperatures and pressures given by Kratzke, by Beattie, Levine, and Douslin [51-bea/lev], and by Wolfe, Kay, and Teja [83-wol/kay] is fitted approximately by a straight line. This could be coincidental (the values given by Rosenthal and Teja [89-ros/tej] also lie on the line, but their investigation was effectively a test of the apparatus for use with higher members of the series and was not claimed to be one of high accuracy), but it can also suggest that the differences between them may have arisen from differences in identification of the critical point. Kratzke's values are the lowest of this group of results and have been rounded up to give the values recommended. This takes some account of the higher value for the critical pressure found by Brunner [88-bru].

Hexane to Decane. With only a few exceptions, in the investigations reported on these compounds the critical point was identified visually, either in sealed tubes (when critical pressure was not reported) or in tubes connected to pressure-measuring equipment (when critical pressure was reported). Values of the critical volume were obtained from the rectilinear diameter of the coexistence curve. Some of the most recent investigations [86-smi/ans-1, 87-smi/tej, 89-ros/tej, 90-ans/gud] have been aimed primarily at the study of compounds of higher molecular weight in apparatus that could either be heated rapidly so as to minimize the effect of decomposition or, by adopting a flow principle, retain the unstable material at a high temperature for only a short time. In those cases, the measure-

Table 2. Critical Properties from the Literature

year	values reported in nonstandard units	T_{90}/K	p/MPa	ϱ/g·cm^{-3}	method[b]	authors
METHANE: molar mass[c] 16.043 g; CASRN 74-82-8						
$T_{68} - T_{48} = 0.032$ K; $T_{90} - T_{68} = 0.012$ K; $T_{90} - T_{48} = 0.044$ K at 190.5 K						
1882-sar	−75.7 °C, 46.8 atm	197.4	4.74	0.145	8	Sarrau
1884-dew	−99.5 °C, 50.0 atm	173.6	5.07		1	Dewar
1884-von	−73.5 °C, 56.8 atm	199.6	5.76		1, 5	Wroblewski
1885-ols, 1895-ols	−81.8 °C, 54.9 atm	191.4	5.56		1, 5	Olszewski
13-car, 15-car	−82.85 °C, 45.60 atm	190.3	4.620	0.1623	1a	Cardoso
22-key/tay	45.8 atm, 6.2 cm^3·g^{-1}	191.07	4.64	0.16	1, 7	Keyes, Taylor, and Smith
29-ben/and	45.7 atm	190.7	4.63	0.162	7	Bennewitz and Andreewa
52-blo/par	668.3 psi	190.59	4.608	0.1625	1a	Bloomer and Parent
61-hes/whi	45.41 atm		4.601		5	Hestermans and White
63-jon/row		190.3			1	Jones and Rowlinson
68-gri/ste	45.6 atm	190.6	4.62	0.1626	3, 7	Grigor and Steele
69-ric/sca		190.56		0.166	3	Ricci and Scafe
70-jan/gie	98.546 cm^3·mol^{-1}, 45.346 atm	190.542	4.5947	0.16280	3	Jansoone, Gielen, de Boelpap, and Verbeke
70-ven/lel	671.0 psi	190.78	4.626	0.1625	3	Vennix, Leland, and Kobayashi
72-pry/goo	45.356 atm	(190.54)	4.5957		5	Prydz and Goodwin
73-gie/jan	45.354 atm	190.567	4.5955	0.15959	8	Gielen, Jansoone, and Verbeke
74-goo		190.56	4.5988	0.1604	8	Goodwin
75-ols	10.16 mol·dm^{-3}			0.1630	2b	Olson
78-ang/arm	10.1095 mol·dm^{-3}	190.567	4.595	0.162187	8	Angus, Armstrong, and de Reuck
79-syc/vas		190.78	4.626	0.1635	8	Sychev et al.
86-kle/dus					3	Kleinrahm, Duschek, and Wagner
86-kle/wag	10.139 mol·dm^{-3}	190.563	4.5992	0.16266	3, 5	Kleinrahm and Wagner
87-you/ely	10.150 mol·dm^{-3}	190.54	4.59797	0.16284	8	Younglove and Ely
88-kur/olc		see text				Kurumov, Olchowy, and Sengers
89-fri/ely	10.139 mol·dm^{-3}	(190.563)	4.5992	0.16266	8	Friend, Ely, and Ingham
91-set/wag		190.564 ± 0.012	4.5992 ± 0.002	0.16266 ± 0.0002	8	Setzmann and Wagner
	recommended values	190.564 ± 0.015	4.599 ± 0.003	0.1627 ± 0.0005		

Sarrau [1882-sar] obtained values by application of an equation of state to *pVT* measurements by Amagat.

Kobe and Lynn [53-kob/lyn] credit E. Mathias, Le point critique des corps purs, Paris, 1904, with measuring the critical density of methane, but the reported value (0.145 g·cm^{-3}) was calculated from densities at lower temperatures.

Keyes, Taylor, and Smith [22-key/tay]: values from *Chem. Abstr.* **1923**, *17*, 668.

Kobe and Lynn [53-kob/lyn] quoted values from R. Wiebe and M. J. Brevoort, *J. Am. Chem. Soc.* **1930**, *52*, 622−33, and W. H. Corcoran, R. R. Bowles, B. H. Sage, and W. N. Lacey, *Ind. Eng. Chem.* **1945**, *37*, 825−8. Wiebe and Brevoort studied heat capacity and did not make measurements at the critical point, but adopted the values recommended in the review by Pickering [24-pic]. The paper by Corcoran et al. reported no experimental work but was a thermodynamic study that depended on the work by Wiebe and Brevoort and on measurements of vapor pressure by A. Eucken and N. Berger, *Z. gesamte Kaelte-Ind.* **1934**, *41*, 145−52, that did not extend as far as the critical point. Eucken and Berger adopted the high vapor pressure values and critical-point values reported by Cardoso [13-car].

Ricci and Scafe [69-ric/sca] measured dielectric constant.

Prydz and Goodwin [72-pry/goo] used the value of critical temperature (corrected to IPTS-68) given by Jansoone et al. [70-jan/gie] for their calculation of critical pressure from vapor pressure measurements.

Gielen, Jansoone, and Verbeke [73-gie/jan] fitted an equation of state and reported that there had been an error in calibration of the thermometer in 70-jan/gie. The difference between the values of critical temperatures (both on IPTS-48 scale) given in 70-jan/gie and 73-gie/jan is 0.025 K, but in 91-set/wag the difference is tabulated as 0.005 K. Primary density value is reported as 0.99475570 × 10^{-2} mol·cm^{-3}.

Olson [75-ols] measured refractive index.

year	values reported in nonstandard units	T_{90}/K	p/MPa	ϱ/g·cm^{-3}	method[b]	authors
ETHANE: molar mass[c] 30.070 g; CASRN 74-84-0						
$T_{68} - T_{48} = -0.010$ K; $T_{90} - T_{68} = -0.008$ K; $T_{90} - T_{48} = -0.018$ K at 305.3 K						
1884-dew	35 °C, 45.2 atm	308	4.58		1	Dewar
1889-ols, 1895-ols	34 °C, 50.2 atm	307	5.09		1, 5	Olszewski
1894-hai	34.5 °C, 50 atm	307.6	5.1		1, 5	Hainlen
1895-kue	32.05 °C, 48.8 atm	305.2	4.94		1a	Kuenen
1897-kue	32.2 °C, 48.64 atm	305.4	4.928		1a	Kuenen
1899-kue/rob	32.16 °C, 48.86 atm	305.31	4.951		1a	Kuenen and Robson
02-kue/rob	31.95 °C, 48.43 atm, 4.84 cm^3·g^{-1}	305.05	4.907	0.207	?	Kuenen and Robson
12-car/bel	32.10 °C, 48.85 atm	305.25	4.950		1a	Cardoso and Bell
15-pri	32.32 °C, 48.13 atm	305.47	4.877		1	Prins
37-sag/web	90.6 °F, 718.1 psi, 0.07553 ft^3·lb^{-1}	305.7	4.951	0.212	3	Sage, Webster, and Lacey
38-kay	32.3 °C, 712 psi, 13.736 lb·ft^{-3}	305.4	4.91	0.220	1a	Kay
39-bea/su	(32.27 ± 0.01) °C, (48.20 ± 0.02) atm	305.40	4.884	0.203 ± 1%	3	Beattie, Su, and Simard
40-mas/nal	32.23 °C	305.36			1a	Mason, Naldrett, and Maass
41-lu/new	32.1 °C, 48.6 atm	305.2	4.92		1	Lu, Newitt, and Ruhemann
50-ata/sch	32.230−32.426 °C	305.5			1a	Atack and Schneider
52-kay/nev	32.11 °C, 707.1 psi	305.24	4.875	0.2019	1a	Kay and Nevens

Table 2 (Continued)

year	values reported in nonstandard units	T_{90}/K	p/MPa	ϱ/g·cm^{-3}	method^b	authors
ETHANE: molar mass^c 30.070 g; CASRN 74-84-0						
$T_{68} - T_{48} = -0.010$ K; $T_{90} - T_{68} = -0.008$ K; $T_{90} - T_{48} = -0.018$ K at 305.3 K						
52-mur/mas	32.23 °C	305.36			2	Murray and Mason
53-kay/bri	89.54 °F, 707.2 psi	305.10	4.876		1a	Kay and Brice
53-whi/mas	32.17 °C	305.30		0.215	1, 3	Whiteway and Mason
54-pal	32.32 °C	305.45			2b	Palmer
54-sch/tho	32.19 °C, 49.78 atm	305.32	5.044		1, 5	Schmidt and Thomas
56-kay/alb	89.54 °F, 707.2 psi	305.10	4.876		1a	Kay and Albert
59-tan	32.26 °C	305.39			4	Tanneberger
64-kay	32.3 °C, 48.7 atm	305.4	4.93		1a	Kay
66-kho	0.1478 dm^3·mol^{-1}	305.6		0.2035	1	Khodeeva
67-tsi/pro	32.15 °C	305.28		0.203	1	Tsiklis and Prokhorov
69-sli	(32.184 ± 0.005) °C	305.326			4	Sliwinski
70-cha/smi		305.49 ± 0.01		0.2051 ± 0.3%	4	Chaskin, Smirnov, and Voronel
71-bul/ost	(32.200 ± 0.015) °C	305.342		0.2062	4	Bulavin, Ostanevich, Simkina, and Strelkov
71-kha/som	(32.19 ± 0.03) °C, (48.2 ± 0.1) atm, (147.5 ± 0.5) cm^3·mol^{-1}	305.33	4.88	0.2039	1a	Khazanova and Sominskaya
71-min/sor	(32.20 ± 0.005) °C, (49.710 ± 0.005) kg·cm^{-2}, (147.2 ± 0.5) cm^3·mol^{-1}	305.34	4.8749	0.2042	?	Miniovich and Sorina
73-dou/har	0.14556 dm^3·mol^{-1}	305.32	4.8718	0.2066	3	Douslin and Harrison
74-bur/bal	(32.079 ± 0.030) °C	305.221		0.2062 ± 0.0003	2b	Burton and Balzarini
74-str/col	32.218 °C	305.360		0.2055	2	Strumpf, Collings, and Pings
79-bul/shi	(32.197 ± 0.005) °C	305.339		0.2058 ± 0.004	4	Bulavin and Shimanskii
82-syc/vas	(4.891 ± 0.030) cm^3·g^{-1}	305.32 ± 0.02	4.8714 ± 0.0050	0.20446	8	Sychev et al.
84-mor/kin	(6.682 ± 0.005) mol·dm^{-3}	305.385 ± 0.001	4.778 ± 0.001	0.2009	2a	Morrison and Kincaid
85-bru, 87-bru		305.60	4.889		2a	Brunner
87-you/ely	6.875 mol·dm^{-3}	305.33	4.87143	0.2067	8	Younglove and Ely
88-bru		305.38 ± 0.1	4.877 ± 0.005		2a	Brunner
91-fri/ing	(6.87 ± 0.1) mol·dm^{-3}	305.32 ± 0.04	4.8718 ± 0.005	0.207	8	Friend, Ingham, and Ely
92-col/siv	32.220 °C, 707.7 psi	305.362	4.879		4	Colgate, Sivaraman, and Dejsupa
	recommended values	305.32 ± 0.04	4.872 ± 0.01	0.2066 ± 0.003		

Kuenen [1897-kue] also gave 31.95 °C and 48.81 atm (305.10 K and 4.946 MPa) and 32.05 °C and 48.91 atm (305.20 K and 4.956 MPa) from his earlier work.

