Designation: D4651 – 14 (Reapproved 2020)

Standard Specification for Isobutane Thermophysical Property Tables[1]

This standard is issued under the fixed designation D4651; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The thermophysical property tables for isobutane are for use in the calculation of the pressure-volume-temperature (PVT), thermodynamic, and transport properties of isobutane for process design and operations. Two tables provide properties at the conditions of liquid-vapor equilibrium (saturation properties), one for liquid and one for vapor, at temperatures between 120 K and the critical point, 407.81 K. A third table provides properties at selected *T*, *p* points for the equilibrium phase at temperatures between 120 K and 570 K at pressures to 20 MPa. The tables were developed using the National Institute of Standards and Technology Standard Reference Database product REFPROP, version 9.1.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Applicability

2.1 These tables apply directly only to pure isobutane. They may also be used in mathematical models and tables for the thermophysical properties of mixtures containing isobutane.

3. Tables

3.1 These tables were produced by equations from a computer package, "NIST Standard Reference Database 23; Reference Fluid Thermodynamic and Transport Properties Database (REFPROP): Version 9.1."[2] A wide selection of units (SI units, engineering units, chemical units) and additional properties are available with this program.

3.2 These thermophysical property tables are:

3.2.1 *Thermophysical Properties of Isobutane Liquid at Vapor-Liquid Equilibrium,* in SI units. See Table 1.

3.2.2 *Thermophysical Properties of Isobutane Vapor at Vapor-Liquid Equilibrium,* in SI units. See Table 2.

3.2.3 *Thermophysical Properties of Isobutane Along Isobars,* in SI units. See Table 3.

3.3 The symbols are:

T, temperature (K)
ρ, molar density ($mol \cdot L^{-1}$)
H, molar enthalpy ($J \cdot mol^{-1}$)
S, molar entropy ($J \cdot K^{-1} \cdot mol^{-1}$)
C_v, constant volume molar heat capacity ($J \cdot K^{-1} \cdot mol^{-1}$)
C_p, constant pressure molar heat capacity ($J \cdot K^{-1} \cdot mol^{-1}$)
c, speed of sound ($m \cdot s^{-1}$)
η, viscosity (μPa·s)
λ, thermal conductivity ($mW \cdot m^{-1} \cdot K^{-1}$)

3.4 The tabulated thermophysical properties are:

ρ, molar density ($mol \cdot L^{-1}$)
H, molar enthalpy ($J \cdot mol^{-1}$)
S, molar entropy ($J \cdot K^{-1} \cdot mol^{-1}$)
C_v, constant volume molar heat capacity ($J \cdot K^{-1} \cdot mol^{-1}$)
C_p, constant pressure molar heat capacity ($J \cdot K^{-1} \cdot mol^{-1}$)
c, speed of sound ($m \cdot s^{-1}$)
η, viscosity (μPa·s)
λ, thermal conductivity ($mW \cdot m^{-1} \cdot K^{-1}$)

4. Additional Information

4.1 Reference state properties are required to calculate the thermodynamic properties enthalpy and entropy from an equation of state formulation. The reference state properties used are those specified by the International Institute of Refrigeration (IIR): enthalpy, $H = 200$ J/g, and entropy, $S = 1$ J/(g·K), for the saturated liquid at 273.15K (0 °C).

4.2 The molar mass of isobutane is 58.122 g/mol.

[1] This specification is under the jurisdiction of ASTM Committee D03 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.08 on Thermophysical Properties.

Current edition approved April 1, 2020. Published May 2020. Originally approved in 1987. Last previous edition approved in 2014 as D4651 – 14. DOI: 10.1520/D4651-14R20.

[2] Available from Standard Reference Data, National Institute of Standards and Technology (NIST), 100 Bureau Drive, Stop 3460, Gaithersburg, MD 20899.

