Reviews

Vapor−Liquid Critical Properties of Elements and Compounds. 9. Organic Compounds Containing Nitrogen

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This is part 9 of a series of contributions by the critical properties group of the previous IUPAC Commission I.2 on Thermodynamics, Subcommittee on Thermodynamic Data and the present IUPAC Project, Critical Compilation of Vapour Liquid Critical Properties, sponsored by the Physical and Biophysical Division. It presents all known experimental data for the critical constants of organic hydrocarbon compounds containing nitrogen. Recommendations are given together with uncertainties.

Introduction

Part 9 presents experimental data for 72 compounds including 32 aliphatic amines, 9 aliphatic nitriles, 11 aromatic amines and nitriles, and 20 nitrogen ring compounds. The presentation and evaluation of the experimental data follow the guidelines of Ambrose et al. in parts 1 and 2 of this series: [95-amb/you] (introductory survey) and [95-amb/tso] (normal alkanes). Succeeding parts have been by Tsonopoulos and Ambrose [95-tso/amb] (aromatic hydrocarbons), Gude and Teja [95-gud/tej] (aliphatic alkanols), Daubert [96-dau] (branched alkanes and cycloalkanes), Tsonopoulos and Ambrose [96-tso/amb] (unsaturated aliphatic hydrocarbons), Kudchadker et al. [2001-kud/amb] (oxygen compounds other than alkanols and cycloalkanols), and Tsonopoulos and Ambrose [2001-tso/amb] (organic sulfur, silicon and tin compounds). The recommended values are given in Table 1, while all known data have been collected in Table 2. Where appropriate, the data on which the recommended values are based are indicated by an asterisk. Critical temperatures and sometimes pressures enclosed in parentheses are not new measurements; they are the values at which investigators determined either the critical pressure and/or the critical density. The references follow the format [year-first three letters of first author/first three letters of second author and, where required, a sequence number].

There are relatively few nitrogen compounds that have been studied as compared with compounds containing oxygen or a halogen. The thermodynamic properties, including critical properties, of a number of organic nitrogen compounds have been reviewed by Chao et al. [90-cha/gad] and Das et al. [93-das/fre]. Many organic compounds containing the nitrogen group are thermally unstable at their critical point, and as a consequence, only a limited number of these compounds have been investigated. Steele and co-workers at the previous National Institute for Petroleum and Energy Research made extensive studies on the thermodynamic properties of nitrogen compounds including estimation of critical properties. Many of the compounds they studied decomposed rapidly below their critical point. To study thermally decomposing compounds, they developed an alternative method for obtaining the critical properties [96-ste/chi]. The properties they measured included vapor pressures by comparative ebulliometry and by use of an inclined piston manometer, saturated liquid densities with a vibrating-tube densitometer, and (vapor + liquid) heat capacities with a differential scanning calorimeter (DSC). For compounds stable close to their critical points, the critical temperature and critical density were obtained graphically from the DSC and density measurements. Critical pressure was then obtained by fitting a Wagner equation to the vapor-pressure values. When the substance decomposed significantly at temperatures below the critical, all three critical properties were estimated from a general fit to the measured properties at lower temperatures. These estimates have not been included in this review. An example of the inadequacy of this estimation method is *N*-(2-

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Table 1. Recommended Values of Critical Properties of Organic Compounds Containing Nitrogen

	molar mass	T_c		p_c		ρ_c		V_c		
	M/g·mol^{-1} [a]	K[b]	(±)	MPa	(±)	g·cm^{-3}	(±)	cm^3·mol^{-1}	(±)	Z_c[c]
Aliphatic Amines										
methanamine	31.057	430.8	(0.2)	7.62	(0.03)	0.22	(0.01)	141	(6)	0.300
ethanamine	45.084	456	(1)	5.6	(0.3)	0.25	(0.02)	180	(13)	0.266
1-propanamine	59.111	499	(1)	4.74	(0.06)					
2-propanamine	59.111	472.2	(0.5)	4.55	(0.04)	0.27	(0.01)	219	(8)	0.254
1-butanamine	73.138	531.9	(0.5)	4.20	(0.05)					
2-butanamine	73.138	514	(1)	5.0	(0.5)					
2-methyl-2-propanamine	73.138	483.7	(0.5)	3.85	(0.05)	0.25	(0.02)	293	(22)	0.281
1-hexanamine	101.190	592.3	(0.8)							
2-heptanamine	115.217	598.0	(0.6)							
1-octanamine	129.226	641	(2)	2.6	(0.1)	0.25	(0.05)	517	(103)	0.252
cyclohexanamine	99.174	626.8	(0.4)							
N-methylmethanamine	45.084	437.2	(0.2)	5.34	(0.01)					
N-ethylethanamine	73.138	499.7	(0.2)	3.754	(0.007)	0.24	(0.01)	304	(12)	0.275
N-methyl-1-propanamine	73.138	550	(2)	3.1	(0.2)					
N-propyl-1-propanamine	101.192	555.8	(0.5)	3.63	(0.08)					
N-(1-methylethyl)-2-propanamine	101.192	523.1	(0.5)	3.02	(0.05)					
N-methylhexanamine	115.217	592	(2)							
N-butyl-1-butanamine	129.246	607.5	(0.5)	3.11	(0.05)					
2-methyl-*N*-(2-methylpropyl)-1-propanamine	129.246	584.4	(0.5)	3.20	(0.05)					
N,*N*-dimethylmethanamine	59.111	433	(1)	4.08	(0.05)	0.23	(0.01)	257	(10)	0.291
N,*N*-diethylethanamine	101.192	535.6	(0.3)	3.03	(0.05)	0.26	(0.05)	389	(75)	0.265
N,*N*-dipropyl-1-propanamine	143.272	637.9	(0.5)							
1,2-ethanediamine	60.099	613.1	(0.3)	6.71	(0.01)					
1,3-propanediamine	74.126	632	(6)	5.6	(0.2)					
1,4-butanediamine	88.153	651	(7)	4.5	(0.2)					
1,6-hexanediamine	116.207	685	(7)	3.6	(0.1)					
1,8-octanediamine	144.260	712	(7)	2.8	(0.1)					
1,9-nonanediamine	158.287	726	(7)	2.6	(0.1)					
1,10-decanediamine	172.314	736	(7)	2.4	(0.1)					
1,12-dodecanediamine	200.368	767	(8)	2.0	(0.1)					
N-(2-aminoethyl)−1,2-ethanediamine	103.167	710	(2)	4.4	(0.1)					
prop-2-ene-1-amine	57.095	540.0	(0.5)	4.83	(0.06)					
Nitriles										
methanenitrile	27.026	457	(1)	5.4	(0.1)	0.20	(0.03)	135	(20)	0.192
ethanenitrile	41.053	545.5	(0.1)	4.85	(0.03)	0.24	(0.05)	171	(36)	0.183
propanenitrile	55.079	561.3	(0.5)	4.26	(0.05)	0.24	(0.01)	246	(10)	0.225
butanenitrile	69.106	585.4	(0.5)	3.88	(0.05)					
pentanenitrile	83.133	610.3	(0.5)	3.58	(0.05)					
hexanenitrile	97.160	633.8	(0.5)	3.30	(0.05)					
octanenitrile	125.214	674.4	(0.5)	2.85	(0.05)					
prop-2-enenitrile	53.064	540	(1)	4.66	(0.03)					
ethanedinitrile	52.035	400	(2)	6.0	(0.1)					
Aromatic Amines and Nitriles										
benzenamine	93.128	705	(2)	5.63	(0.05)	0.32	(0.02)	291	(18)	0.280
2-methylbenzenamine	107.155	717	(3)	4.7	(0.1)	0.31	(0.01)	346	(11)	0.273
3-methylbenzenamine	107.155	709	(15)	4.2	(1)					
4-methylbenzenamine	107.155	667	(15)	2.4	(0.4)					
N-methylbenzenamine	107.155	702	(2)	5.2	(0.2)					
N,*N*-dimethylbenzenamine	121.182	688	(10)	3.6	(0.4)					
N-ethylbenzenamine	121.182	700	(30)							
N,*N*-2-trimethylbenzenamine	135.209	668	(15)	3.1	(0.5)					
2-aminobiphenyl	169.226	838	(3)	3.93	(0.20)	0.29	(0.02)	584	(40)	0.329
benzonitrile	103.123	700	(15)	4.2	(0.5)					
4-methylbenzonitrile	117.150	723	(15)							
Nitrogen Ring Compounds										
pyrrole	67.090	640	(2)	5.7	(0.8)					
pyrrolidine	71.122	569	(1)	5.7	(0.2)	0.29	(0.01)	245	(8)	0.295
pyridine	79.101	620.0	(0.4)	5.65	(0.02)	0.32	(0.01)	247	(8)	0.271
2-methylpyridine	93.128	621	(1)	4.62	(0.05)	0.31	(0.01)	300	(10)	0.269
3-methylpyridine	93.128	644.6	(0.3)	4.65	(0.1)	0.31	(0.01)	300	(10)	0.262
4-methylpyridine	93.128	646.0	(0.5)	4.67	(0.05)	0.31	(0.01)	300	(10)	0.261
2,3-dimethylpyridine	107.155	655.5	(0.3)	4.10	(0.05)	0.30	(0.01)	357	(12)	0.269
2,4-dimethylpyridine	107.155	647	(1)	3.95	(0.05)	0.30	(0.01)	357	(12)	0.262
2,5-dimethylpyridine	107.155	644.3	(0.3)	3.85	(0.05)	0.30	(0.01)	357	(12)	0.257
2,6-dimethylpyridine	107.155	624.0	(0.3)	3.85	(0.05)	0.30	(0.01)	357	(12)	0.265
3,4-dimethylpyridine	107.155	683.7	(0.3)	4.20	(0.05)	0.30	(0.01)	357	(12)	0.264
3,5-dimethylpyridine	107.155	667.7	(0.3)	4.05	(0.05)	0.30	(0.01)	357	(12)	0.261
piperidine	85.149	594.1	(0.3)							
piperazine	86.137	659	(3)	5.6	(0.3)	0.32	(0.03)	269	(17)	0.284
pyrazine	80.088	627	(1)	6.70	(0.05)	0.35	(0.01)	229	(7)	0.294
2-methylpyrazine	94.116	634	(2)	5.01	(0.05)	0.33	(0.02)	285	(17)	0.271
quinoline	129.161	782	(2)							
isoquinoline	129.161	803	(5)							
2-methylquinoline	143.188	778	(3)	4.0	(0.2)	0.32	(0.02)	447	(28)	0.276
8-methylquinoline	143.188	787	(3)	4.3	(0.2)	0.33	(0.02)	434	(26)	0.285