Kuenen and Robson [02-kue/rob]: this paper is primarily concerned with application of corresponding states and the source of the critical properties used is not clear.

Atack and Schneider [50-ata/sch] were concerned primarily with mixtures and the effect of stirring; the value given (305.5 K) is the mean of the disappearance and reappearance values obtained without stirring for the single component.

Palmer [54-pal] used a Schlieren system.

Chashkin et al. [70-cha/smi]: values obtained by thermal analysis.

Bulavin et al. [71-bul/ost] measured density distribution by absorption of neutrons.

Colgate et al. [92-col/siv] did not indicate the temperature scale they used in their acoustic measurements; it was assumed to be IPTS-68.

year	values reported in nonstandard units	T_{90}/K	p/MPa	ϱ/g·cm^{-3}	method^b	authors
PROPANE: molar mass^c 44.097 g; CASRN 74-98-6						
$T_{68} - T_{48} = -0.001$ K; $T_{90} - T_{68} = -0.025$ K; $T_{90} - T_{48} = -0.026$ K at 369.8 K						
1889-ols, 1895-ols	97 °C, 44 atm	370	4.5		1, 5	Olszewski
1894-hai	102 °C, 48.5 atm	375	4.91		1, 5	Hainlen
05-leb	97.5 °C, 45 atm	370.6	4.6		1	Lebeau
21-maa/wri	95.6 °C	368.8			1	Maass and Wright
34-sag/sch	212.2 °F, 643.3 psi, 0.06896 ft^3·lb^{-1}	373.3	4.435	0.2323	3	Sage, Schaafsma, and Lacey
35-bea/pof	(96.81 ± 0.01) °C, (42.01 ± 0.02) atm, (0.195 ± 1%) L·mol^{-1}	369.93	4.257	0.226	3	Beattie, Poffenberger, and Hadlock
39-sch/gil	210 °F, 636 psi	372	4.38		1	Scheeline and Gilliland
40-des/bro	96.85 °C, 42.1 atm	369.97	4.26	0.224	1, 5	Deschner and Brown
42-ipa/mon	96-98 °C	369−371			3, 5	Ipatieff and Monroe
42-mey	0.201 L·mol^{-1}			0.219	10	Meyers
49-rea/sag	3.202 ft^3·(lb·mol)$^{-1}$			0.2206	10	Reamer, Sage, and Lacey
53-kay/ram	206.00 °F, 616.3 psi	369.79	4.249		1a	Kay and Rambosek
53-kre	(97.30 ± 0.03) °C, (42.93 ± 0.01) atm, 4.07−4.67 cm^3·g^{-1}	370.42	4.350	0.214−0.246	1	Kreglewski
55-cle/row	96.66 °C, 41.93 atm, 4.92 mol·dm^{-3}	369.78	4.248	0.217	1a	Clegg and Rowlinson

Table 2 (Continued)

year	values reported in nonstandard units	T_{90}/K	p/MPa	ρ/g·cm^{-3}	method^b	authors
PROPANE: molar mass^c 44.097 g; CASRN 74-98-6						
$T_{68} - T_{48} = -0.001$ K; $T_{90} - T_{68} = -0.025$ K; $T_{90} - T_{48} = -0.026$ K at 369.8 K						
57-kre	96.7 °C	369.8			1	Kreglewski
64-kay	96.8 °C, 42.0 atm	370.0	4.26		1a	Kay
69-kre/kay	617.9 psi	370.00	4.260	0.226	1a	Kreglewski and Kay
69-sli	(96.692 ± 0.005) °C	369.817			4	Sliwinski
70-kay	(96.87 ± 0.5) °C, (617.9 ± 2) psi	370.00	4.260	0.226	1a	Kay
72-mou/kay	616.95 psi	369.72	4.254	0.214	1a	Mousa, Kay, and Kreglewski
74-kay/you		369.74	4.255		1a	Kay and Young
74-kay/you-1		369.73	4.261		1a	Kay and Young
77-mou		369.72	4.254		1a	Mousa
80-kra		(369.775)	4.2390		5	Kratzke
82-bar/kay	0.1975 m^3·kmol^{-1}	370.00	4.260	0.2233	1a	Barber, Kay, and Teja
82-goo/hay		369.83	4.24746	0.2205	8	Goodwin and Haynes
82-tho/har	4.955 mol·dm^{-3}	369.83	4.24709	0.2185	3	Thomas and Harrison
85-bru		369.96	4.243		2a	Brunner
87-you/ely	5.000 mol·dm^{-3}	369.83	4.24766	0.2205	8	Younglove and Ely
88-bru		369.89 ± 0.1	4.260 ± 0.005		2a	Brunner
89-syc/vas		369.83	4.2475	0.22049	8	Sychev et al.
	recommended values	369.83 ± 0.1	4.248 ± 0.01	0.220 ± 0.003		

Meyers [42-mey] and Reamer, Sage, and Lacey [49-rea/sag] gave values for critical density recalculated from results by Beattie, Poffenberger, and Hadlock [35-bea/pof].

Kratzke [80-kra] used value of T_c (369.800 K) selected by Goodwin.

year	values reported in nonstandard units	T_{90}/K	p/MPa	ρ/g·cm^{-3}	method^b	authors
BUTANE: molar mass^c 58.123 g; CASRN 106-97-8						
$T_{68} - T_{48} = 0.021$ K; $T_{90} - T_{68} = -0.035$ K; $T_{90} - T_{48} = -0.014$ K at 425.1 K						
11-kue	150.8 °C, 37.5 atm	424.0	3.80		1a	Kuenen
13-vis	150.8 °C, 37.5 atm	424.0	3.80		1a	Visser
15-sei/bur	153.2 °C, 27113 mmHg	426.4	3.615		1	Seibert and Burrell
35-har	150.7 °C	423.8			1	Harand
39-bea/sim	(152.01 ± 0.01) °C, (37.47 ± 0.029) atm	425.15	3.797	0.225 ± 1%	3	Beattie, Simard, and Su
40-kay, 41-kay	306.0 °F, 550.1 psi, 14.24 lb·ft^3	425.4	3.793	0.228	1a	Kay
62-con	151.97 °C, 37.35 atm	425.106	3.7845		1a	Connolly
64-kay	152.2 °C, 37.5 atm	425.4	3.80		1a	Kay
69-kre/kay	550.8 psi	425.32	3.798	0.228	1a	Kreglewski and Kay
70-kay	(152.2 ± 0.5) °C, (550.8 ± 2) psi	425.4	3.798	0.228 ± 0.001	1a	Kay
73-das/ree	37.47 atm	425.12	3.797	0.228	8	Das, Reed, and Eubank
82-hay/goo		(425.12)	3.7960	0.22785	8	Haynes and Goodwin
82-kra/spi		(425.105)	3.78385		5	Kratzke, Spillner, and Müller
87-you/ely	3.920 mol·dm^{-3}	425.12	3.796	0.2278	8	Younglove and Ely
88-bru		425.06 ± 0.1	3.793 ± 0.005		2a	Brunner
88-li/kir	151.5 °C, 263.0 cm^3·mol^{-1}	424.6	3.80	0.2210	1	Li and Kiran
	recommended values	425.12 ± 0.1	3.796 ± 0.01	0.228 ± 0.003		

Kobe and Lynn [53-kob/lyn] quoted values from W. C. Edmister, *Ind. Eng. Chem.* **1938**, *30*, 352–8, and G. H. Hanson, *Trans. Am. Inst. Chem. Eng.* **1946**, *42*, 959. Values in first are calculated and in second are from literature survey.

Haynes and Goodwin [82-hay/goo] took value of critical temperature from Das, Reed, and Eubank [73-das/ree].

Kratzke, Spillner, and Müller [82-kra/spi] took value of critical temperature from Connolly [62-con] and adjusted it to IPTS-68.

year	values reported in nonstandard units	T_{90}/K	p/MPa	ρ/g·cm^{-3}	method^b	authors
PENTANE: molar mass^c 72.150 g; CASRN 109-66-0						
$T_{68} - T_{48} = 0.041$ K; $T_{90} - T_{68} = -0.040$ K; $T_{90} - T_{48} = 0.001$ K at 469.7 K						
1893-alt	187.1 °C, 33.3 kg·cm^{-2}	460.2	3.27		1	Altschul
1897-you, 10-you	197.2 °C, 25100 mmHg	470.4	3.346	0.2323	1, 7	Young
42-sag/lac	387 °F, 484 psi, 0.0699 ft^3·lb^{-1}	470	3.34	0.229	3	Sage and Lacey
51-bea/lev	(196.62 ± 0.05) °C, (33.31 ± 0.05) atm	469.77	3.375	0.244 ± 1%	3	Beattie, Levine, and Douslin
55-kre	197.55 °C	470.70			1	Kreglewski
60-amb/cox	(196.34 ± 0.02) °C	469.49			1	Ambrose, Cox, and Townsend
60-mcc/sto	387 °F, 485 psi	470	3.34		4	McCracken, Storvick, and Smith
60-par/row	196.4 °C	469.6			1	Partington, Rowlinson, and Weston
69-kre/kay	489.7 psi	469.71	3.376	0.232	1a	Kreglewski and Kay