TABLE 1 Thermophysical Properties of Isobutane Liquid at Vapor-Liquid Equilibrium

T	P	ρ	H	S	C_v	C_p	c	η	λ
K	MPa	$mol \cdot l^{-1}$	$J \cdot mol^{-1}$	$J \cdot mol^{-1} \cdot K^{-1}$	$J \cdot mol^{-1} \cdot K^{-1}$	$J \cdot mol^{-1} \cdot K^{-1}$	$m \cdot s^{-1}$	μPa·s	$mW \cdot m^{-1} \cdot K^{-1}$
120	1.0633E-07	12.636	-5912.6	-34.216	69.001	99.308	1945.4	6055.8	156.73
122	1.6734E-07	12.603	-5713.6	-32.571	69.251	99.681	1928.5	5441.0	156.30
124	2.5915E-07	12.571	-5513.9	-30.948	69.501	100.06	1911.9	4910.8	155.85
126	3.9524E-07	12.538	-5313.4	-29.344	69.752	100.43	1895.5	4450.9	155.38
128	5.9407E-07	12.506	-5112.1	-27.759	70.004	100.81	1879.3	4049.9	154.89
130	8.8064E-07	12.473	-4910.1	-26.193	70.255	101.18	1863.4	3698.4	154.39
132	1.2883E-06	12.441	-4707.4	-24.646	70.505	101.56	1847.7	3389.0	153.86
134	1.8611E-06	12.408	-4503.9	-23.116	70.754	101.93	1832.2	3115.4	153.32
136	2.6564E-06	12.376	-4299.7	-21.603	71.003	102.30	1816.9	2872.5	152.76
138	3.7483E-06	12.343	-4094.7	-20.107	71.250	102.68	1801.7	2656.0	152.19
140	5.2314E-06	12.311	-3889.0	-18.627	71.497	103.05	1786.8	2462.5	151.60
142	7.2252E-06	12.278	-3682.5	-17.162	71.743	103.42	1772.0	2288.8	150.99
144	9.8793E-06	12.245	-3475.3	-15.713	71.988	103.79	1757.4	2132.5	150.37
146	1.3379E-05	12.213	-3267.4	-14.279	72.233	104.16	1742.9	1991.3	149.74
148	1.7953E-05	12.180	-3058.7	-12.859	72.477	104.53	1728.6	1863.6	149.09
150	2.3880E-05	12.147	-2849.3	-11.454	72.720	104.89	1714.4	1747.6	148.43
152	3.1496E-05	12.115	-2639.1	-10.062	72.964	105.26	1700.3	1642.0	147.75
154	4.1206E-05	12.082	-2428.2	-8.6838	73.207	105.63	1686.4	1545.6	147.07
156	5.3493E-05	12.049	-2216.6	-7.3185	73.451	106.00	1672.6	1457.5	146.37
158	6.8925E-05	12.016	-2004.2	-5.9659	73.695	106.36	1658.9	1376.7	145.67
160	8.8176E-05	11.984	-1791.1	-4.6257	73.940	106.73	1645.3	1302.4	144.95
162	0.00011203	11.951	-1577.3	-3.2975	74.186	107.10	1631.8	1234.1	144.22
164	0.00014139	11.918	-1362.8	-1.9812	74.432	107.47	1618.3	1171.0	143.48
166	0.00017732	11.885	-1147.5	-0.67634	74.679	107.83	1605.0	1112.6	142.74
168	0.00022101	11.852	-931.41	0.61730	74.928	108.20	1591.8	1058.6	141.98
170	0.00027386	11.819	-714.63	1.9000	75.178	108.57	1578.6	1008.4	141.22
172	0.00033740	11.786	-497.11	3.1721	75.430	108.95	1565.6	961.80	140.45
174	0.00041343	11.752	-278.84	4.4337	75.684	109.32	1552.6	918.37	139.67
176	0.00050391	11.719	-59.816	5.6852	75.939	109.69	1539.6	877.85	138.88
178	0.00061107	11.686	159.96	6.9268	76.197	110.07	1526.8	839.98	138.09
180	0.00073738	11.653	380.48	8.1588	76.456	110.45	1514.0	804.54	137.30
182	0.00088560	11.619	601.77	9.3813	76.718	110.83	1501.3	771.33	136.49
184	0.0010588	11.586	823.82	10.595	76.983	111.21	1488.6	740.15	135.68
186	0.0012602	11.552	1046.6	11.799	77.250	111.60	1476.0	710.84	134.87