[a] Molar masses based on carbon = 12.0107, hydrogen = 1.00794, nitrogen = 14.0067 from *Pure Appl. Chem.* **2003**, *75*, 1107−1122. [b] Temperatures are expressed in ITS-90. [c] $Z_c = p_c V_c / RT_c$, where R = 8.314 472 J·mol^{-1}·K^{-1}.

Table 2. Critical Properties of Organic Compounds Containing Nitrogen from the Literature

ref	values reported in nonstandard units	T_{90}/K	p/MPa	ρ/g·cm^{-3}	method	authors
		ALIPHATIC AMINES				
		METHANAMINE (methylamine): molar mass 31.057 g; CH_5N; CASRN 74-89-5				
1885-vin/cha	155 °C, 72 atm	428	7.30		1	Vincent and Chappuis
17-ber	156.9 °C, 73.6 atm	430.1	7.46		1	Berthoud
73-wea		430.7* ± 0.1	7.614* ± 0.002		1, 5	Weaver
88-li/kir	(157.7 ± 0.5) °C[a], 138.5 cm^3·mol^{-1}	430.9*	7.65* ± 0.03[a,]	0.224*	2a	Li and Kiran
	recommended values	430.8 ± 0.2	7.62 ± 0.03	0.22 ± 0.01		
		ETHANAMINE (ethylamine): molar mass 45.084 g; C_2H_7N; CASRN 75-04-7				
1886-vin/cha	177 °C, 66 atm	450	6.69		1	Vincent and Chappuis
1891-sch	185.2 °C	458.4			1	Schmidt
17-ber	183.2 °C, 55.54 atm	456.4*	5.628*		1	Berthoud
33-poh/meh	183.4 °C, 57.4 kg·cm^{-2}	456.6*	5.63*	0.2483*	3, 7	Pohland and Mehl
	recommended values	456 ± 1	5.6 ± 0.3	0.25 ± 0.02		
		1-PROPANAMINE (propylamine): molar mass 59.111 g; C_3H_9N; CASRN 107-10-8				
1886-vin/cha	218 °C, 50 atm	491	5.07		1	Vincent and Chappuis
17-ber	223.8 °C, 46.76 atm	497.0	4.738*		1	Berthoud
57-gla/rue	223.8 °C, 46.76 atm	497.0[b]	4.738[b,]*		3	Glaser and Rüland
2004-mor/lui		499.2* ± 0.5			1	Morton et al.
	recommended values	499 ± 1	4.74 ± 0.06			
		2-PROPANAMINE (isopropylamine): molar mass 59.111 g; C_3H_9N; CASRN 75-31-0				
70-kob/mat	(389.5 ± 0.5) °F, (660 ± 2) psia	471.8*	4.55	0.268 ± 0.002	3	Kobe and Mathews
2004-mor/lui		472.5* ± 0.2			1	Morton et al.
	recommended values	472.2 ± 0.5	4.55 ± 0.04	0.27 ± 0.01		
		1-BUTANAMINE (butylamine): molar mass 73.138 g; $C_4H_{11}N$; CASRN 109-73-9				
57-gla/rue	251 °C, 41 atm	524	4.15		3	Glaser and Rüland
80-toc/you		531.9* ± 0.3	4.20*		1, 5	Toczylkin and Young
	recommended values	531.9 ± 0.5	4.20 ± 0.05			
		2-BUTANAMINE (*sec*-butylamine): molar mass 73.138 g; $C_4H_{11}N$; CASRN 13952-84-6				
80-toc/you		514.3 ± 0.3	5.0[c]		1, 5	Toczylkin and Young
	recommended values	514 ± 1	5.0 ± 0.5			
		2-METHYL-2-PROPANAMINE (*tert*-butylamine): molar mass 73.138 g; $C_4H_{11}N$; CASRN 75-64-9				
70-kob/mat	(411.0 ± 0.5) °F, (558 ± 2) psia	483.7	3.85	0.25 ± 0.01	3	Kobe and Mathews
	recommended values	483.7 ± 0.5	3.85 ± 0.05	0.25 ± 0.02		
		1-HEXANAMINE (hexylamine): molar mass 101.190 g; $C_6H_{15}N$; CASRN 111-26-2				
2004-mor/lui		592.3 ± 0.4			1	Morton et al.
	recommended values	592.3 ± 0.8				
		2-HEPTANAMINE (heptylamine): molar mass 115.217 g; $C_7H_{17}N$; CASRN 123-82-0				
2004-mor/lui		598.0 ± 0.3			1	Morton et al.
	recommended values	598.0 ± 0.6				
		1-OCTANAMINE (octylamine): molar mass 129.246 g; $C_8H_{19}N$; CASRN 111-86-4				
96-ste/chi		641 ± 2[d]	2.617± 0.10	0.25 ± 0.02[c]	4, 6, 7	Steele et al.
	recommended values	641 ± 2	2.6 ± 0.1	0.25 ± 0.05		
		CYCLOHEXANAMINE (cyclohexylamine): molar mass 99.174 g; $C_6H_{13}N$; CASRN 108-91-8				
2004-mor/lui		626.8 ± 0.2			1	Morton et al.
	recommended values	626.8 ± 0.4				
		N-METHYLMETHANAMINE (dimethylamine): molar mass 45.084 g; C_2H_7N; CASRN 124-40-3				
1885-vin/cha	163 °C, 56 atm	436	5.67		1	Vincent and Chappuis
17 ber	164.55 °C, 52.35 atm	437.73	5.31		1	Berthoud
73-wea		437.22* ± 0.1	5.340* ± 0.002		1, 5	Weaver
	recommended values	437.2 ± 0.2	5.34 ± 0.01			
		N-ETHYLETHANAMINE (diethylamine): molar mass 73.138 g; $C_4H_{11}N$; CASRN 109-89-7				
1878-saj	220.0 °C, 38.7 atm	493.2	3.92		1	Sajotschewsky
1884-kan/dja	222.8 °C	496.0			1	Kannegiesser and Djatschewski
1886-vin/cha	216 °C, 40 atm	489	4.05		1	Vincent and Chappuis
1891-sch	223.0 °C	496.2			1	Schmidt
17-ber	223.3 °C, 36.58 atm	496.5	3.706		1	Berthoud
23-her/neu	(223.8 ± 0.2) °C	497.0		0.243	1, 7	Herz and Neukirch
68-khe	545.0 psia	499.89* ± 0.1	3.758* ± 0.002		1, 5	Khera
85-man/kay	543.6 psia	499.51* ± 0.1	3.748* ± 0.0068		1, 5	Mandlekar et al.
	recommended values	499.7 ± 0.2	3.754 ± 0.007	0.24 ± 0.01		
		N-METHYL-1-PROPANAMINE: molar mass 73.138 g; $C_4H_{11}N$; CASRN 627-35-0				
17-ber	277 °C, 30 atm	550.2	3.04		1	Berthoud
	recommended values	550 ± 2	3.1 ± 0.2			
		N-PROPYL-1-PROPANAMINE (dipropylamine): molar mass 101.192 g; $C_6H_{15}N$; CASRN 142-84-7				
1886-vin/cha	277 °C, 31 atm	550	3.14		1	Vincent and Chappuis
80-toc/you		555.8* ± 0.3	3.63* ± 0.05		1, 5	Toczylkin and Young
2004-mor/lui		555.8* ± 0.5			1	Morton et al.
	recommended values	555.8 ± 0.5	3.63 ± 0.08			