Table 2 (Continued)

year	values reported in nonstandard units	T_{90}/K	p/MPa	ϱ/g·cm^{-3}	method[b]	authors
PENTANE: molar mass[c] 72.150 g; CASRN 109-66-0						
$T_{68} - T_{48} = 0.041$ K; $T_{90} - T_{68} = -0.040$ K; $T_{90} - T_{48} = 0.001$ K at 469.7 K						
70-art/shi	(196.46 ± 0.01) °C	469.57		0.232	2b, 7	Artyukhovskaya, Shimanskaya, and Shimanskii
70-kay	196.6 °C, 489.7 psi	469.8	3.376	0.232	1a	Kay
74-you		469.7			1	Young
75-you		469.7			1	Young
77-aft/zaw	0.3098 dm^3·mol^{-1}	470.36	3.378	0.2329	1, 7	Aftienjew and Zawisza
77-das/ree	(32.25 ± 0.01) atm	469.6 ± 0.15	3.268	0.237 ± 0.005	8	Das, Reed, and Eubank
83-wol/kay		469.8	3.38	0.2310	1a	Wolfe, Kay, and Teja
85-kra, 85-kra/mue		(469.65)	3.364	0.232	1, 5, 8	Kratzke et al.
88-bru			3.382 ± 0.005		2	Brunner
89-ros/tej		469.7 ± 0.6	3.369 ± 0.02		1c	Rosenthal and Teja
90-ans/gud		469.7 ± 0.3		0.230 ± 0.005	1c	Anselme, Gude, and Teja
90-gri/ras		469.51 ± 0.06	3.360	0.237 ± 0.004	4	Grigoryev et al.
91-qua/khi		469.7 ± 0.4	3.36 ± 0.01		1c	Quadri, Khilar, Kudchadker, and Patni
91-ma/ma	(197.11 ± 0.1) °C	470.22	3.377 ± 0.01	0.2318 ± 0.0009	1, 7	Ma, Ma, and Zhang
92-ste		469.6 ± 1		0.230 ± 0.012	4	Steele
93-nik/pav, 94-nik/pav		466.5	3.36		4	Nikitin, Pavlov, and Bessonova
94-gud/tej		469.7	3.369 ± 0.02	0.230−0.231	1c	Gude and Teja
	recommended values	469.7 ± 0.2	3.370 ± 0.02	0.232 ± 0.003		

McCracken, Storvick, and Smith [60-mcc/sto] obtained values calorimetrically.
Das, Reed and Eubank [77-das/ree] used critical temperature selected by Kudchadker, Alani, and Zwolinski [68-kud/ala]
Grigoryev et al. [90-gri/ras] measured isobaric heat capacities, including a wide range around the critical point, and liquid and vapor volumes. A slightly different p_c (3.363 MPa) is given in their Table 4.1.
Steele [92-ste] obtained values by DSC.
Gude and Teja [94-gud/tej] reported three sets of results: (469.7 ± 0.2) K, (0.231 ± 0.005) g·cm^{-3} (static method/gas furnace); (469.7 ± 0.3) K, (0.230 ± 0.003) g·cm^{-3} (static method/platinum furnace); and (469.7 ± 0.6) K, (3.369 ± 0.02) MPa (flow method).

year	values reported in nonstandard units	T_{90}/K	p/MPa	ϱ/g·cm^{-3}	method[b]	authors
HEXANE: molar mass[c] 86.177 g; CASRN 110-54-3						
$T_{68} - T_{48} = 0.056$ K; $T_{90} - T_{68} = -0.040$ K; $T_{90} - T_{48} = 0.016$ K at 507.6 K						
1883-paw	250.3 °C	523.4			1	Pawlewski
1893-alt	234.5 °C, 30.0 kg·cm^{-2}	507.6	2.94		1	Altschul
1895-tho/you, 10-you	234.8 °C, 22510 mmHg	508.0	3.001	0.2344	1, 7	Thomas and Young
42-ipa/mon	226−9 °C	499−502			3	Ipatieff and Monroe
43-fis/rei	241.0 °C	514.2			1	Fischer and Reichel
46-kay	234.7 °C, 29.94 atm	507.8	3.034	0.233	1a	Kay
57-gla/rue	234.8 °C, 29.6 atm	508.0	3.00		3	Glaser and Rüland
57-kre-1	236.7 °C	509.8			1	Kreglewski
57-nic/rea	454.6 °F, 433.9 psi	507.9	2.992		3	Nichols, Reamer, and Sage
60-amb/cox	(234.15 ± 0.01) °C	507.32			1	Ambrose, Cox, and Townsend
60-par/row	234.5 °C	507.6			1	Partington, Rowlinson, and Weston
64-kay	234.7 °C, 29.9 atm	507.8	3.03		1a	Kay
67-kay/his	234.4 °C, 442.5 psi	507.6	3.051		1a	Kay and Hissong
69-kre/kay	440.0 psi	507.87	3.034	0.233	1a	Kreglewski and Kay
72-mou/kay	440.16 psi	507.64	3.035		1a	Mousa, Kay, and Kreglewski
72-pak/kay	234.1 °C, 441.8 psi	507.2	3.046		1a	Pak and Kay
72-rae/str		508.5			1	Rätzsch and Strauch
72-tas	(235 ± 1) °C	508			4	Tashmukhamedov
74-you		507.4			1	Young
75-kay/you		507.81	3.032		1a	Kay and Young
75-you		507.8			1	Young
77-mou		507.64	3.035		1a	Mousa
80-gen/tej		507.82	3.03162	0.235	1a	Genco, Teja, and Kay
82-kur/gri	(4.281 ± 0.038) cm^3·g^{-1}		3.058	0.2336	3, 5	Kurumov and Grigoryev
85-man/kay		507.4 ± 0.1	3.036 ± 0.007		1a	Mandlekar, Kay, Smith, and Teja
85-zaw	0.3713 dm^3·mol^{-1}	507.33	3.051	0.2321	1, 7	Zawisza
88-bru		507.49 ± 0.1	3.025 ± 0.005		2a	Brunner
88-gri/ras		507.33	3.036	0.2336	3, 10	Grigoryev et al.
89-ros/tej		507.4 ± 0.6	3.014 ± 0.02		1c	Rosenthal and Teja
90-ans/gud		507.3 ± 0.3		0.233 ± 0.005	1c	Anselme, Gude, and Teja
91-qua/khi		507.5 ± 0.4	2.99 ± 0.01		1c	Quadri, Khilar, Kudchadker, and Patni
92-ste		507.2 ± 1		0.232 ± 0.012	4	Steele
93-nik/pav, 94-nik/pav		504.7	2.99		4	Nikitin, Pavlov, and Bessonova
	recommended values	507.6 ± 0.2	3.025 ± 0.02	0.234 ± 0.003		

Table 2 (Continued)

Pawlewski [1883-paw]: Kobe and Lynn [53-kob/lyn] also attributed values of critical pressure and density to Pawlewski, but the reference does not contain any such values.

Kobe and Lynn [53-kob/lyn] credit A. Winkelmann, *Handbuch der Physik*, 1906, p 73, with measuring the critical temperature of hexane, but that value (234.8 °C) was most likely taken from Thomas and Young [1895-tho/you].

Kobe and Lynn [53-kob/lyn] gave a value of the critical density, as obtained by rectilinear diameter, from A. F. O. Germann and S. F. Pickering, *International Critical Tables*, 1926, p 248; there seems no reason to think it is not from the work by S. Young [10-you].

Kobe and Lynn [53-kob/lyn] also credit J. H. C. Merckel, *Proc. Koninkl. Nederland. Akad. Wetenschap.* **1937**, *40*, 164–73, with measuring the critical temperature and pressure of hexane, but Merckel only correlated the properties of hexane and other alkanes.

Ipatieff and Monroe [42-ipa/mon] gave the values above; that quoted by Kobe and Lynn [53-kob/lyn], 236 °C, appears to derive from measurements, 234–9 °C, made in tubes containing hydrogen.

Kay and Hissong [67-kay/his] and Pak and Kay [72-pak/kay] used air-saturated samples.

Kreglewski and Kay [69-kre/kay] also gave in Table II two additional sets of values from earlier work at The Ohio State University: 507.38 K and 440.4 psi (3.036 MPa), 507.55 K and 442.1 psi (3.048 MPa).

Tashmukhamedov [72-tas] determined the critical temperature by ultrasonic absorption.

Steele [92-ste] obtained values by DSC.

year	values reported in nonstandard units	T_{90}/K	p/MPa	ρ/g·cm^{-3}	method^b	authors
HEPTANE: molar mass^c 100.204 g; CASRN 142-82-5						
$T_{68} - T_{48} = 0.066$ K; $T_{90} - T_{48} = -0.040$ K; $T_{90} - T_{48} = 0.026$ K at 540.2 K						
1898-you, 10-you	266.85 °C, 20430 mmHg	540.0	2.724	0.2341	1, 7	Young
29-edg/cal	269.5 °C, 27.65 atm	542.6	2.802		3	Edgar and Calingaert
37-bea/kay	(267.01 ± 0.02) °C, (27.00 ± 0.02) atm	540.19	2.736	0.241 ± 1%	3	Beattie and W. C. Kay
38-kay	267.4 °C, 396 psi, 14.653 lb·ft^{-3}	540.6	2.73	0.23472	1a	Kay
39-kha	265.2 °C	538.4			4	Khalilov
41-kay	513.3 °F, 396 psi, 14.65 lb·ft^{-3}	540.5	2.73	0.235	1a	Kay
48-kay	513.3 °F, 396 psi, 14.6 lb·ft^{-3}	540.5	2.73	0.234	1a	Kay
55-kob/cra	(512.9 ± 0.6) °F, (399 ± 5) psi, (4.15 ± 0.35) cm^3·g^{-1}	540.3	2.75	0.241	3, 5	Kobe, Crawford, and Stephenson
60-amb/cox	(267.13 ± 0.01) °C	540.31			1	Ambrose, Cox, and Townsend
64-kay	267.4 °C, 27.3 atm	540.6	2.77		1a	Kay
65-mcm/kay	(266.85 ± 0.05) °C, (27.002 ± 0.03) atm	540.03	2.7360	0.232	1a	McMicking and Kay
67-kay/his	267.0 °C, 400 psi	540.2	2.76		1a	Kay and Hissong
69-kre/kay	396.9 psi	539.96	2.736		1a	Kreglewski and Kay
70-kob/mat	(513.5 ± 0.5) °F, (400 ± 2) psi	540.6	2.76	0.234 ± 0.002	3, 5	Kobe and Mathews
72-art/shi, 74-art/shi	266.710 °C	539.82		0.2340	2b, 7	Artyukhovskaya, Shimanskaya, and Shimanskii
72-rae/str		542.7			1	Rätzsch and Strauch
74-you		539.9			1	Young
75-you		540.2			1	Young
82-zaw/vej	0.4253 dm^3·mol^{-1}	540.64	2.775	0.2356	1, 7	Zawisza and Vejrosta
88-bru		540.13 ± 0.1	2.734 ± 0.005		2a	Brunner
89-ros/tej		540.3 ± 0.6	2.734 ± 0.02		1c	Rosenthal and Teja
90-ans/gud		539.8 ± 0.3	± 0.005	0.233	1c	Anselme, Gude, and Teja
91-qua/khi		540.4 ± 0.4	2.73 ± 0.01		1c	Quadri, Khilar, Kudchadker, and Patni
92-ste		540.0 ± 1		0.232 ± 0.012	4	Steele
93-nik/pav, 94-nik/pav		536.8	2.73		4	Nikitin et al.
	recommended values	540.2 ± 0.3	2.74 ± 0.03	0.234 ± 0.003		

Edgar and Calingaert [29-edg/cal]: values were measured by Keyes and R. V. Kleinschmidt in apparatus described by Keyes, Taylor, and Smith [22-key/tay].

Khalilov [39-kha] obtained values from viscosity study.

Kobe, Crawford, and Stephenson [55-kob/cra] identified critical point by break in vapor pressure curve.

Kay and Hissong [67-kay/his] used an air-saturated sample.

Kobe and Mathews [70-kob/mat] gave 540.8 K as equivalent of 513.5 °F.