188	0.0014935	11.519	1270.2	12.995	77.519	111.98	1463.4	683.26	134.05
190	0.0017628	11.485	1494.6	14.182	77.792	112.37	1450.9	657.25	133.23
192	0.0020724	11.451	1719.8	15.360	78.067	112.77	1438.5	632.72	132.40
194	0.0024270	11.418	1945.7	16.531	78.345	113.16	1426.1	609.54	131.57
196	0.0028316	11.384	2172.5	17.694	78.627	113.56	1413.7	587.61	130.73
198	0.0032918	11.350	2400.0	18.849	78.911	113.96	1401.4	566.84	129.90
200	0.0038135	11.316	2628.4	19.996	79.199	114.37	1389.1	547.15	129.06
202	0.0044031	11.282	2857.6	21.136	79.490	114.78	1376.9	528.46	128.21
204	0.0050671	11.248	3087.6	22.269	79.785	115.19	1364.7	510.71	127.37
206	0.0058130	11.213	3318.5	23.394	80.082	115.61	1352.6	493.83	126.52
208	0.0066482	11.179	3550.1	24.513	80.384	116.03	1340.5	477.76	125.67
210	0.0075808	11.145	3782.7	25.626	80.689	116.46	1328.4	462.45	124.82
212	0.0086196	11.110	4016.1	26.731	80.998	116.88	1316.3	447.85	123.97
214	0.0097734	11.075	4250.4	27.831	81.310	117.32	1304.4	433.92	123.12
216	0.011052	11.041	4485.5	28.924	81.626	117.76	1292.4	420.62	122.27
218	0.012465	11.006	4721.5	30.011	81.946	118.20	1280.5	407.90	121.41
220	0.014023	10.971	4958.5	31.092	82.269	118.65	1268.6	395.73	120.56
222	0.015736	10.936	5196.3	32.168	82.596	119.10	1256.7	384.08	119.71
224	0.017618	10.901	5435.1	33.238	82.927	119.55	1244.9	372.92	118.86
226	0.019678	10.865	5674.8	34.302	83.262	120.02	1233.0	362.23	118.02
228	0.021930	10.830	5915.4	35.361	83.601	120.48	1221.3	351.97	117.17
230	0.024387	10.794	6157.0	36.415	83.944	120.96	1209.5	342.12	116.32
232	0.027061	10.759	6399.5	37.464	84.290	121.43	1197.8	332.66	115.47
234	0.029967	10.723	6643.0	38.508	84.640	121.92	1186.1	323.57	114.63
236	0.033118	10.687	6887.5	39.547	84.995	122.41	1174.4	314.83	113.79
238	0.036530	10.651	7133.0	40.582	85.353	122.90	1162.8	306.42	112.94
240	0.040218	10.615	7379.5	41.612	85.714	123.40	1151.2	298.32	112.10
242	0.044196	10.578	7627.1	42.637	86.080	123.91	1139.6	290.53	111.27
244	0.048482	10.542	7875.6	43.658	86.450	124.42	1128.0	283.01	110.43
246	0.053092	10.505	8125.2	44.675	86.823	124.94	1116.4	275.77	109.60
248	0.058042	10.468	8375.9	45.688	87.200	125.46	1104.9	268.78	108.77
250	0.063350	10.431	8627.7	46.697	87.581	126.00	1093.4	262.04	107.94
252	0.069033	10.394	8880.5	47.703	87.966	126.54	1081.9	255.54	107.12
254	0.075109	10.357	9134.4	48.704	88.354	127.08	1070.4	249.25	106.30
256	0.081597	10.319	9389.5	49.702	88.746	127.63	1059.0	243.18	105.48
258	0.088516	10.281	9645.6	50.696	89.142	128.19	1047.5	237.31	104.67
260	0.095885	10.243	9903.0	51.687	89.541	128.76	1036.1	231.63	103.86
262	0.10372	10.205	10161	52.674	89.944	129.33	1024.7	226.14	103.05
264	0.11205	10.167	10421	53.658	90.351	129.91	1013.3	220.83	102.25
266	0.12089	10.128	10682	54.639	90.761	130.50	1002.0	215.68	101.45