Table 2. (Continued)

ref	values reported in nonstandard units	T_{90}/K	p/MPa	ρ/g·cm^{-3}	method	authors
N-(1-METHYLETHYL)-2-PROPANAMINE (diisopropylamine): molar mass 101.192 g; $C_6H_{15}N$; CASRN 108-18-9						
80-toc/you		523.1 ± 0.3	3.02		1, 5	Toczylkin and Young
	recommended values	523.1 ± 0.5	3.02 ± 0.05			
N-ETHYLHEXANAMINE (*N*-methylhexylamine): molar mass 115.217 g; $C_7H_{17}N$; CASRN 35161-70-7						
2004-mor/lui		592 ± 1			1	Morton et al.
	recommended values	592 ± 2				
N-BUTYL-1-BUTANAMINE (dibutylamine): molar mass 129.246 g; $C_8H_{19}N$; CASRN 111-92-2						
80-toc/you		607.5* ± 0.3	3.11		1, 5	Toczylkin and Young
2004-mor/lui		607.5* ± 0.5			1	Morton et al.
	recommended values	607.5 ± 0.5	3.11 ± 0.05			
2-METHYL-*N*-(2-METHYLPROPYL)-1-PROPANAMINE (diisobutylamine): molar mass 129.246 g; $C_8H_{19}N$; CASRN 110-96-3						
80-toc/you		584.4 ± 0.3	3.20		1, 5	Toczylkin and Young
	recommended values	584.4 ± 0.5	3.20 ± 0.05			
N,*N*-DIMETHYLMETHANAMINE (trimethylamine): molar mass 59.111 g; C_3H_9N; CASRN 75-50-3						
1885-vin/cha	160.5 °C, 41 atm	433.7	4.15		1	Vincent and Chappuis
50-day/fel	(160.15 ± 0.10) °C, (40.24 ± 0.05) atm, (4.28 ± 0.05) mL·g^{-1}	433.3* ± 0.1	4.077* ± 0.005	0.234 ± 0.003	3, 5	Day and Felsing
73-wea		432.3* ± 0.1	4.09* ± 0.02		1, 5	Weaver
	recommended values	433 ± 1	4.08 ± 0.05	0.23 ± 0.01		
N,*N*-DIETHYLETHANAMINE (triethylamine): molar mass 101.192 g; $C_6H_{15}N$; CASRN 121-44-8						
1883-paw	267.1 °C	540.2			1	Pawlewski
1886-vin/cha	259 °C, 30 atm	532	3.04		1	Vincent and Chappuis
23-her/neu	(262.2 ± 0.2) °C	535.4*		0.257	1, 7	Herz and Neukirch
75-you		535.6* ± 0.2			1	Young
77-cam/hur	29.92 atm	(535.6)	3.032*		5	Campbell et al.
	recommended values	535.6 ± 0.3	3.03 ± 0.05	0.26 ± 0.05		
N,*N*-DIPROPYL-1-PROPANAMINE (tripropylamine): molar mass 143.272 g; $C_9H_{21}N$; CASRN 102-69-2						
88-chr		637.9 ± 0.5			1	Christou
	recommended values	637.9 ± 0.5				
1,2-ETHANEDIAMINE (ethylenediamine): molar mass 60.099 g; $C_2H_8N_2$; CASRN 107-15-3						
96-wil/wil		613.1* ± 0.2	6.707* ± 0.007		2a,c	Wilson et al.
2006-nik/pop		614 ± 6	6.65 ± 0.20		4	Nikitin and Popov
	recommended values	613.1 ± 0.3	6.71 ± 0.01			
1,3-PROPANEDIAMINE: molar mass 74.126 g; $C_3H_{10}N_2$; CASRN 109-76-2						
2006-nik/pop		632 ± 6	5.59 ± 0.17		4	Nikitin and Popov
	recommended values	632 ± 6	5.6 ± 0.2			
1,4-BUTANEDIAMINE: molar mass 88.153 g; $C_4H_{12}N_2$; CASRN 110-60-1						
2006-nik/pop		651 ± 7	4.54 ± 0.14		4	Nikitin and Popov
	recommended values	651 ± 7	4.5 ± 0.2			
1,6-HEXANEDIAMINE: molar mass 116.207 g; $C_6H_{16}N_2$; CASRN 124-09-4						
2006-nik/pop		685 ± 7	3.59 ± 0.11		4	Nikitin and Popov
	recommended values	685 ± 7	3.6 ± 0.1			
1,8-OCTANEDIAMINE: molar mass 144.260 g; $C_8H_{20}N_2$; CASRN 373-44-4						
2006-nik/pop		712 ± 7	2.80 ± 0.08		4	Nikitin and Popov
	recommended values	712 ± 7	2.8 ± 0.1			
1,9-NONANEDIAMINE: molar mass 158.287 g; $C_9H_{22}N_2$; CASRN 646-24-2						
2006-nik/pop		726 ± 7	2.63 ± 0.08		4	Nikitin and Popov
	recommended values	726 ± 7	2.6 ± 0.1			
1,10-DECANEDIAMINE: molar mass 172.314 g; $C_{10}H_{24}N_2$; CASRN 646-25-3						
2006-nik/pop		736 ± 7	2.43 ± 0.07		4	Nikitin and Popov
	recommended values	736 ± 7	2.4 ± 0.1			
1,12-DODECANEDIAMINE: molar mass 200.368 g; $C_{12}H_{28}N_2$; CASRN 2783-17-7						
2006-nik/pop		767 ± 8	2.01 ± 0.06		4	Nikitin and Popov
	recommended values	767 ± 8	2.0 ± 0.1			
N-(2-AMINOETHYL)-1,2-ETHANEDIAMINE (diethylenetriamine): molar mass 103.167 g; $C_4H_{13}N_3$; CASRN 111-40-0						
2000-von/wil		709* ± 6	4.3* ± 0.4		2a,c	VonNiederhausern et al.
2002-wil/von		709.8* ± 2	4.38* ± 0.09		3	Wilson et al.
	recommended values	710 ± 2	4.4 ± 0.1			
PROP-2-ENE-1-AMINE (allylamine): molar mass 57.095 g; C_3H_7N; CASRN 107-11-9						
2000-lia/ma		539.97 ± 0.28	4.83 ± 0.02		1	Liang et al.
	recommended values	540 ± 0.5	4.83 ± 0.06			
NITRILES						
METHANENITRILE (hydrocyanic acid, hydrogen cyanide): molar mass 27.026 g; CHN; CASRN 74-90-8						
25-bre/tei	(183.5 ± 0.1) °C, (53.2 ± 0.5) atm	456.7	5.39	0.195	1, 7	Bredig and Teichmann
	recommended values	457 ± 1	5.4 ± 0.1	0.20 ± 0.03		
ETHANENITRILE (acetonitrile): molar mass 41.053 g; C_2H_3N; CASRN 75-05-8						
02-guy/mal	270.2 °C, 47.7 atm	543.3	4.83		1	Guye and Mallet
06-ter	274.74 °C	547.9		0.2371	1, 7	Ter-Gazarian
68-khe, 75-kay/you		544.99 ± 0.1	4.934 ± 0.002		1, 5	Khera, Kay and Young
79-rod/mcl		545.5* ± 0.3	4.83* ± 0.02		1, 5	Rodriguez and McLure
87-cas/tre		545.5* ± 0.2	4.89* ± 0.01		1, 5	Castillo-Lopez and Trejo