Artyukhovskaya et al. [72-art/shi] determined density by use of microfloats.

Steele [92-ste] obtained values by DSC.

year	values reported in nonstandard units	T_{90}/K	p/MPa	ρ/g·cm^{-3}	method^b	authors
OCTANE: molar mass^c 114.231 g; CASRN 111-65-9						
$T_{68} - T_{48} = 0.072$ K; $T_{90} - T_{68} = -0.039$ K; $T_{90} - T_{48} = 0.033$ K at 568.7 K						
1893-alt	296.4 °C 25.2 kg·cm^{-2}	569.6	2.47		1	Altschul
00-you, 10-you	296.2 °C 18730 mmHg	569.4	2.497	0.2327	1	Young
55-kre	295.4 °C	568.6			1	Kreglewski
55-kre-1, 57-kre-1	295.6 °C	568.8			1	Kreglewski

Table 2 (Continued)

year	values reported in nonstandard units	T_{90}/K	p/MPa	ϱ/g·cm^{-3}	method^b	authors
OCTANE: molar mass^c 114.231 g; CASRN 111-65-9						
$T_{68} - T_{48} = 0.072$ K; $T_{90} - T_{68} = -0.039$ K; $T_{90} - T_{48} = 0.033$ K at 568.7 K						
60-amb/cox	(295.41 ± 0.01) °C	568.59			1	Ambrose, Cox, and Townsend
62-con/kan	295.62 °C, 24.55 atm	568.80	2.488		1a	Connolly and Kandalic
65-mcm/kay	(295.59 ± 0.05) °C, (24.537 ± 0.03) atm	568.77	2.4862	0.232	1a	McMicking and Kay
67-kay/his	295.7 °C, 363.3 psi	568.8	2.505		1a	Kay and Hissong
69-kre/kay	360.7 psi	568.78	2.487	0.232	1a	Kreglewski and Kay
74-kay/you-1		567.2	2.512		1a	Kay and Young
74-you		569.0			1	Young
82-mog/kay		568.76			1a	Mogollon, Kay, and Teja
85-mat/sch		568.8	2.49		1	Matzik and Schneider
86-smi/ans		568.6 ± 0.1			1c	Smith, Anselme, and Teja
86-smi/ans-1		568.6 ± 0.1			1c	Smith, Anselme, and Teja
87-smi/tej		568.6 ± 0.1			1c	Smith, Teja, and Kay
88-bru		568.88 ± 0.1	2.480 ± 0.005		2a	Brunner
89-ros/tej		568.8 ± 0.6	2.495 ± 0.02		1c	Rosenthal and Teja
90-ans/gud		568.6 ± 0.3		0.232 ± 0.005	1c	Anselme, Gude, and Teja
90-tej/ans		568.65 ± 0.1			1c	Teja and Anselme
92-ste		568.5 ± 1		0.233 ± 0.012	4	Steele
	recommended values	568.7 ± 0.3	2.49 ± 0.03	0.232 ± 0.003		

Kay and Hissong [67-kay/his] and Kay and Young [74-kay/you-1] used air-saturated samples.
Steele [92-ste] obtained values by DSC.

year	values reported in nonstandard units	T_{90}/K	p/MPa	ϱ/g·cm^{-3}	method^b	authors
NONANE: molar mass^c 128.258 g; CASRN 111-84-2						
$T_{68} - T_{48} = 0.075$ K; $T_{90} - T_{68} = -0.040$ K; $T_{90} - T_{48} = 0.036$ at 594.6 K						
60-amb/cox	(321.41 ± 0.04) °C	594.60			1	Ambrose, Cox, and Townsend
67-kay/his	320.4 °C, 335.5 psi	593.6	2.313		1a	Kay and Hissong
68-amb/tow			2.288 ± 0.005		1	Ambrose and Townsend
72-pak/kay	320.6 °C, 332.7 psi	593.8	2.294		1a	Pak and Kay
80-kay/pak		595.81	2.2911		1a	Kay and Pak
		595.81	2.2904			
82-mog/kay		593.57			1a	Mogollon, Kay, and Teja
85-mat/sch		594.6	2.27		1	Matzik and Schneider
86-smi/ans-1		594.6 ± 0.1			1c	Smith, Anselme, and Teja
87-smi/tej		594.6 ± 0.1			1c	Smith, Teja, and Kay
88-bru		593.77 ± 0.1	2.299 ± 0.005		2a	Brunner
89-ros/tej		594.7 ± 0.6	2.280 ± 0.02		1c	Rosenthal and Teja
90-ans/gud		594.5 ± 0.3		0.231 ± 0.005	1c	Anselme, Gude, and Teja
92-ste		594.6 ± 1		0.236 ± 0.012	4	Steele
	recommended values	594.6 ± 0.6	2.29 ± 0.05	0.231 ± 0.005		

Kay and Hissong [67-kay/his] and Pak and Kay [72-pak/kay] used air-saturated samples.
Kay and Pak [80-kay/pak] used gallium (first entry) and mercury (second entry) as confining fluids (the mercury at ambient temperature). In other experiments they found the critical temperature to be 595.65 K and the critical pressure to be 2.3056 MPa; with the mercury at the sample temperature, the critical temperature was increased by 0.1 K and the pressure by 0.0517 MPa.
Steele [92-ste] obtained values by DSC.

year	values reported in nonstandard units	T_{90}/K	p/MPa	ϱ/g·cm^{-3}	method^b	authors
DECANE: molar mass^c 142.285 g; CASRN 124-18-5						
$T_{68} - T_{48} = 0.077$ K; $T_{90} - T_{68} = -0.041$ K; $T_{90} - T_{48} = 0.036$ K at 617.7 K						
1893-alt	330.4 °C, 21.3 kg·cm^{-2}	603.6	2.09		1	Altschul
57-fra	348.2 °C	621.4			1	Francis
57-kre-1	344.3 °C	617.4			1	Kreglewski
60-amb/cox	(344.4 ± 0.08) °C	617.59			1	Ambrose, Cox, and Townsend
67-kay/his	344.18 °C, 306.8 psi	617.37	2.115		1a	Kay and Hissong
68-amb/tow			2.104 ± 0.005		1	Ambrose and Townsend
72-pak/kay	343.6 °C, 310.2 psi	616.71	2.139		1a	Pak and Kay
74-kay/you-1		617.1	2.141		1a	Kay and Young
80-kay/pak		618.41	2.1229		1a	Kay and Pak
82-mog/kay		617.50 ± 0.05			1a	Mogollon, Kay, and Teja
83-geh/len				0.2269	7	Gehrig and Lentz
86-smi/ans-1		617.9 ± 0.3			1c	Smith, Anselme, and Teja
87-smi/tej		617.9 ± 0.3			1c	Smith, Teja, and Kay
87-bru		618.0	2.110		2a	Brunner
88-bru		617.66 ± 0.1	2.099 ± 0.005		2a	Brunner

Table 2 (Continued)

year	values reported in nonstandard units	T_{90}/K	p/MPa	ϱ/g·cm^{-3}	method[b]	authors
		DECANE: molar mass[c] 142.285 g; CASRN 124-18-5				
		$T_{68} - T_{48} = 0.077$ K; $T_{90} - T_{68} = -0.041$ K; $T_{90} - T_{48} = 0.036$ K at 617.7 K				
89-ros/tej		617.9 ± 0.6	2.099 ± 0.02		1c	Rosenthal and Teja
89-kni/arc		618.2	2.003 ± 0.022	0.238	4, 7	Knipmeyer et al.
90-ans/gud		617.5 ± 0.3		0.228 ± 0.005	1c	Anselme, Gude, and Teja
92-ste		618.2 ± 1		0.238 ± 0.012	4	Steele
	recommended values	617.7 ± 0.6	2.11 ± 0.05	0.228 ± 0.005		

The values in the table for Kay and Hissong [67-kay/his] and for Kay and Pak [80-kay/pak] are those obtained when the mercury was at ambient temperature. With the mercury at the sample temperature, Kay and Hissong obtained values 0.06 K higher for the critical temperature and 0.016 MPa lower for the critical pressure. In the same conditions Kay and Pak obtained an unchanged value for the critical temperature and a critical pressure 0.074 MPa higher than their value when the mercury was at ambient temperature.

Pak and Kay [72-pak/kay] used an air-saturated sample.

Gehrig and Lentz [83-geh/len] obtained critical volume from equations fitted to orthobaric densities at critical temperature 617.4 K selected by Kudchadker, Alani, and Zwolinski [68-kud/ala].

Knipmeyer et al. [89-kni/arc] determined critical temperature by DSC, critical pressure from vapor pressure curve, and critical density from corresponding states equation fitted to measured densities at lower temperatures.

Steele [92-ste] obtained values by DSC.

year	values reported in nonstandard units	T_{90}/K	p/MPa	ϱ/g·cm^{-3}	method[b]	authors
		UNDECANE: molar mass[c] 156.312 g; CASRN 1120-21-4				
		$T_{68} - T_{48} = 0.077$ K; $T_{90} - T_{68} = -0.043$ K; $T_{90} - T_{48} = 0.034$ at 639.0 K				
60-amb/cox	(365.58 ± 0.05) °C	638.76			1	Ambrose, Cox, and Townsend
68-amb/tow			1.966 ± 0.005		1	Ambrose and Townsend
82-mog/kay		638.7 ± 0.3			1a	Mogollon, Kay, and Teja
85-mat/sch		638.7	1.99		1	Matzik and Schneider
86-smi/ans-1		637.1 ± 0.3			1c	Smith, Anselme, and Teja
87-smi/tej		637.1 ± 0.3			1c	Smith, Teja, and Kay
88-bru		638.85 ± 0.1	2.008 ± 0.005		2a	Brunner
89-ros/tej		638.4 ± 0.6	1.948 ± 0.02		1c	Rosenthal and Teja
90-ans/gud[a]		639.0 ± 0.3		0.227 ± 0.005	1c	Anselme, Gude, and Teja
	recommended values	639 ± 1	1.98 ± 0.1	0.227 ± 0.01		
		DODECANE: molar mass[c] 170.338 g; CASRN 112-40-3				
35-bea/doc	385 °C, 13300 mmHg	658	1.77		1	Beale and Docksey
57-fra	391.5 °C	664.6			1	Francis
60-amb/cox	(385.1 ± 0.1) °C	658.2			1	Ambrose, Cox, and Townsend
68-amb/tow			1.824 ± 0.005		1	Ambrose and Townsend
72-pak/kay	(385.8 ± 0.2) °C, (269.8 ± 0.5) psi	659.0	1.860		1a	Pak and Kay
82-mog/kay		657.7 ± 0.3			1a	Mogollon, Kay, and Teja
86-smi/ans-1		657.4 ± 0.3			1c	Smith, Anselme, and Teja
87-smi/tej		657.4 ± 0.3			1c	Smith, Teja, and Kay
89-ros/tej		658.8 ± 0.6	1.810 ± 0.02		1c	Rosenthal and Teja
90-ans/gud[a]		658.2 ± 0.3		0.226 ± 0.005	1c	Anselme, Gude, and Teja
	recommended values	658 ± 1	1.82 ± 0.1	0.226 ± 0.01		
		TRIDECANE: molar mass[c] 184.365 g; CASRN 629-50-5				
72-pak/kay	(401.7 ± 0.8) °C, (250.2 ± 4.0) psi	674.8	1.725		1a	Pak and Kay
82-mog/kay		676.2 ± 0.5			1a	Mogollon, Kay, and Teja
86-smi/ans-1		674.0 ± 0.6			1c	Smith, Anselme, and Teja
87-smi/tej		674.0 ± 0.6			1c	Smith, Teja, and Kay
89-ros/tej		676.0 ± 0.6	1.679 ± 0.02		1c	Rosenthal and Teja
90-ans/gud[a]		675.8 ± 0.4		0.224 ± 0.005	1c	Anselme, Gude, and Teja
	recommended values	675 ± 1	1.68 ± 0.1	0.224 ± 0.01		
		TETRADECANE: molar mass[c] 198.392 g; CASRN 629-59-4				
63-amb	(421 ± 1) °C	694			1	Ambrose
72-pak/kay	(423.7 ± 1.5) °C, (208.5 ± 9.0) psi	696.8	1.438		1a	Pak and Kay
82-mog/kay		692.8 ± 0.4			1a	Mogollon, Kay, and Teja
86-smi/ans-1		691.2 ± 0.6			1c	Smith, Anselme, and Teja
87-smi/tej		691.2 ± 0.6			1c	Smith, Teja, and Kay
89-ros/tej		691.8 ± 0.7	1.573 ± 0.02		1c	Rosenthal and Teja
90-ans/gud[a]		693.0 ± 1.15		0.222 ± 0.005	1c	Anselme, Gude, and Teja
	recommended values	693 ± 2	1.57 ± 0.2	0.222 ± 0.02		