TABLE 1 *Continued*

T K	P MPa	ρ $mol \cdot l^{-1}$	H $J \cdot mol^{-1}$	S $J \cdot mol^{-1} \cdot K^{-1}$	C_v $J \cdot mol^{-1} \cdot K^{-1}$	C_p $J \cdot mol^{-1} \cdot K^{-1}$	c $m \cdot s^{-1}$	η μPa·s	λ $mW \cdot m^{-1} \cdot K^{-1}$
268	0.13025	10.090	10944	55.617	91.175	131.10	990.63	210.70	100.66
270	0.14017	10.051	11207	56.592	91.592	131.70	979.29	205.87	99.867
272	0.15066	10.012	11472	57.564	92.012	132.32	967.96	201.19	99.082
274	0.16174	9.9721	11738	58.534	92.436	132.94	956.65	196.65	98.301
276	0.17344	9.9324	12005	59.501	92.864	133.57	945.35	192.25	97.524
278	0.18577	9.8925	12273	60.465	93.294	134.21	934.06	187.98	96.753
280	0.19876	9.8523	12543	61.427	93.728	134.86	922.77	183.83	95.986
282	0.21243	9.8118	12813	62.386	94.165	135.52	911.50	179.81	95.224
284	0.22681	9.7710	13086	63.343	94.606	136.19	900.23	175.89	94.467
286	0.24192	9.7300	13359	64.298	95.050	136.87	888.97	172.09	93.715
288	0.25777	9.6887	13635	65.250	95.496	137.56	877.72	168.40	92.969
290	0.27440	9.6470	13911	66.201	95.946	138.26	866.47	164.80	92.227
292	0.29183	9.6051	14189	67.150	96.400	138.97	855.22	161.31	91.491
294	0.31008	9.5628	14468	68.096	96.856	139.70	843.98	157.91	90.761
296	0.32917	9.5202	14749	69.042	97.315	140.43	832.74	154.59	90.036
298	0.34914	9.4773	15031	69.985	97.778	141.18	821.50	151.37	89.316
300	0.37000	9.4339	15315	70.927	98.243	141.94	810.25	148.22	88.602
302	0.39177	9.3902	15600	71.867	98.711	142.72	799.01	145.16	87.894
304	0.41450	9.3462	15887	72.806	99.183	143.51	787.76	142.17	87.191
306	0.43819	9.3017	16176	73.743	99.657	144.32	776.50	139.26	86.494
308	0.46288	9.2568	16466	74.680	100.13	145.14	765.24	136.41	85.803
310	0.48858	9.2114	16758	75.615	100.62	145.98	753.97	133.64	85.118
312	0.51534	9.1657	17051	76.549	101.10	146.84	742.69	130.92	84.439
314	0.54317	9.1194	17346	77.482	101.59	147.71	731.40	128.27	83.765
316	0.57209	9.0727	17643	78.414	102.07	148.61	720.10	125.68	83.098
318	0.60215	9.0255	17942	79.346	102.57	149.52	708.78	123.15	82.437
320	0.63335	8.9777	18242	80.276	103.06	150.46	697.45	120.67	81.781
322	0.66573	8.9295	18544	81.207	103.56	151.42	686.10	118.24	81.132
324	0.69932	8.8806	18848	82.137	104.06	152.40	674.72	115.86	80.489
326	0.73415	8.8312	19154	83.066	104.57	153.41	663.33	113.53	79.851
328	0.77023	8.7811	19462	83.995	105.08	154.45	651.91	111.25	79.220
330	0.80761	8.7304	19772	84.925	105.59	155.52	640.46	109.01	78.595
332	0.84630	8.6790	20084	85.854	106.11	156.62	628.99	106.81	77.976