Table 2. (Continued)

ref	values reported in nonstandard units	T_{90}/K	p/MPa	ρ/g·cm^{-3}	method	authors
		ETHANENITRILE (continued)				
2000-von/wil		545.6* ± 0.1	4.884* ± 0.006		2a,c	VonNiederhausern et al.
2004-ewi/san		(545.45)	4.835* ± 0.018[e]		6	Ewing and Sanchez Ochoa
	recommended values	545.5 ± 0.1	4.85 ± 0.03	0.24 ± 0.05		
		PROPANENITRILE: molar mass 55.079 g; C_3H_5N; CASRN 107-12-0				
02-guy/mal	285.7 °C, 41.3 atm	564.4	4.18		1	Guye and Mallet
03-ves	258.09 °C, 53.8 atm	531.24	5.45		1	Vespignani
06-ter	291.20 °C	564.4		0.2401	1, 7	Ter-Gazarian
87-cas/tre		561.3* ± 0.2	4.26* ± 0.01		1, 5	Castillo-Lopez and Trejo
	recommended values	561.3 ± 0.5	4.26 ± 0.05	0.24 ± 0.01		
		BUTANENITRILE: molar mass 69.106 g; C_4H_7N; CASRN 109-74-0				
02-guy/mal	309.1 °C, 37.4 atm	582.2	3.79		1	Guye and Mallet
87-cas/tre		585.4* ± 0.2	3.88* ± 0.01		1, 5	Castillo-Lopez and Trejo
	recommended values	585.4 ± 0.5	3.88 ± 0.05			
		PENTANENITRILE: molar mass 83.133 g; C_5H_9N; CASRN 110-59-8				
87-cas/tre		610.3 ± 0.2	3.58 ± 0.01		1, 5	Castillo-Lopez and Trejo
	recommended values	610.3 ± 0.5	3.58 ± 0.05			
		HEXANENITRILE: molar mass 97.160 g; $C_6H_{11}N$; CASRN 628-73-9				
02-guy/mal	348.8 °C, 32.15 atm	622.0	3.258		1	Guye and Mallet
87-cas/tre		633.8* ± 0.2	3.30* ± 0.01		1, 5	Castillo-Lopez and Trejo
	recommended values	633.8 ± 0.5	3.30 ± 0.05			
		OCTANENITRILE: molar mass 125.214 g; $C_8H_{15}N$; CASRN 124-12-9				
87-cas/tre		674.4 ± 0.2	2.85 ± 0.01		1, 5	Castillo-Lopez and Trejo
	recommended values	674.4 ± 0.5	2.85 ± 0.05			
		PROP-2-ENENITRILE (acrylonitrile): molar mass 53.064 g; C_3H_3N; CASRN 107-13-1				
96-wil/wil		540 ± 1	4.660 ± 0.014		2a,c	Wilson et al.
	recommended values	540 ± 1	4.66 ± 0.03			
		ETHANEDINITRILE (cyanogen): molar mass 52.035 g; C_2N_2; CASRN 460-19-5				
1884-dew	124.0 °C, 61.7 atm	397.2	6.25		1	Dewar
10-car/bau	128.3 °C, 59.6 atm	401.5*	6.04*		1a	Cardoso and Baume
12-car/bau	128.3 °C, 59.75 atm	401.5*	6.054*		1a	Cardoso and Baume
16-ter	126.55 °C, 58.20 atm	399.7*	5.897*		1	Terwen
	recommended values	400 ± 2	6.0 ± 0.1			
		AROMATIC AMINES AND NITRILES				
		BENZENAMINE (aniline): molar mass 93.128 g; C_6H_7N; CASRN 62-53-3				
02-guy/mal	425.65 °C, 52.35 atm	698.80	5.30		1	Guye and Mallet
2002-ste/chi		705* ± 1	5.63* ± 0.02	0.319 ± 0.009	4, 6, 7	Steele et al.
	recommended values	705 ± 2	5.63 ± 0.05	0.32 ± 0.02		
		2-METHYLBENZENAMINE (*o*-toluidine, *o*-methylaniline): molar mass 107.155 g; C_7H_9N; CASRN 95-53-4				
57-gla/rue	421 °C, 37 atm	694	3.75		3	Glaser and Rüland
94-ste/chi		716.5* ± 1.0	4.70* ± 0.05	0.308	4, 6, 7	Steele et al.
	recommended values	717 ± 3	4.7 ± 0.1	0.31 ± 0.01		
		3-METHYLBENZENAMINE (*m*-toluidine, *m*-methylaniline): molar mass 107.155 g; C_7H_9N; CASRN 108-44-1				
57-gla/rue	436 °C, 41 atm	709	4.15		3	Glaser and Rüland
	recommended values	709 ± 15	4.2 ± 1.0			
		4-METHYLBENZENAMINE (*p*-toluidine, *p*-methylaniline): molar mass 107.155 g; C_7H_9N; CASRN 106-49-0				
57-gla/rue	394 °C, 23.5 atm	667	2.38		3	Glaser and Rüland
	recommended values	667 ± 15	2.4 ± 0.4			
		N-METHYLBENZENAMINE (*N*-methylaniline): molar mass 107.155 g; C_7H_9N; CASRN 100-61-8				
1899-rad	428.6 °C	701.8			1	Radice
23-her/neu	(51.3 ± 0.5) atm		5.20		1	Herz and Neukirch
	recommended values	702 ± 2	5.2 ± 0.2			
		N,*N*-DIMETHYLBENZENAMINE (*N*,*N*-dimethylaniline): molar mass 121.182 g; $C_8H_{11}N$; CASRN 121-69-7				
02-guy/mal	414.45 °C, 35.8 atm	687.60	3.63		1	Guye and Mallet
	recommended values	688 ± 10	3.6 ± 0.4			
		N-ETHYLBENZENAMINE (*N*-ethylaniline): molar mass 121.182 g; $C_8H_{11}N$; CASRN 103-69-5				
1899-rad	425.4 °C [f]	698			1	Radice
	recommended values	700 ± 30				
		N,*N*-2-TRIMETHYLBENZENAMINE (*N*,*N*-dimethyl-*o*-toluidine): molar mass 135.209 g; $C_9H_{13}N$; CASRN 609-72-3				
02-guy/mal	394.8 °C, 30.8 atm	668.0	3.12		1	Guye and Mallet
	recommended values	668 ± 15	3.1 ± 0.5			
		2-AMINOBIPHENYL: molar mass 169.226 g; $C_{12}H_{11}N$; CASRN 90-41-5				
91-ste/chi		838 ± 2	3.93 ± 0.08	0.285 ± 0.015	4, 6, 7	Steele et al.
	recommended values	838 ± 3	3.93 ± 0.20	0.29 ± 0.02		
		BENZONITRILE: molar mass 103.123 g; C_7H_5N; CASRN 100-47-0				
02-guy/mal	426.2 °C, 41.6 atm	699.4	4.22		1	Guye and Mallet
	recommended values	700 ± 15	4.2 ± 0.5			
		4-METHYLBENZONITRILE (*p*-tolunitrile): molar mass 117.150 g; C_8H_7N; CASRN 104-85-8				
1899-rad	450 °C	723			1	Radice
	recommended values	723 ± 15				