Table 2 (Continued)

year	values reported in nonstandard units	T_{90}/K	p/MPa	ϱ/g·cm^{-3}	method[b]	authors
PENTADECANE: molar mass[c] 212.419 g; CASRN 629-62-9						
82-mog/kay		709.2 ± 0.5			1a	Mogollon, Kay, and Teja
86-smi/ans-1		706.4 ± 0.6			1c	Smith, Anselme, and Teja
87-smi/tej		706.4 ± 0.6			1c	Smith, Teja, and Kay
87-tej/smi		706.3			1c	Teja and Smith
89-ros/tej		707.5 ± 0.7	1.479 ± 0.02		1c	Rosenthal and Teja
90-ans/gud[a]		708.4 ± 1.2		0.220 ± 0.005	1c	Anselme, Gude, and Teja
	recommended values	708 ± 2	1.48 ± 0.2	0.220 ± 0.02		
HEXADECANE: molar mass[c] 226.446 g; CASRN 544-76-3						
63-amb	(444 ± 2) °C	717			1	Ambrose
82-mog/kay		723.0 ± 2.0			1a	Mogollon, Kay, and Teja
86-smi/ans-1		721.7 ± 1			1c	Smith, Anselme, and Teja
87-smi/tej		722 ± 1			1c	Smith, Teja, and Kay
89-ros/tej		722.4 ± 1.1	1.401 ± 0.05		1c	Rosenthal and Teja
90-ans/gud[a]		723.0 ± 1.8		0.219 ± 0.005	1c	Anselme, Gude, and Teja
	recommended values	723 ± 2	1.40 ± 0.2	0.219 ± 0.02		
HEPTADECANE: molar mass[c] 240.473 g; CASRN 629-78-7						
82-mog/kay		736.0 ± 3.0			1a	Mogollon, Kay, and Teja
89-ros/tej		735.9 ± 1.0	1.342 ± 0.16		1c	Rosenthal and Teja
90-ans/gud		735.3 ± 1.5		0.218 ± 0.005	1c	Anselme, Gude, and Teja
94-nik/pav		731.1	1.32		4	Nikitin, Pavlov, and Bessonova
	recommended values	736 ± 2	1.34 ± 0.2	0.218 ± 0.02		
OCTADECANE: molar mass[c] 254.500 g; CASRN 593-45-3						
63-amb	483 °C (see text)	756			1	Ambrose
89-ros/tej		747.7 ± 1.0	1.292 ± 0.11		1c	Rosenthal and Teja
90-ans/gud		745.8 ± 3.2		0.214 ± 0.005	1c	Anselme, Gude, and Teja
	recommended values	747 ± 3	1.29 ± 0.2	0.214 ± 0.03		
NONADECANE: molar mass[c] 268.527 g; CASRN 629-92-5						
94-nik/pav		755.3	1.16		4	Nikitin, Pavlov, and Bessonova
EICOSANE: molar mass[c] 282.553 g; CASRN 112-95-8						
94-nik/pav		767.5	1.07		4	Nikitin, Pavlov, and Bessonova
HENEICOSANE: molar mass[c] 296.580 g; CASRN 629-94-7						
94-nik/pav		777.6	1.03		4	Nikitin, Pavlov, and Bessonova
DOCOSANE: molar mass[c] 310.607 g; CASRN 629-97-0						
94-nik/pav		785.6	0.982		4	Nikitin, Pavlov, and Bessonova
TRICOSANE: molar mass[c] 324.634 g; CASRN 638-67-5						
94-nik/pav		789.7	0.915		4	Nikitin, Pavlov, and Bessonova
TETRACOSANE: molar mass[c] 338.661 g; CASRN 646-31-1						
94-nik/pav		799.8	0.866		4	Nikitin, Pavlov, and Bessonova

[a] Values for the critical temperatures of undecane to hexadecane are given in 89-tej/gud, but they are identical with those in 90-ans/gud and appear to be repetition of the same numbers not independently determined. [b] See Table 3. [c] Molar masses based on carbon 12.011, hydrogen 1.00794, but are rounded off to three decimal figures.

ment of the critical temperature of the C_6–C_{10} compounds was intended as a demonstration of satisfactory operation of the apparatus rather than as a highly accurate determination of the properties of a stable compound.

The investigations by Kay and Hissong [67-kay/his] on decane and by Kay and Pak [80-kay/pak] on nonane and decane were discussed in part 1 of this series [95-amb/you] in connection with the effect of the presence of mercury on the measurement of critical properties. Only those values obtained without mercury present (i.e., either those obtained when gallium was used as the confining fluid or those obtained with the mercury interface at ambient temperature) are included in Table 2. Some details of the comparative results they obtained when mercury was present in the experimental system are given in the comments on the literature values in Table 2.

No investigation of the critical properties of the C_6–C_{10} compounds can be attributed greater accuracy in compari-

Table 3. Keys to Methods of Critical Point Determination (Reprinted with permission from 95-amb/you. Copyright 1995 American Chemical Society)

1.	visual—in glass tube
2.	visual—in cell with windows
3.	nonvisual—pVT measurements
4.	other nonvisual methods
5.	critical pressure measurements combined with vapor pressure measurements up to the critical point
6.	critical pressure by extrapolation of vapor pressure curve
7.	orthobaric density measurements
8.	equation of state, thermodynamic study
9.	calculation from another physical property
10.	literature survey
(a)	with stirring
(b)	instrumental detection of critical point
(c)	special feature of apparatus

son with the remainder. The samples used in all investigations since about 1960 have been of established high purity, and there are no serious discrepancies among the results obtained in different investigations. Middle values have been chosen as those recommended, and the uncertainties given cover the range of all the most reliable investigations.

Undecane to Octadecane. These compounds are unstable at the critical point, becoming progressively more unstable as the carbon number increases, and investigators have had to take account of this by devising apparatus that allowed observations to be made before significant decomposition had taken place. For example, Ambrose [63-amb] found it was possible to observe only one disappearance of the meniscus with octadecane before the tube burst, and it was impossible to make a reasoned estimate of the uncertainty in the value reported; it could have been as much as 10 K. For such unstable compounds there is no point in seeking to obtain samples of the highest purity. Speed is the enemy of accuracy, and there is a wide scatter in the values reported for the critical temperatures. In general, the greatest weight has been put on the results reported by Teja and his co-workers, who have much improved the techniques for study of unstable compounds; for example, Anselme, Gude, and Teja [90-ans/gud] include a figure showing six cycles through the critical point for heptadecane within 10 min of starting an experiment. Account has also been taken of other results in the selection of the recommended values. The selected value for the critical pressure of undecane, 1.98 MPa, is the average of all reported values. However, the result of Rosenthal and Teja [89-ros/tej], 1.95 MPa, is in better agreement with the values selected for decane and dodecane. The value for the critical pressure of tetradecane given by Rosenthal and Teja [89-ros/tej] is preferred to that given by Pak and Kay [72-pak/kay], because the latter does not conform to any correlation of critical pressure against alkane carbon number. One such correlation was proposed by Ambrose and Walton [89-amb/wal], and overall there is excellent agreement between the correlated values of critical temperatures and critical pressures and the subsequently determined experimental values recommended here.

It has been customary to correlate critical densities and volumes empirically on the basis that molar critical volumes are directly related to the structures of molecules and are additive [87-rei/pra]. Each addition of a $-CH_2-$ group, therefore, in a normal alkane should lead to a fixed increase in the molar critical volume, and the critical density will tend toward a limiting value. Kurata and Isida [55-kur/isi] studied the property theoretically and rejected an equation arising from their treatment, because it predicted a maximum in the critical density and, after the maximum, a constantly increasing increment in critical volume for each additional $-CH_2-$ group, so that the hypothetical critical density of an indefinitely long chain would be zero. Until recently values have been available only for compounds up to octane, and because of the limited availability of data, Tsonopoulos [87-tso] based discussion on analogy with the liquid density at the melting or triple point. This tends toward a limiting value as the carbon number increased, that of linear polythene, and Tsonopoulos inferred that critical density behaved in a similar way.

Anselme, Gude, and Teja [90-ans/gud] have now provided experimental values for the critical densities of nonane upward and found that, contrary to the expectation outlined in the preceding paragraph, the critical density passes through a maximum. The alkanes with the largest critical density are hexane and heptane, and for each compound above heptane the critical density is slightly less than that of its predecessor in the series. As presented, and overall, the figures are progressive, and those for the whole series are consistent; they are adopted in this review as the only experimental evidence for these properties.

However, there is an inconsistency in the presentation in reference 90-ans/gud in that, on p 320, the authors claim an uncertainty of ± 0.005 $g{\cdot}cm^{-3}$ for stable substances and add: "The errors are larger for unstable substances...", yet the same figure, ± 0.005 $g{\cdot}cm^{-3}$, appears in their Table 2 for the uncertainties of the unstable alkanes. The authors may have failed to express their intended meaning at this point, and the technique they used is more advanced than that used by any other investigators, but it cannot be doubted that the uncertainties in the values for undecane to octadecane will increase progressively. A doubling, or more, of the uncertainties in the values for undecane to octadecane, which is not unlikely for compounds as unstable at their critical points as hexadecane to octadecane, would cast doubt upon the conclusions they reach from their work. Using the same apparatus, Gude, Rosenthal, and Teja have now published values for the critical densities of alkenes fron 1-pentene to 1-dodecene [91-gud/ros], and these also show a maximum, confirming the results for alkanes. However, independent confirmation by other workers would add greatly to the confidence that can be placed in these series of decreasing densities. Additional discussion on this issue is provided by Elhassan et al. [92-elh/bar] and by Tsonopoulos and Tan [93-tso/tan].