334	0.88635	8.6270	20398	86.783	106.63	157.75	617.48	104.65	77.363
336	0.92776	8.5741	20715	87.713	107.15	158.92	605.94	102.53	76.757
338	0.97059	8.5206	21033	88.643	107.68	160.13	594.36	100.45	76.156
340	1.0148	8.4662	21354	89.574	108.21	161.39	582.74	98.394	75.561
342	1.0606	8.4109	21677	90.505	108.74	162.69	571.08	96.375	74.973
344	1.1078	8.3548	22002	91.438	109.28	164.04	559.37	94.387	74.390
346	1.1565	8.2977	22330	92.371	109.83	165.44	547.62	92.427	73.814
348	1.2068	8.2396	22661	93.306	110.38	166.91	535.81	90.495	73.243
350	1.2587	8.1805	22994	94.242	110.93	168.44	523.94	88.587	72.679
352	1.3123	8.1202	23330	95.180	111.49	170.04	512.02	86.704	72.120
354	1.3674	8.0588	23668	96.120	112.06	171.73	500.02	84.842	71.567
356	1.4243	7.9961	24010	97.062	112.63	173.50	487.96	83.000	71.020
358	1.4829	7.9321	24354	98.007	113.21	175.38	475.82	81.177	70.479
360	1.5433	7.8666	24702	98.954	113.80	177.37	463.60	79.371	69.944
362	1.6054	7.7996	25053	99.904	114.39	179.48	451.29	77.580	69.415
364	1.6694	7.7310	25408	100.86	114.99	181.74	438.89	75.802	68.891
366	1.7352	7.6606	25766	101.82	115.60	184.15	426.38	74.034	68.374
368	1.8030	7.5883	26128	102.78	116.22	186.76	413.76	72.277	67.862
370	1.8727	7.5139	26494	103.75	116.86	189.58	401.01	70.526	67.356
372	1.9444	7.4372	26864	104.72	117.50	192.66	388.14	68.779	66.856
374	2.0181	7.3580	27239	105.7	118.17	196.03	375.12	67.036	66.363
376	2.0939	7.2762	27619	106.68	118.84	199.74	361.94	65.292	65.877
378	2.1718	7.1913	28005	107.68	119.54	203.88	348.59	63.544	65.398
380	2.2519	7.1031	28396	108.68	120.26	208.53	335.05	61.791	64.926
382	2.3343	7.0111	28794	109.69	121.01	213.80	321.32	60.027	64.465
384	2.4189	6.9149	29198	110.72	121.79	219.85	307.36	58.248	64.014
386	2.5058	6.8138	29611	111.76	122.62	226.90	293.15	56.450	63.577
388	2.5951	6.7072	30032	112.81	123.49	235.25	278.69	54.626	63.158
390	2.6869	6.5941	30464	113.88	124.42	245.34	263.93	52.770	62.764
392	2.7812	6.4732	30907	114.98	125.42	257.82	248.86	50.870	62.403
394	2.8782	6.3430	31365	116.11	126.52	273.75	233.42	48.915	62.093
396	2.9778	6.2012	31840	117.27	127.74	294.88	217.58	46.887	61.861
398	3.0802	6.0444	32336	118.48	129.14	324.44	201.26	44.761	61.762
400	3.1856	5.8674	32862	119.75	130.78	369.01	184.38	42.498	61.898
402	3.2940	5.6611	33429	121.12	132.80	444.47	166.79	40.030	62.501
404	3.4057	5.4067	34065	122.65	135.47	601.19	148.23	37.215	64.151
406	3.5210	5.0501	34847	124.52	139.62	1125.7	128.12	33.651	68.999
407.81	3.6284	4.0403	36583	128.73	152.07	329210	106.84	25.500	348.88