Table 2. (Continued)

ref	values reported in nonstandard units	T_{90}/K	p/MPa	ρ/g·cm^{-3}	method	authors
		NITROGEN RING COMPOUNDS				
		PYRROLE: molar mass 67.090 g; C_4H_5N; CASRN 109-97-7				
57-gla/rue	352 °C, 56 atm	625	5.67		3	Glaser and Rüland
62-che/mcc		639.7* ± 1			1	Cheng et al.
	recommended values	640 ± 2	5.7 ± 0.8			
		PYRROLIDINE: molar mass 71.122 g; C_4H_9N; CASRN 123-75-1				
56-kob/rav	(567 ± 3) °F, (827 ± 15) psia, (3.5 ± 0.1) cm^3·g^{-1}	570*	5.70	0.286 ± 0.008	3	Kobe et al.
62-che/mcc		568.6* ± 0.1			1	Cheng et al.
	recommended values	569 ± 1	5.7 ± 0.2	0.29 ± 0.01		
		PYRIDINE: molar mass 79.101 g; C_5H_5N; CASRN 110-86-1				
1899-rad	(344.2 ± 3) °C[f]	617.4			1	Radice
23-her/neu	(60.0 ± 0.5) atm		6.08		1	Herz and Neukirch
54-swi/kre	345.0 °C	618.2			1	Swietoslawski and Kreglewski
56-kob/rav	(656 ± 3) °F, (818 ± 15) psia, (3.2 ± 0.1) cm^3·g^{-1}	620*	5.64*	0.312*	3	Kobe et al.
57-amb/gra	(346.8 ± 0.05) °C, (56 ± 1) atm	620.0*		0.315* ± 0.006	1, 6, 7	Ambrose and Grant
87-bru	$\Delta p/p$ < 0.004	620.2* ± 0.3	5.660* ± 0.02		2a	Brunner
96-chi/ste		620* ± 1	5.65 ± 0.10	0.3268* ± 0.010	4, 6, 7	Chirico et al.
	recommended values	620.0 ± 0.4	5.65* ± 0.02	0.32 ± 0.01		
		2-METHYLPYRIDINE (2-picoline): molar mass 93.128 g; C_6H_7N; CASRN 109-06-8				
70-kob/mat	(658.0 ± 1.0) °F, (667 ± 4) psia	620.9*	4.60*	0.278 ± 0.02*	3	Kobe and Mathews
99-chi/kni		622.0* ± 0.5	4.650* ± 0.040	0.3091* ± 0.0030	4, 6, 7	Chirico et al.
	recommended values	621 ± 1	4.62 ± 0.05	0.31 ± 0.01		
		3-METHYLPYRIDINE (3-picoline): molar mass 93.128 g; C_6H_7N; CASRN 108-99-6				
57-amb/gra	(371.7 ± 0.10) °C, (45 ± 1) atm	644.9* ± 0.10	4.60*		1, 6	Ambrose and Grant
99-chi/kni		644.5* ± 0.5	4.680* ± 0.040	0.310 ± 0.003	4, 6, 7	Chirico et al.
	recommended values	644.6 ± 0.3	4.65 ± 0.10	0.31 ± 0.01		
		4-METHYLPYRIDINE (4-picoline): molar mass 93.128 g; C_6H_7N; CASRN 108-89-4				
57-amb/gra	(372.5 ± 0.20) °C, (45 ± 1) atm	645.7*	4.60*		1, 6	Ambrose and Grant
70-kob/mat	(703.3 ± 0.5) °F, (677 ± 2) psia	646.1	4.67*	0.286 ± 0.01*	3	Kobe and Mathews
99-chi/kni		647* ± 1	4.66* ± 0.04	0.3092* ± 0.003	4	Chirico et al.
	recommended values	646.0 ± 0.5	4.65 ± 0.10	0.31 ± 0.01		
		2,3-DIMETHYLPYRIDINE (2,3-lutidine): molar mass 107.155 g; C_7H_9N; CASRN 583-61-9				
60-amb/cox	(382.30 ± 0.05) °C	655.45*			1	Ambrose et al.
95-ste/chi		655* ± 1	4.100	0.301 ± 0.01	4, 6, 7	Steele et al.
	recommended values	655.5 ± 0.3	4.10 ± 0.05	0.30 ± 0.01		
		2,4-DIMETHYLPYRIDINE (2,4-lutidine): molar mass 107.155 g; C_7H_9N; CASRN 108-47-4				
57-amb/gra	(374 ± 1) °C	647*			1	Ambrose and Grant
95-ste/chi		647* ± 1	3.950	0.297 ± 0.01	4, 6, 7	Steele et al.
	recommended values	647 ± 1	3.95 ± 0.05	0.30 ± 0.01		
		2,5-DIMETHYLPYRIDINE (2,5-lutidine): molar mass 107.155 g; C_7H_9N; CASRN 589-93-5				
60-amb/cox	(371.01 ± 0.06) °C	644.16*			1	Ambrose et al.
95-ste/chi		645* ± 1	3.850	0.297 ± 0.01	4, 6, 7	Steele et al.
	recommended values	644.3 ± 0.3	3.85 ± 0.05	0.30 ± 0.01		
		2,6-DIMETHYLPYRIDINE (2,6-lutidine): molar mass 107.155 g; C_7H_9N; CASRN 108-48-5				
57-amb/gra	(350.6 ± 0.02) °C	623.8*			1	Ambrose and Grant
95-ste/chi		624* ± 1	3.850	0.297 ± 0.01	4, 6, 7	Steele et al.
	recommended values	624.0 ± 0.3	3.85 ± 0.05	0.30 ± 0.01		
		3,4-DIMETHYLPYRIDINE (3,4-lutidine): molar mass 107.155 g; C_7H_9N; CASRN 583-58-4				
60-amb/cox	(410.56 ± 0.03) °C	683.71*			1	Ambrose et al.
95-ste/chi		684* ± 1	4.200	0.302 ± 0.01	4, 6, 7	Steele et al.
	recommended values	683.7 ± 0.3	4.20 ± 0.05	0.30 ± 0.01		
		3,5-DIMETHYLPYRIDINE (3,5-lutidine): molar mass 107.155 g; C_7H_9N; CASRN 591-22-0				
60-amb/cox	(394.10 ± 0.04) °C	667.25*			1	Ambrose et al.
95-ste/chi		668* ± 1	4.050	0.297 ± 0.01	4, 6, 7	Steele et al.
	recommended values	667.7 ± 0.3	4.05 ± 0.05	0.30 ± 0.01		
		PIPERIDINE: molar mass 85.149 g; $C_5H_{11}N$; CASRN 110-89-4				
02-guy/mal	45.9 atm[f]		46.5		1	Guye and Mallet
62-che/mcc		594.0* ± 0.1			1	Cheng et al.
63-amb	(320.95 ± 0.01) °C	594.10*			1	Ambrose
	recommended values	594.1 ± 0.3				
		PIPERAZINE: molar mass 86.137 g; $C_4H_{10}N_2$; CASRN 110-85-0				
97-ste/chi		661* ± 1	5.800*	0.322	4, 6, 7	Steele et al.
2001-von/gil		656.3* ± 2.0	5.42* ± 0.15		3	VonNiederhausern and Giles
	recommended values	659 ± 3	5.6 ± 0.3	0.32 ± 0.03		
		PYRAZINE: molar mass 80.088 g; $C_4H_4N_2$; CASRN 290-37-9				
2002-ste/chi-1		627 ± 1	6.700	0.353 ± 0.01	4, 6, 7	Steele et al.
	recommended values	627 ± 1	6.70 ± 0.05	0.35 ± 0.01		

Table 2. (Continued)

ref	values reported in nonstandard units	T_{90}/K	p/MPa	ρ/g·cm^{-3}	method	authors
	2-METHYLPYRAZINE: molar mass 94.116 g; $C_5H_6N_2$; CASRN 109-08-0					
70-kob/mat	(681.7 ± 1.0) °F, (726 ± 4) psia	634.3	5.01	0.333 ± 0.01	3	Kobe and Matthews
	recommended values	634 ± 2	5.01 ± 0.05	0.33 ± 0.02		
	QUINOLINE: molar mass 129.161 g; C_9H_7N; CASRN 91-22-5					
1899-rad	>520 °C[f]	>793			1	Radice
63-amb	(509 ± 2) °C[g]	782			1	Ambrose
	recommended values	782 ± 2				
	ISOQUINOLINE: molar mass 129.161 g; C_9H_7N; CASRN 119-65-3					
63-amb	(530 ± 5) °C	803			1	Ambrose
	recommended values	803 ± 5				
	2-METHYLQUINOLINE: molar mass 143.188 g; $C_{10}H_9N$; CASRN 91-63-4					
2005-chi/ste		778 ± 2	4.03	0.3205	4, 6, 7	Chirico and Steele
	recommended values	778 ± 3	4.0 ± 0.2	0.32 ± 0.02		
	8-METHYLQUINOLINE: molar mass 143.188 g; $C_{10}H_9N$; CASRN 611-32-5					
2005-chi/ste		787 ± 2	4.30	0.3261	4, 6, 7	Chirico and Steele
	recommended values	787 ± 3	4.3 ± 0.2	0.33 ± 0.02		

[a] Uncertainty associated with the temperature and pressure transducers used in the work, not actual uncertainty. [b] 57-gla/rue apparently made a new determination. [c] The authors believe the p_c they reported is too high. [d] Uncertainty determined from graph. [e] Vapor pressure extrapolated to $T = 545.45$ K. [f] Decomposes below the critical temperature. [g] Decomposes at the critical temperature.