Nonadecane to Tetracosane. Measurements on these alkanes, which are very unstable at their critical temperatures, have been reported recently by Nikitin et al. [94-nik/pav], who used a pulse-heating method described in detail in an earlier paper [93-nik/pav]. Briefly, the method is based on measurement of the temperature of the attainable superheat by means of a thin wire probe that is heated with electric current pulses. With increasing pressure, the temperature of the attainable superheat tends to the critical temperature. A feature of this method is that the time of attainment of the critical temperature is only 10^{-5} to 3×10^{-3} s, and the authors reported that in their experiments all of these alkanes behaved as stable compounds.

Nikitin et al. estimated the error in their T_c values to be 1% and in their p_c values 2%. They tested their method with stable substances (pentane, hexane, heptane, water) and found that they were *under*estimating the T_c by 1% and the p_c by 1−4%. This was also true of their measurements on the normally unstable heptadecane.

Nikitin's rounded-off values for $C_{19}-C_{24}$ are the recommended values, but with higher uncertainties for p_c. The uncertainty in T_c is 8 K for all alkanes, in accord with their estimate. However, pending confirmation of Nikitin's values by other work, we have assumed that the uncertainty in p_c is 0.2 MPa for all alkanes, in line with the uncertainties for $C_{14}-C_{18}$. The error bands attributed to Nikitin's work are sufficient to contain the inconsistencies between Teja's $C_{18}-$ and Nikitin's $C_{19}+$ results in the increments in critical pressure (and less so in critical temperature) for successive additions of a $-CH_2-$ group.

Acknowledgment

This work is a product of the IUPAC Commission I.2 on Thermodynamics, Subcommittee on Thermodynamic Data, critical properties group, under the leadership of C. L. Young (University of Melbourne, Melbourne, Australia). The following members commented on the preliminary draft of the paper: K. M. de Reuck (Imperial College, London, England), J. H. Dymond (University of Glasgow, Glasgow, Scotland), and C. L. Young. Use was made of the source database (Thermodynamic Research Center, Texas A&M University, College Station, TX). C.T. is grateful to Exxon Research and Engineering for permission to publish this paper.

Registry No. Supplied by the Author: Methane, 74-82-8; ethane, 74-84-0; propane, 74-98-6; butane, 106-97-8; pentane, 109-66-0; hexane, 110-54-3; heptane, 142-82-5; octane, 111-65-9; nonane, 111-84-2; decane, 124-18-5; undecane, 1120-21-4; dodecane, 112-40-3; tridecane, 629-50-5; tetradecane, 629-59-4; pentadecane, 629-62-9; hexadecane, 544-76-3; heptadecane, 629-78-7; octadecane, 593-45-3; nonadecane, 629-92-5; eicosane, 112-95-8; heneicosane, 629-94-7; docosane, 629-97-0; tricosane, 638-67-5; tetracosane 646-31-1.

Literature Cited

1882-sar Sarrau, E. *Compt. Rend.* **1882**, *94*, 718–720 (methane).

1883-paw Pawlewski, B. *Ber. Dtsch. Chem. Ges.* **1883**, *16*, 2633–2636 (hexane).

1884–dew Dewar, J. *Philos. Mag.* **1884**, *18*, 210–216 (methane, ethane).

1884-von von Wroblewski, S. *Compt. Rend.* **1884**, *99*, 136–137 (methane).

1885-ols Olszewski, K. *Compt. Rend.* **1885**, *100*, 940–943 (methane).

1889-ols Olszewski, K. *Bull. Int. Acad. Sci. Cracovie* **1889**, I (reference from 1895-ols) (ethane, propane).

1893-alt Altschul, M. *Z. Phys. Chem.* **1893**, *11*, 577–597 (pentane, hexane, octane, decane).

1894-hai Hainlen, A. *Justus Liebigs Ann. Chem.* **1894**, *282*, 229–245 (ethane, propane).

1895-kue Kuenen, J. P. *Philos. Mag.* **1895**, *40*, 173–194; *Commun. Kamerlingh Onnes Lab., Univ. Leiden* **1895**, *No. 16* (ethane).

1895-ols Olszewski, Charles (sic). *Philos. Mag.* **1895**, *39*, 188–212 (review of author's work, methane, ethane, propane).

1895-tho/you Thomas, G. L.; Young, S. *J. Chem. Soc.* **1895**, *67*, 1071–1084 (hexane).

1897-kue Kuenen, J. P. *Philos Mag.* **1897**, *44*, 174–199 (ethane).

1897-you Young, S. *J. Chem. Soc.* **1897**, *71*, 446–457 (pentane).

1898-you Young, S. *J. Chem. Soc.* **1898**, *73*, 675–681 (heptane).

1899-kue/rob Kuenen, J. P.; Robson, W. G. *Z. Phys. Chem.* **1899**, *28*, 342–365 (ethane).

00-you Young, S. *J. Chem. Soc.* **1900**, *77*, 1145–1151 (octane).

02-kue/rob Kuenen, J. P.; Robson, W. G. *Philos. Mag.* **1902**, 622–630 (ethane).

05-leb Lebeau, P. *Bull. Soc. Chim.* **1905**, *33*, 1137–1139 (propane).

10-you Young, S. *Sci. Proc. R. Dublin Soc.* **1909–10**, *12*, 374–443 (pentane, hexane, heptane, octane).

11-kue Kuenen, J. P. *Commun. Kamerlingh Onnes Lab., Univ. Leiden* **1911**, *No. 125*; from *Landolt-Börnstein, Physikalisch-Chemische Tabellen*, 5th ed.; Springer: Berlin, 1923; pp 253–266 (butane).

12-car/bel Cardoso, E.; Bell, R. *J. Chim. Phys.* **1912**, *10*, 497–503 (ethane).

13-car Cardoso, E. *Arch. Sci. Phys. Nat.* **1913**, *36*, 97–100; values from *Chem. Abstr.* **1914**, *8*, 1896 (methane).

13-vis Visser, S. W. Dissertation, Leiden 1913; from *Landolt-Börnstein, Physikalisch-Chemische Tabellen*, 5th ed.; Springer: Berlin, 1923; pp 253–266 (butane).

15-car Cardoso, E. *Arch. Sci. Phys. Nat.* **1915**, *39*, 400–402, 403–404; *Chem. Abstr.* **1915**, *9*, 2474, 2828; *J. Chim. Phys.* **1915**, *13*, 312–350 (methane).

15-pri Prins, A. *Proc. Acad. Sci. Amsterdam* **1915**, *17*, 1095–1111; from *Chem. Abstr.* **1915**, *9*, 1564 (ethane).

15-sei/bur Seibert, F. M.; Burrell, G. A. *J. Am. Chem. Soc.* **1915**, *37*, 2683–2691 (butane).

21-maa/wri Maass, O.; Wright, C. H. *J. Am. Chem. Soc.* **1921**, *43*, 1098–1111 (propane).

22-key/tay Keyes, F. G.; Taylor, R. S.; Smith, L. B. *J. Math. Phys. (Cambridge, Mass.)* **1922**, *1*, 211–242; values from *Chem. Abstr.* **1923**, *17*, 668 (not the same as given in Kobe and Lynn [53-kob/lyn]) (methane).

24-pic Pickering, S. F. *J. Phys. Chem.* **1924**, *28*, 97–124 (review).

29-ben/and Bennewitz, K.; Andreewa, N. *Z. Phys. Chem.* **1929**, *142A*, 37–66 (methane).

29-edg/cal Edgar, G.; Calingaert, G. *J. Am. Chem. Soc.* **1929**, *51*, 1540–1550; reporting values obtained by F. G. Keyes and R. V. Kleinschmidt in apparatus described in 22-key/tay (heptane).

34-sag/sch Sage, B. H.; Schaafsma, J. G.; Lacey, W. N. *Ind. Eng. Chem.* **1934**, *26*, 1218–1224 (propane).

35-bea/doc Beale, E. S. L.; Docksey, P. *J. Inst. Petrol. Technol.* **1935**, *21*, 860–870 (dodecane).

35-bea/pof Beattie, J. A.; Poffenberger, N.; Hadlock, C. *J. Chem. Phys.* **1935**, *3*, 96–97 (propane).

35-har Harand, J. *Monatsh. Chem.* **1935**, *65*, 153–184 (butane).

37-bea/kay Beattie, J. A.; Kay, W. C. *J. Am. Chem. Soc.* **1937**, *59*, 1586–1587 (heptane).

37-sag/web Sage, B. H.; Webster, D. C.; Lacey, W. N. *Ind. Eng. Chem.* **1937**, *29*, 658–666 (ethane).

38-kay Kay, W. B. *Ind. Eng. Chem.* **1938**, *30*, 459–465 (ethane, heptane).

39-bea/sim Beattie, J. A.; Simard, G. L.; Su, G.-J. *J. Am. Chem. Soc.* **1939**, *61*, 24–26 (butane).

39-bea/su Beattie, J. A.; Su, G.-J.; Simard, G. L. *J. Am. Chem. Soc.* **1939**, *61*, 924–925 (ethane).

39-kha Khalilov, K. *J. Exp. Theor. Phys. (USSR)* **1939**, *9*, 335; from *Chem. Abstr.* **1939**, *33*, 8069 (heptane).

39-sch/gil Scheeline, H. W.; Gilliland, E. R. *Ind. Eng. Chem.* **1939**, *31*, 1050–1057 (propane).

40-des/bro Deschner, W. W.; Brown, G. G. *Ind. Eng. Chem.* **1940**, *32*, 836–840 (propane).

40-kay Kay, W. B. *Ind. Eng. Chem.* **1940**, *32*, 358–360 (butane).

40-mas/nal Mason, J. G.; Naldrett, S. N.; Maass, O. *Can. J. Res. B* **1940**, *18*, 103–117 (ethane).

41-kay Kay, W. B. *Ind. Eng. Chem.* **1941**, *33*, 590–594 (butane, heptane).

41-lu/new Lu, H.; Newitt, D. M.; Ruhemann, M. *Proc. R. Soc. London* **1941**, *A178*, 506–525 (ethane).

42-ipa/mon Ipatieff, V. N.; Monroe, G. S. *Ind. Eng. Chem., Anal. Ed.* **1942**, *14*, 171–174 (propane, hexane).

42-mey Meyers, C. H. *J. Res. Natl. Bur. Stand.* **1942**, *29*, 157–176 (propane).

42-sag/lac Sage, B. H.; Lacey, W. N. *Ind. Eng. Chem.* **1942**, *34*, 730–737 (pentane).

43-fis/rei Fischer, R.; Reichel, T. *Mikrochemie* **1943**, *31*, 102–108 (hexane).

46-kay Kay, W. B. *J. Am. Chem. Soc.* **1946**, *68*, 1336–1339 (hexane).

48-kay Kay, W. B. *Ind. Eng. Chem.* **1948**, *40*, 1459–1464 (heptane).

49-rea/sag Reamer, H. H.; Sage, B. H.; Lacey, W. N. *Ind. Eng. Chem.* **1949**, *41*, 482–484 (propane).

50-ata/sch Atack, D.; Schneider, W. G. *J. Phys. Colloid Chem.* **1950**, *54*, 1323–1336 (ethane).

51-bea/lev Beattie, J. A.; Levine, S. W.; Douslin, D. R. *J. Am. Chem. Soc.* **1951**, *73*, 4431–4432 (pentane).