Table 3. Key to Methods of Critical Point Determination

1	visual, in glass tube
2	visual, in cell with windows
3	non-visual, *pVT* measurement or vapor pressure measurement
4	other non-visual measurement
5	critical pressure measurement combined with vapor pressure measurement 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
d	decomposition at critical temperature

aminoethyl)-1,2-ethanediamine where Steele et al. [97-ste/chi] reported an estimated critical temperature of (677 ± 5) K and a critical pressure of (3.05 ± 0.2) MPa based on extrapolation of heat capacity measurements and other data where the maximum temperature was 150 K below the critical temperature. Subsequent direct measurements by VonNiederhausen et al. [2000-von/wil] and Wilson et al. [2002-wil/von] using separate techniques gave T_c = {(709 ± 6) K and (709.8 ± 1) K}, respectively, and p_c = {(4.3 ± 0.4) MPa and (4.38 ± 0.09) MPa}, respectively.

In compiling and evaluating the available data we have followed the same classification of experimental methods outlined in Part 1 [95-amb/you] of this series as given in Table 3. In 2000, VonNiederhausern et al. [2000-von/wil-1] described a modification of a technique, used among others, by Glaser and Rüland [57-gla/rue] where the critical temperature and pressure were inferred from the variation of the pressure with the temperature of a fluid in a flow loop. The modification was developed to measure the critical properties of fluids that exhibited decomposition in the vicinity of the critical temperature and the residence times were as low as 0.1 s for the total heating time from ambient with the residence time within 20 K of the critical temperature being about 0.02 s. Uncertainty in the measurement is considerably greater than conventional techniques, being about ± 1 K for the critical temperature and about ± 2 % for the critical pressure. However, the method extends the range of fluids that can be studied by about 100 K. This new method is classified under method 3. The Glaser and Rüland apparatus, in comparison with the VonNiederhausern et al. apparatus, was massive and had a very high thermal inertia. Most of the values for thermally unstable compounds reported by Glaser and Rüland are thought to be in considerable error. In this review values which have been extrapolated from vapor pressure measurements have either been given very large uncertainties or have been omitted.

Following previous reviews in this series, the temperatures are expressed as International Kelvin temperatures on ITS-90 [see 90-mcg]. Those values originally expressed as Celsius temperatures have been converted to Kelvin temperatures by the addition of 273.15 K. There are no measurements on nitrogen compounds that are of sufficient accuracy to require adjustment from the earlier temperature scales.

Selection of Best Values

Aliphatic Amines. For methanamine there is good agreement between the critical temperatures and critical pressures reported by Weaver [73-wea] and by Li and Kiran [88-li/kir]. For ethanamine all the measurements reported in the literature are old, and the selected values are subject to considerable uncertainty. For 1-propanamine, the critical temperatures of Glaser and Rüland [57 gla/rue] and Berthoud [17-ber] agree but are lower by 2 K from the more recent value of Morton et al. [2004-mor/lui] on which the selection is based. The selected critical pressure is based on the Glaser and Rüland [57 gla/rue] and Berthoud [17-ber] results with allowance for the uncertainty in T_c. For 1-butanamine, there is considerable disagreement between the values of Glaser and Rüland [57 gla/rue] and the values of Toczylkin and Young [80-toc/you]. The selected value is based on the latter work. For 2-butanamine, Toczylkin and Young [80-toc/you] indicated that they felt their critical pressure was too high.

Nikitin and Popov (2006-nik/pop) have recently determined the critical temperature and pressure of eight diaminoalkanes from C_2 to C_{12} by identifying the critical temperature and pressure from measurement of the pressure dependence of the attainable superheat. Since the material is exposed to high temperatures for only a few milliseconds, the method is suitable for highly unstable compounds.

Aliphatic Nitriles. There is good agreement between the critical temperatures for ethanenitrile reported by Rodriguez and McLure [79-rod/mcl], Castello-Lopez and Trejo [87-cas/tre], and VonNiederhausern et al. [2000-von/wil]. The critical pressures differ by twice the combined experimental error. The recent measurement by VonNiederhausern et al. [2000-von/wil] supports the Castello-Lopez and Trejo value while Ewing and Sanchez Ochoa [2004-ewi/san] extrapolated their vapor pressure data to a value close to the Rodriguez and McLure value. The recommended values for critical properties are based on an average of the four sets of results. The values for the remainder of the nitriles are based on recent measurements except for ethanedinitrile where the most recent measurements were in 1916 by Terwen [16-ter].

Aromatic Amines and Nitriles. 2-Methylbenzenamine decomposes at its critical point, which could account for some of the 23 K discrepancy between the results of Glaser and Rüland [57-gla/rue] and the more recent results of Steele et al. [94-ste/chi]. Hence the values for 3-and 4-methylbenzenamine should be regarded with caution. The data for the rest of the aromatic amines are pre-1923 and have large uncertainties.

Nitrogen Ring Compounds. The critical temperature of pyrrole reported by Glaser and Rüland [57-gla/rue] is lower by 15 K from the value of Cheng et al. [62-che/mcc]. For pyridine the critical temperatures reported in the four most recent papers agree within the combined experimental error. Critical pressures are reported in two of these papers and these agree within experimental error. The recommended values of the critical temperature is based on Ambrose and Grant [57-amb/gra] and the critical pressure value is based on an average of the value of Brunner [87-bru] and Kobe et al. [56-kob/rav]. The substituted pyridines that have been studied recently generally show good agreement between the various values. The critical temperatures of 2,3-dimethylpyridine, 2,4-dimethylpyridine, 2,5-dimethylpyridine, 2,6-dimethylpyridine, 3,4-dimethylpyridine, and 3,5-dimethylpyridine have been measured by Ambrose and coworkers [57-amb/gra, 60-amb/cox]. Steele et al. [95-ste/chi] also studied these compounds. The critical properties reported by this group were based on their new experimental results together with those of Ambrose. The critical volumes (densities) were based on their own measurements while the critical pressures were obtained by (a long) extrapolation of vapor pressures measured at lower temperatures. Quinoline, isoquinoline, 2-methylquinoline, and 8-methylquinoline are unstable at their critical point, and the uncertainty assigned reflects this problem. The critical properties reported are in some cases values arrived at by limited extrapolation.

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Registry Numbers Supplied by the Author. Methanamine, 74-89-5; ethanamine, 75-04-7; 1-propanamine, 107-10-8; 2-propanamine, 75-31-0; 1-butanamine, 109-73-9; 2-butanamine, 13952-84-6; 2-methyl-2-propanamine, 75-64-9; 1-hexanamine, 111-26-2; 2-heptanamine, 123-82-0; 1-octanamine, 111-86-4; cyclohexanamine, 108-91-8; *N*-methylmethanamine, 124-40-3; *N*-ethylethanamine, 109-89-7; *N*-methyl-1-propanamine, 627-35-0; *N*-propyl-1-propanamine, 142-84-7; *N*-(1-methylethyl)-2-propanamine, 108-18-9; *N*-methylhexanamine, 35161-70-7; *N*-butyl-1-butanamine, 111-92-2; 2-methyl-*N*-(2-methylpropyl)-1-propanamine, 110-96-3; *N*,*N*-dimethylmethanamine, 75-50-3; *N*,*N*-diethylethanamine, 121-44-8; *N*,*N*-dipropyl-1-propanamine, 102-69-2; 1,2-ethanediamine, 107-15-3; 1,3-propanediamine, 109-76-2; 1,4-butanediamine, 110-60-1; 1,6-hexanediamine, 124-09-4; 1,8-octanediamine, 373-44-4; 1,9-nonanediamine, 646-24-2; 1,10-decanediamine, 646-25-3; 1,12-dodecanediamine, 2783-17-7; *N*-(2-aminoethyl)-1,2-ethanediamine, 111-40-0; prop-2-ene-1-amine, 107-11-9; methanenitrile, 74-90-8; ethanenitrile, 75-05-8; propanenitrile, 107-12-0; butanenitrile, 109-74-0; pentanenitrile, 110-59-8; hexanenitrile, 628-73-9; octanenitrile, 124-12-9; prop-2-enenitrile, 107-13-1; ethanedinitrile, 460-19-5; benzenamine, 62-53-3; 2-methylbenzenamine, 95-53-4; 3-methylbenzenamine, 108-44-1; 4-methylbenzenamine, 106-49-0; *N*-methylbenzenamine, 100-61-8; *N*,*N*-dimethylbenzenamine, 121-69-7; *N*-ethylbenzenamine, 103-69-5; *N*,*N*-2-trimethylbenzenamine, 609-72-3; 2-aminobiphenyl, 90-41-5; benzonitrile, 100-47-0; 4-methylbenzonitrile, 104-85-8; pyrrole, 109-97-2; pyrrolidine, 123-75-1; pyridine, 110-86-1; 2-methylpyridine, 109-06-8; 3-methylpyridine, 108-99-6; 4-methylpyridine, 108-89-4; 2,3-dimethylpyridine, 583-61-9; 2,4-dimethylpyridine, 108-47-4; 2,5-dimethylpyridine, 589-93-5; 2,6-dimethylpyridine, 108-48-5; 3,4-dimethylpyridine, 583-58-4; 3,5-dimethylpyridine, 591-22-0; piperidine, 110-89-4; piperazine, 110-85-0; pyrazine, 290-37-9; 2-methylpyrazine, 109-08-0; quinoline, 91-22-5; isoquinoline, 119-65-3; 2-methylquinoline, 91-63-4; 8-methylquinoline, 611-32-5.

Literature Cited

1878-saj	Sajotschewsky, W. *Kiewer Univers. Unters*. **1878**, nos. 4 and 8; from *Beibl. Ann. Phys.* **1879**, *3*, 741−744 (*N*-ethylethanamine).
1883-paw	Pawlewski, B. *Chem. Ber*. **1883**, *16*, 2633−2636 (*N*,*N*-diethylethanamine).
1884-dew	Dewar, J. *Philos. Mag*. **1884**, *18*, 210−216 (ethanedinitrile).
1884-jou	Jouk, J. *Beibl* **1884**, *8*, 808−809.
1884-kan/dja	Kannegiesser; Djatschewski. *J. Russ. Chem.-Phys. Ges.* **1884**, *16*, 304−306; quoted in 1884-jou and 23-lan/boe (*N*-ethylethanamine).
1885-vin/cha	Vincent, C.; Chappuis, J. *Compt. Rend.* **1885**, *101*, 427−429 (methanamine, *N*-methylmethanamine, *N*,*N*-dimethylmethanamine).
1886-vin/cha	Vincent, C.; Chappuis, J. *J. Phys. Radium* **1886**, *5*, 58−64 (ethanamine, 1-propanamine, *N*-ethylethanamine, *N*-propyl-1-propanamine, *N*,*N*-diethylethanamine). The journal is given as *J. Phys.* in [23-lan/boe] but as *J. Phys. Radium* in [52-kob/lyn]. See also *Compt. Rend.* **1886**, *103*, 379−381.
1891-sch	Schmidt, G. C. *Justus Liebigs Ann. Chem.* **1891**, *266*, 266−292 (ethanamine, *N*-ethylethanamine).
1899-rad	Radice, G. Doctoral thesis, Geneve, 1899; quoted in 02-guy/mal, pp 30−40 (*N*-methylbenzenamine, *N*-ethylbenzenamine, 4-methylbenzonitrile, pyridine, quinoline).
02-guy/mal	Guye, P. A.; Mallet, E. *Arch. Sci. Phys. Nat.* **1902**, *13*, 30−40, 129−143, 274−296, and 462−489 (ethanenitrile, propanenitrile, butanenitrile, hexanenitrile, benzenamine, *N*,*N*-dimethylbenzenamine, *N*,*N*-2-trimethylbenzenamine, benzonitrile, piperidine).
03-ves	Vespignani, G. B. *Gazz. Chim. Ital.* **1903**, *33*, 73−78 (propanenitrile).
06-ter	Ter-Gazarian, G. *J. Chim. Phys*. **1906**, *4*, 140−169 (ethanenitrile, propanenitrile).
10-car/bau	Cardoso, E.; Baume, G. *Compt. Rend*. **1910**, *151*, 141−143 (ethanedinitrile).
12-car/bau	Cardoso, E.; Baume, G. *J. Chim. Phys*. **1912**, *10*, 509−516 (ethanedinitrile).
16-ter	Terwen, J. W. *Z. Phys. Chem*. **1916**, *91*, 469−499 (ethanedinitrile).
17-ber	Berthoud, A. *J. Chem. Phys.* **1917**, *15*, 3−29 (methanamine, ethanamine, 1-propanamine, *N*-methylmethanamine, *N*-ethylethanamine, *N*-methyl-1-propanamine).
23-her/neu	Herz, W.; Neukirch, E. *Z. Phys. Chem*. **1923**, *104*, 433−450 (*N*-ethylethanamine, *N*,*N*-diethylethanamine, *N*-methylbenzenamine, pyridine).

23-lan/boe Landolt-Börnstein. *Physikalische-Chemische Tabellen*, 5th ed.; Springer: Berlin, 1923; pp 253−266.

25-bre/tei Bredig, H. G.; Teichmann, L. *Z. Elektrochem.* **1925**, *31*, 449−454 (methanenitrile).

33-poh/meh Pohland, E.; Mehl, W. *Z. Phys. Chem.* **1933**, *A 164*, 48−54 (ethanamine).

50-day/fel Day, H. O.; Felsing, W. A. *J. Am. Chem. Soc.* **1950**, *72*, 1698−1699 (*N*,*N*-dimethylmethanamine).

53-kob/lyn Kobe, K. A.; Lynn, R. E. *Chem. Rev.* **1953**, *52*, 117−236.

54-swi/kre Swietoslawski, W.; Kreglewski, A. *Bull. Acad. Polonaise* **1954**, *cl III*, *2*, 77 (pyridine).

56-kob/rav Kobe, K. A.; Ravicz, A. E.; Vohra, S. P. *J. Chem. Eng. Data* **1956**, *1*, 50−56 (pyrrolidine, pyridine).

57-amb/gra Ambrose, D.; Grant, D. G. *Trans. Faraday Soc.* **1957**, *53*, 771−778 (pyridine, 3-methylpyridine, 4-methylpyridine, 2,4-dimethylpyridine, 2,6-dimethylpyridine).

57-gla/rue Glaser, F.; Rüland, H. *Chem.-Ing.-Tech.* **1957**, *29*, 772−775 (1-propanamine, 1-butanamine, 2-methylbenzenamine, 3-methylbenzenamine, 4-methylbenzenamine, pyrrole).

60-amb/cox Ambrose, D.; Cox, J. D.; Townsend, R. *Trans. Faraday Soc.* **1960**, *56*, 1452−1459 (2,3-dimethylpyridine, 2,5-dimethylpyridine, 3,4-dimethylpyridine, 3,5-dimethylpyridine).

62-che/mcc Cheng, D. C.-H.; McCoubrey, J. C.; Phillips, D. G. *Trans. Faraday Soc.* **1962**, *58*, 224−229 (pyrrole, pyrrolidine, piperidine).

63-amb Ambrose, D. *Trans. Faraday Soc.* **1963**, *59*, 1988−1993 (piperidine, quinoline, isoquinoline).

68-khe Khera, R. M.Sc. Thesis, The Ohio State University, 1968; quoted in 69-kre/kay and 76-kay/you (*N*-ethylethanamine, ethanenitrile).

69-kre/kay Kreglewski, A.; Kay, W. B. *J. Phys. Chem.* **1969**, *73*, 3359−3366.

70-kob/mat Kobe, K. A.; Mathews, J. F. *J. Chem. Eng. Data* **1970**, *15*, 182−186 (2-propanamine, 2-methyl-2-propanamine, 2-methylpyridine, 4-methylpyridine, 2-methylpyrazine).

73-wea Weaver, D. L. M.Sc. Thesis, Ohio State University, 1973; quoted in 74-kay/you (methanamine, *N*-methylmethanamine, *N*,*N*-dimethylmethanamine).

74-kay/you Kay, W. B.; Young, C. L. *Int. Data Ser., Ser. A* **1974**, *2*, 154−159.