52-blo/par Bloomer, O. T.; Parent, J. D. *Inst. Gas Technol., Res. Bull.* **1952**, *No. 17; Chem. Eng. Prog., Symp. Ser.* **1953**, *49* (6), 11–24 (methane).

52-kay/nev Kay, W. B.; Nevens, T. D. *Chem. Eng. Prog., Symp. Ser.* **1952**, *48* (3), 108–114 (ethane).

52-mur/mas Murray, F. E.; Mason, S. G. *Can. J. Chem.* **1952**, *30*, 550–561 (ethane).

53-kay/bri Kay, W. B.; Brice, D. B. *Ind. Eng. Chem.* **1953**, *45*, 615–618 (ethane).

53-kay/ram Kay, W. B.; Rambosek, G. M. *Ind. Eng. Chem.* **1953**, *45*, 221–226 (propane).

53-kob/lyn Kobe, K. A.; Lynn, R. E., Jr. *Chem. Rev.* **1953**, *52*, 117–236 (review).

53-kre Kreglewski, A. *Rocz. Chem.* **1953**, *27*, 125–133 (propane).

53-whi/mas Whiteway, S. G.; Mason, S. G. *Can. J. Chem.* **1953**, *31*, 569–584 (ethane).

54-pal Palmer, H. B. *J. Chem. Phys.* **1954**, *22*, 625–634 (ethane).

54-sch/tho Schmidt, E.; Thomas, W. *Forsch. Geb. Ingenieurwes.* **1954**, *20B*, 161–170 (ethane).

55-cle/row Clegg, H. P.; Rowlinson, J. S. *Trans. Faraday Soc.* **1955**, *51*, 1333–1340 (propane).

55-kob/cra Kobe, K. A.; Crawford, H. R.; Stephenson, R. W. *Ind. Eng. Chem.* **1955**, *47*, 1767–1772 (heptane).

55-kre Kreglewski, A. *Rocz. Chem.* **1955**, *29*, 95–106 (pentane, octane).

55-kre-1 Kreglewski, A. *Rocz. Chem.* **1955**, *29*, 754–762 (octane).

55-kur/isi Kurata, M.; Isida, S. *J. Chem. Phys.* **1955**, *23*, 1126–1131.

56-kay/alb Kay, W. B.; Albert, R. E. *Ind. Eng. Chem.* **1956**, *48*, 422–426 (ethane).

57-fra Francis, A. W. *Ind. Eng. Chem.* **1957**, *49*, 1787–1788 (decane, dodecane).

57-gla/rue Glaser, F.; Rüland, H. *Chem.-Ing.-Tech.* **1957**, *29*, 772–775 (hexane).

57-kre Kreglewski, A. *Bull. Acad. Pol., Cl. 3* **1957**, *5*, 323–327 (propane).

57-kre-1 Kreglewski, A. *Bull. Acad. Pol., Cl. 3* **1957**, *5*, 329–333; *Rocz. Chem.* **1957**, *31*, 1001–1012 (hexane, octane, decane).

57-nic/rea Nichols, W. B.; Reamer, H. H.; Sage, B. H. *AIChE J.* **1957**, *3*, 262–267 (hexane).

59-tan Tanneberger, H. *Z. Phys.* **1959**, *153*, 445–457 (ethane).

60-amb/cox Ambrose, D.; Cox, J. D.; Townsend, R. *Trans. Faraday Soc.* **1960**, *56*, 1452–1459 (pentane, hexane, heptane, octane, nonane, decane, undecane, dodecane).

60-mcc/sto McCracken, P. G.; Storvick, T. S.; Smith, J. M. *J. Chem. Eng. Data* **1960**, *5*, 130–132 (pentane).

60-par/row Partington, E. J.; Rowlinson, J. S.; Weston, J. F. *Trans. Faraday Soc.* **1960**, *56*, 479–485 (pentane, hexane).

61-hes/whi Hestermans, P.; White, D. *J. Phys. Chem.* **1961**, *65*, 362–365 (methane).

62-con Connolly, J. F. *J. Phys. Chem.* **1962**, *66*, 1082–1086 (butane).

62-con/kan Connolly, J. F.; Kandalic, G. A. *J. Chem. Eng. Data* **1962**, *7*, 137–139 (octane).

63-amb Ambrose, D. *Trans. Faraday Soc.* **1963**, *59*, 1988–1993 (tetradecane, hexadecane, octadecane).

63-jon/row Jones, I. W.; Rowlinson, J. S. *Trans. Faraday Soc.* **1963**, *59*, 1702–1708 (methane).

64-kay Kay, W. B. *J. Phys. Chem.* **1964**, *68*, 827–831 (ethane, propane, butane, hexane, heptane).

65-mcm/kay McMicking, J. H.; Kay, W. B. *Proc. Am. Petrol. Inst., Ref. Div.* **1965**, *45* (III), 75–90 (heptane, octane).

66-kho Khodeeva, S. M. *Russ. J. Phys. Chem.* **1966**, *40*, 1061–1063 (ethane).

67-kay/his Kay, W. B.; Hissong, D. W. *Proc. Am. Petrol. Inst., Ref. Div.* **1967**, *47*, 653–722 (hexane, heptane, octane, nonane, decane).

67-tsi/pro Tsiklis, D. S.; Prokhorov, V. M. *Russ. J. Phys. Chem.* **1967**, *41*, 1182–1184 (ethane).

68-amb/tow Ambrose, D.; Townsend, R. *Trans. Faraday Soc.* **1968**, *64*, 2622–2631 (nonane, decane, undecane, dodecane).

68-gri/ste Grigor, A. F.; Steele, W. A. *J. Chem. Phys.* **1968**, *48*, 1032–1037 (methane).

68-kud/ala Kudchadker, A. P.; Alani, G. H.; Zwolinski, B. J. *Chem. Rev.* **1968**, *68*, 659–735 (review).

69-kre/kay Kreglewski, A.; Kay, W. B. *J. Phys. Chem.* **1969**, *73*, 3359–3366 (propane, butane, pentane, hexane, heptane, octane).

69-ric/sca Ricci, F. P.; Scafe, E. *Phys. Lett. A* **1969**, *29*, 650–651 (methane).

69-sli Sliwinski, P. *Z. Phys. Chem.* (*Frankfurt*) **1969**, *68*, 91–98 (ethane, propane).

70-art/shi Artyukhovskaya, L. M.; Shimanskaya, E. T.; Shimanskii, Yu. I. *Zh. Eksp. Teor. Fiz.* **1970**, *59*, 688–695; *Sov. Phys. JETP* **1971**, *32*, 375–379 (pentane).

70-cha/smi Chashkin, Yu. R.; Smirnov, V. A.; Voronel, A. V. *Teplofiz. Svoistva Veshchestv. Mater.* **1970** (2), 139–145; from *Chem. Abstr.* **1972**, *76*, 103866 (ethane).

70-jan/gie Jansoone, F.; Gielen, H.; de Boelpap, J.; Verbeke, O. B. *Physica* **1970**, *46*, 213–221 (methane).

70-kay Kay, W. B. *J. Chem. Eng. Data* **1970**, *15*, 46–52 (propane, butane, pentane).

70-kob/mat Kobe, K. A.; Mathews, J. F. *J. Chem. Eng. Data* **1970**, *15*, 182–186 (heptane).

70-ven/lel Vennix, A. J.; Leland, T. W.; Kobayashi, R. *J. Chem. Eng. Data* **1970**, *15*, 238–243 (methane).

71-bul/ost Bulavin, L. A.; Ostanevich, Yu. M.; Simkina, A. P.; Strelkov, A. V. *Ukr. Fiz. Zh. (Russ. Ed.)* **1971**, *16*, 90–98; *Chem. Abstr.* **1971**, *75*, 10355 (ethane).

71-kha/som Khazanova, N. E.; Sominskaya, E. E. *Russ. J. Phys. Chem.* **1971**, *45*, 88–89 (ethane).

71-min/sor Miniovich, V. M.; Sorina, G. A. *Russ. J. Phys. Chem.* **1971**, *45*, 306–307 (ethane).

72-art/shi Artyukhovskaya, L. M.; Shimanskaya, E. T.; Shimanskii, Yu. I. *Zh. Eksp. Teor. Fiz.* **1972**, *63*, 2159–2164; *Sov. Phys. JETP* **1973**, *36*, 1140–1142 (heptane).

72-mou/kay Mousa, A. H. N.; Kay, W. B.; Kreglewski, A. *J. Chem. Thermodyn.* **1972**, *4*, 301–311 (propane, hexane).

72-pak/kay Pak, S. C.; Kay, W. B. *Ind. Eng. Chem. Fundam.* **1972**, *11*, 255–267 (hexane, nonane, decane, dodecane, tridecane, tetradecane).

72-pry/goo Prydz, R.; Goodwin, R. D. *J. Chem. Thermodyn.* **1972**, *4*, 127–133 (methane).

72-rae/str Rätzsch, M. T.; Strauch, G. *Z. Phys. Chem. (Leipzig)* **1972**, *249*, 243–252 (hexane, heptane).

72-tas Tashmukhamedov, F. *Sov. Phys. Acoust.* **1972**, *17*, 527–528 (hexane).

73-das/ree Das, T. R.; Reed, C. O., Jr.; Eubank, P. T. *J. Chem. Eng. Data* **1973**, *18*, 244–253 (butane).

73-dou/har Douslin, D. R.; Harrison, R. H. *J. Chem. Thermodyn.* **1973**, *5*, 491–512 (ethane).

73-gie/jan Gielen, H.; Jansoone, F.; Verbeke, O. B. *J. Chem. Phys.* **1973**, *59*, 5763–5769 (methane).

74-art/shi Artyukhovskaya, L. M.; Shimanskaya, E. T.; Shimanskii, Yu. I. *Opt. Spektrosk.* **1974**, *37* (5), 935–941; *Opt. Spectrosc.* **1974**, *37*, 533–536 (heptane).

74-bur/bal Burton, M.; Balzarini, D. *Can. J. Phys.* **1974**, *52*, 2011–2013 (ethane).

74-goo Goodwin, R. D. *NBS Tech. Note* **1974**, *No. 653* (methane).

74-kay/you Kay, W. B.; Young, C. L. *Int. Data Ser. A* **1974**, 154–159 (propane).

74-kay/you-1 Kay, W. B.; Young, C. L. *Int. Data Ser. A* **1974**, 192–197, 200 (propane, octane, decane).

74-str/col Strumpf, H. J.; Collings, A. F.; Pings, C. J. *J. Chem. Phys.* **1974**, *60*, 3109–3123 (ethane).

74-you Young, C. L. *Int. Data Ser. A* **1974**, 47–57 (pentane, hexane, heptane, octane).

75-kay/you Kay, W. B.; Young, C. L. *Int. Data Ser. A* **1975**, 52 (hexane).

75-ols Olson, J. D. *J. Chem. Phys.* **1975**, *63*, 474–484 (methane).

75-you Young, C. L. *Int. Data Ser. A* **1975**, 66–70 (pentane, hexane, heptane).

77-aft/zaw Aftienjew, J.; Zawisza, A. *J. Chem. Thermodyn.* **1977**, *9*, 153–165 (pentane).

77-das/ree Das, T. R.; Reed, C. O., Jr.; Eubank, P. T. *J. Chem. Eng. Data* **1977**, *22*, 3–9 (pentane).

77-mou Mousa, A. H. N. *J. Chem. Thermodyn.* **1977**, *9*, 1063–1065 (propane, hexane).

78-ang/arm Angus, S.; Armstrong, B.; de Reuck, K. M. *IUPAC International Thermodynamic Tables of the Fluid State, Vol. 5: Methane*; Pergamon Press, Oxford, U.K., 1978.

79-bul/shi Bulavin, L. A.; Shimanskii, Yu. I. *Pis'ma Zh. Eksp. Teor. Fiz.* **1979**, *29*, 482–485; from *Chem. Abstr.* **1979**, *91*, 44623 (ethane).

79-syc/vas Sychev, V. V.; Vasserman, A. A.; Zagoruchenko, V. A.; Kozlov, A. D.; Spiridonov, G. A.; Tsymarny, V. A. *Thermodynamic Properties of Methane*; Hemisphere: Washington, DC, 1987 (originally published in Moscow, 1979).

80-gen/tej Genco, J. M.; Teja, A. S.; Kay, K. B. *J. Chem. Eng. Data* **1980**, *25*, 350–355 (hexane).

80-kay/pak Kay, W. B.; Pak, S. C. *J. Chem. Thermodyn.* **1980**, *12*, 673–681 (nonane, decane).

80-kra Kratzke, H. *J. Chem. Thermodyn.* **1980**, *12*, 305–309 (propane).

82-bar/kay Barber, J. R.; Kay, W. B.; Teja, A. S. *AIChE J.* **1982**, *28*, 134–138 (propane).

82-goo/hay Goodwin, R. D.; Haynes, W. M. *NBS Monogr.* **1982**, *No. 170* (propane).

82-hay/goo Haynes, W. M.; Goodwin, R. D. *NBS Monogr.* **1982**, *No. 169* (butane).

82-kra/spi Kratzke, H.; Spillner, E.; Müller, S. *J. Chem. Thermodyn.* **1982**, *14*, 1175–1181 (butane).

82-kur/gri Kurumov, D. S.; Grigoryev, B. A. *Russ. J. Phys. Chem.* **1982**, *56*, 338–341 (hexane).

82-mog/kay Mogollon, E.; Kay, W. B.; Teja, A. S. *Ind. Eng. Chem. Fundam.* **1982**, *21*, 173–175 (octane, nonane, decane, undecane, dodecane, tridecane, tetradecane, pentadecane, hexadecane, heptadecane).

82-syc/vas Sychev, V. V.; Vasserman, A. A.; Kozlov, A. D.; Zagoruchenko, V. A.; Spiridonov, G. A.; Tsymarny, V. A. *Thermodynamic Properties of Ethane*; Hemisphere: Washington, DC, 1987 (originally published in Moscow, 1982).

82-tho/har Thomas, R. H. P.; Harrison, R. H. *J. Chem. Eng. Data* **1982**, *27*, 1–11 (propane).

82-zaw/vej Zawisza, A.; Vejrosta, J. *J. Chem. Thermodyn.* **1982**, *14*, 239–249 (heptane).

83-geh/len Gehrig, M.; Lentz, H. *Erdoel Kohle, Erdgas, Petrochem.* **1983**, *36* (6), 277–278 (decane).

83-wol/kay Wolfe, D.; Kay, W. B.; Teja, A. S. *J. Chem. Eng. Data* **1983**, *28*, 319–322 (pentane).

84-mor/kin Morrison, G.; Kincaid, J. M. *AIChE J.* **1984**, *30*, 257–262 (ethane).

85-bru Brunner, E. *J. Chem. Thermodyn.* **1985**, *17*, 871–885 (ethane, propane).

85-kra Kratzke, H. *AIChE J.* **1985**, *31*, 693–694 (pentane).

85-kra/mue Kratzke, H.; Müller, S.; Bohn, M.; Kohlen, R. *J. Chem. Thermodyn.* **1985**, *17*, 283–294 (pentane).

85-man/kay Mandlekar, A. V.; Kay, W. B.; Smith, R. L., Jr.; Teja, A. S. *Fluid Phase Equilib.* **1985**, *23*, 79–88 (hexane).

85-mat/sch Matzik, I.; Schneider, G. M. *Ber. Bunsenges. Phys. Chem.* **1985**, *89*, 551–555 (octane, nonane, undecane).

85-zaw Zawisza, A. *J. Chem. Thermodyn.* **1985**, *17*, 941–947 (hexane).

86-kle/dus Kleinrahm, R.; Duschek, W.; Wagner, W. *J. Chem. Thermodyn.* **1986**, *18*, 1103–1114 (methane).

86-kle/wag Kleinrahm, R.; Wagner, W. *J. Chem. Thermodyn.* **1986**, *18*, 739–760 (methane).

86-smi/ans Smith, R. L., Jr.; Anselme, M.; Teja, A. S. *Fluid Phase Equilib.* **1986**, *31*, 161–170 (octane).

86-smi/ans-1 Smith, R. L., Jr.; Anselme, M.; Teja, A. S. *Proc. World Congr. III Chem. Eng., Tokyo* **1986**, *II*, 135–139 (octane, nonane, decane, undecane, dodecane, tridecane, tetradecane, pentadecane, hexadecane).

87-bru Brunner, E. *J. Chem. Thermodyn.* **1987**, *19*, 823–835 (ethane, decane).

87-rei/pra Reid, R. C.; Prausnitz, J. M.; Poling, J. E. *Properties of Gases and Liquids*, 4th ed.; McGraw Hill: New York, 1987.

87-smi/tej Smith, R. L., Jr.; Teja, A. S.; Kay, W. B. *AIChE J.* **1987**, *33*, 232–238 (octane, nonane, decane, undecane, dodecane, tridecane, tetradecane, pentadecane, hexadecane).

87-tej/smi Teja, A. S.; Smith, R. L., Jr.; *AIChE J.* **1987**, *33*, 1560–1562 (pentadecane).

87-tso Tsonopoulos, C. *AIChE J.* **1987**, *33*, 2080–2083.

87-you/ely Younglove, B. A.; Ely, J. F. *J. Phys. Chem. Ref. Data* **1987**, *16*, 577–798 (methane, ethane, propane, butane).

88-bru Brunner, E. *J. Chem. Thermodyn.* **1988**, *20*, 273–297 (ethane, propane, butane, pentane, hexane, heptane, octane, nonane, decane, undecane).

88-gri/ras Grigoryev, B. A.; Rastorguyev, Yu. L.; Gerasimov, A. A.; Kurumov, D. S.; Plotnikov, S. A. *Int. J. Thermophys.* **1988**, *9*, 439–452 (hexane).

88-kur/olc Kurumov, D. S.; Olchowy, G. A.; Sengers, J. V. *Int. J. Thermophys.* **1988**, *9*, 73–84 (methane).

88-li/kir Li, L.; Kiran, E. *J. Chem. Eng. Data* **1988**, *33*, 342–344 (butane).

89-amb/wal Ambrose, D.; Walton, J. *Pure Appl. Chem.* **1989**, *61*, 1395–1403.

89-fri/ely Friend, D. G.; Ely, J. F.; Ingham, H. *J. Phys. Chem. Ref. Data* **1989**, *18*, 583–638 (methane).

89-kni/arc Knipmeyer, S. E.; Archer, D. G.; Chirico, R. D.; Gammon, B. E.; Hossenlopp, I. A.; Nguyen, A.; Smith, N. K.; Steele, W. V.; Strube, M. M. *Fluid Phase Equilib.* **1989**, *52*, 185–192 (decane).

89-ros/tej Rosenthal, D. J.; Teja, A. S. *AIChE J.* **1989**, *35*, 1829–1834 (pentane, hexane, heptane, octane, nonane, decane, undecane, dodecane, tridecane, tetradecane, pentadecane, hexadecane, heptadecane, octadecane).

89-tej/gud Teja, A. S.; Gude, M.; Rosenthal, D. J. *Fluid Phase Equilib.* **1989**, *52*, 193–200 (undecane, dodecane, tridecane, tetradecane, pentadecane, hexadecane).

89-syc/vas Sychev, V. V.; Vasserman, A. A.; Kozlov, A. D.; Tsymarny, V. A. *Thermodynamic Properties of Propane*; Hemisphere: Washington, DC, 1991 (originally published in Moscow, 1989).

90-ans/gud Anselme, M. J.; Gude, M.; Teja, A. S. *Fluid Phase Equilib.* **1990**, *57*, 317–326 (pentane, hexane, heptane, octane, nonane, decane, undecane, dodecane, tridecane, tetradecane, pentadecane, hexadecane, heptadecane, octadecane).

90-gri/ras Grigoryev, B. A.; Rastorguyev, Yu. L.; Kurumov, D. S.; Gerasimov, A. A.; Kharin, V. E.; Plotnikov, S. A. *Int. J. Thermophys.* **1990**, *11*, 487–502 (pentane).

90-tej/ans Teja, A. S.; Anselme, M. *AIChE Symp. Ser.* **1990**, *86* (No. 279), 115–121 (octane).

91-fri/ing Friend, D. G.; Ingham, H.; Ely, J. F. *J. Phys. Chem. Ref. Data* **1991**, *20*, 275–347 (ethane).

91-gud/ros Gude, M. T.; Rosenthal, D. G.; Teja, A. S. *Fluid Phase Equilib.* **1991**, *70*, 55–64.

91-ma/ma Ma, P.; Ma, Y.; Zhang, J. *J. Chem. Eng. Chin. Univ.* **1991**, *5*, 175–181 (pentane).

91-qua/khi Quadri, S. K.; Khilar, K. C.; Kudchadker, A. P.; Patni, M. J. *J. Chem. Thermodyn.* **1991**, *23*, 67–76 (pentane, hexane, heptane).

91-set/wag Setzmann, U.; Wagner, W. *J. Phys. Chem. Ref. Data* **1991**, *20*, 1061–1155 (methane).

92-col/siv Colgate, S. O.; Sivaraman, A.; Dejsupa, C. *Fluid Phase Equilib.* **1992**, *76*, 175–185 (ethane).

92-elh/bar Elhassan, A. E.; Barrufet, M. A.; Eubank, P. T. *Fluid Phase Equilib.* **1992**, *78*, 139–155.

92-ste Steele, W. V. Private communication, 1992 (pentane, hexane, heptane, octane, nonane, decane).

93-nik/pav Nikitin, E. D.; Pavlov, P. A.; Skripov, P. F. *J. Chem. Thermodyn.* **1993**, *25*, 869–880 (pentane, hexane, heptane).

93-tso/tan Tsonopoulos, C.; Tan, Z. *Fluid Phase Equilib.* **1993**, *83*, 127–138.

94-gud/tej Gude, M. T.; Teja, A. S. *AIChE Symp. Ser.* **1994**, *90* (No. 298), 14–22 (pentane).

94-nik/pav Nikitin, E. D.; Pavlov, P. A.; Bessonova, N. V. *J. Chem. Thermodyn.* **1994**, *26*, 177–182 (pentane–heptane, heptadecane, nonadecane–tetracosane).

95-amb/you Ambrose, D.; Young, C. L. *J. Chem. Eng. Data* **1995**, *40*, 345–357.

Received for review January 31, 1994. Revised September 21, 1994. Accepted December 18, 1994.[⊗]

JE940010D

[⊗] Abstract published in *Advance ACS Abstracts,* February 1, 1995.