75-kay/you Kay, W. B.; Young, C. L. *Int. Data Ser., Ser. A* **1975**, *1*, 62−65 (ethanenitrile).

75-you Young, C. L. *Int. Data Ser., Ser. A* **1975**, *1*, 66−69 (*N*,*N*-diethylethanamine).

76-kay/you Kay, W. B.; Young, C. L. *Int. Data Ser., Ser. A* **1976**, *1*, 74−77.

77-cam/hur Campbell, G. J.; Hurle, R. L.; Lie, S. P.; Young, C. L. *Aust. J. Chem.* **1977**, *30*, 401−405 (*N*,*N*-diethylethanamine).

79-rod/mcl Rodriguez, A. T.; McLure, I. A. *J. Chem. Thermodyn.* **1979**, *11*, 1113−1114 (ethanenitrile).

80-toc/you Toczylkin, L. S.; Young, C. L. *J. Chem. Thermodyn.* **1980**, *12*, 365−370 (1-butanamine, 2-butanamine, *N*-propyl-1-propanamine, *N*-(1-methylethyl)-2-propanamine, *N*-butyl-1-butanamine, 2-methyl-*N*-(2-methylpropyl)-1-propanamine).

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

87-bru Brunner, E. *J. Chem. Thermodyn.* **1987**, *19*, 823−835 (pyridine).

87-cas/tre Castillo-Lopez, N.; Trejo, A. *J. Chem. Thermodyn.* **1987**, *19*, 671−672 (ethanenitrile, propanenitrile, butanenitrile, pentanenitrile, hexanenitrile, octanenitrile).

88-chr Christou, G. Critical properties of binary mixtures. Ph.D. Thesis, University of Melbourne, 1988 (*N*,*N*-dipropyl-1-propanamine).

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

90-cha/gad Chao, J.; Gadella, N. A. M.; Gammon, B. E.; Marsh, K. N.; Rodgers, A. S.; Somayajulu, G. R.; Wilhoit, R. C. *J. Phys. Chem. Ref. Data* **1990**, *19*, 6, 1547−1615.

90-mcg McGlashan, M. L. *J. Chem. Thermodyn.* **1990**, *22*, 653−663.

91-ste/chi Steele, W. V.; Chirico, R. D.; Knipmeyer, S. A.; Nguyen, A. *J. Chem. Thermodyn.* **1991**, *23*, 957−977 (2-aminobiphenyl).

93-das/fre Das, A.; Frenkel, M.; Gadella, N. A. M.; Kudchadker, S.; Marsh, K. N.; Rodgers, A. S.; Wilhoit, R. C. *J. Phys. Chem. Ref. Data.* **1993**, *22*, 659−782.

94-ste/chi Steele, W. V.; Chirico, R. D.; Nguyen, A.; Knipmeyer, S. E. *J. Chem. Thermodyn.* **1994**, *26*, 515−544 (2-methylbenzenamine).

95-amb/you Ambrose, D.; Young, C. L. *J. Chem. Eng. Data* **1995**, *40*, 345−357; **1996**, *41*, 154 (part 1).

95-amb/tso Ambrose, D.; Tsonopoulos, C. *J. Chem. Eng. Data* **1995**, *40*, 531−546 (part 2).

95-gud/tej Gude, M.; Teja, A. J. *J. Chem. Eng. Data* **1995**, *40*, 1025−1036 (part 4).

95-ste/chi Steele, W. V.; Chirico, R. D.; Nguyen, A.; Knipmeyer, S. E. *J. Chem. Thermodyn.* **1995,** *27*, 311−334 (2,3-dimethylpyridine, 2,4-dimethylpyridine, 2,5-dimethylpyridine, 2,6-dimethylpyridine, 3,4-dimethylpyridine, 3,5-dimethylpyridine).

95-tso/amb Tsonopoulos, C.; Ambrose, D. *J. Chem. Eng. Data* **1995**, *40*, 547−558 (part 3).

96-chi/ste Chirico, R. D.; Steele, W. V.; Nguyen, A.; Klots, T. D.; Knipmeyer, S. E. *J. Chem. Thermodyn.* **1996**, *28*, 797−818 (pyridine).

96-dau Daubert, T. E. *J. Chem. Eng. Data* **1996**, *41*, 365−372 (part 5).

96-ste/chi Steele, W. V.; Chirico, R. D.; Knipmeyer, S. E.; Nguyen, A.; Smith, N. K.; Tasker, I. R. *J. Chem. Eng. Data* **1996**, *41*, 1269−1284 (1-octanamine).

96-tso/amb Tsonopoulos, C.; Ambrose, D. *J. Chem. Eng. Data* **1996**, *41*, 645−656 (part 6).

96-wil/wil Wilson, L. C.; Wilson, H. L.; Wilding, W. V.; Wilson, G. M. *J. Chem. Eng. Data* **1996**, *41*, 1252−1254 (1,2-ethanediamine, prop-2-enenitrile).

97-ste/chi Steele, W. V.; Chirico, R. D.; Knipmeyer, S. E.; Nguyen, A.; Smith, N. K. *J. Chem. Eng. Data* **1997**, *42*, 1037−1052 (piperazine).

99-chi/kni Chirico, R. D.; Knipmeyer, S. E.; Nguyen, A.; Steele, W. V. *J. Chem. Thermodyn.* **1999**, *31*, 339−378 (2-methylpyridine, 3-methylpyridine, 4-methylpyridine).

2000-lia/ma Liang, Y.; Ma, P.; Zhang, H. *J. Chem. Ind. Eng. China* **2000**, *51*, 243−247 (prop-2-ene-1-amine).

2000-von/wil VonNiederhausern, D. M.; Wilson, L. C.; Giles, N. F.; Wilson, G. M. *J. Chem. Eng. Data* **2000**, *45*, 154−156 (*N*-(2-aminoethyl)-1,2-ethanediamine, ethanenitrile).

2000-von/wil-1 VonNiederhausern, D. M.; Wilson, G. M.; Giles, N. F. *J. Chem. Eng. Data* **2000**, *45*, 157−160.

2001-kud/amb Kudchadker, A. P.; Ambrose, D.; Tsonopoulos, C. *J. Chem. Eng. Data* **2001**, *46*, 457−479 (part 7).

2001-tso/amb Tsonopoulos, C.; Ambrose, D. *J. Chem. Eng. Data* **2001**, *46*, 480−485 (part 8).

2001-von/gil VonNiederhausern, D. M.; Giles, N. F. DIPPR Project 851: Final Report for 2001. To be submitted for publication in *J. Chem. Eng. Data* (piperazine).

2002-ste/chi Steele, W. V.; Chirico, R. D.; Knipmeyer, S. E.; Nguyen, A. *J. Chem. Eng. Data* **2002**, *47*, 648−666 (benzenamine).

2002-ste/chi-1 Steele, W. V.; Chirico, R. D.; Knipmeyer, S. E.; Nguyen, A. *J. Chem. Eng. Data* **2002**, *47*, 689−699 (pyrazine).

2002-wil/von Wilson, G. M.; VonNiederhausern, D. M.; Giles, N. F.; *J. Chem. Eng. Data* **2002**, *47*, 761−764 (*N*-(2-aminoethyl)-1,2-ethanediamine).

2004-ewi/san Ewing, M. B.; Sanchez Ochoa, J. C. *J. Chem. Eng. Data* **2004**, *49*, 486-490 (ethanenitrile).

2004-mor/lui Morton, D. W.; Lui, M. P. W.; Tran, C.; Young, C. L. *J. Chem. Eng. Data* **2004**, *49*, 283−285 (1-propanamine, 2-propanamine, 1-hexanamine, 2-heptanamine, cyclohexanamine,

N-propyl-1-propanamine, *N*-methylhexanamine, *N*-butyl-1-butanamine).

2005-chi/ste Chirico, R. D.; Steele, W. V. *J. Chem. Eng. Data* **2005**, *50*, 697−708 (2-methylquinoline, 8-methylquinoline).

2006-nik/pop Nikitin, E. D.; Popov, A. P. *J. Chem. Eng. Data* **2006**, *51*, 609−611 (1,2-ethanediamine, 1,3-propanediamine, 1,4-butanediamine, 1,6-hexanediamine, 1,8-ooctanediamine, 1,9-nonanediamine, 1,10-decanediamine, 1, 12-dodecanediamine).

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