

2.29 n-Butane

Equations for thermodynamic properties have been cited from reference [1].

2.29.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

2.29.2 The Names of Substance, Library File and Single Shot Program

Name of Substance:	n-Butane, Normal Butane
Library File for UNIX:	libjnc4h10.a
Library File for DOS,Windows95/NT:	JNC4H10.LIB
Single Shot Program for UNIX:	nc4h10-ss
Single Shot Program for DOS,Windows95/NT:	NC4H10-SS.EXE

2.29.3 Important Constants and Others

Molecular Formula:	CH ₃ CH ₂ CH ₂ CH ₃
Relative Molecular Mass:	58.1243
Gas Constant:	143.05 J/(kg·K)

Critical Constants:

Critical Pressure:	3.79612×10 ⁶ Pa (37.9612 bar)
Critical Temperature:	425.16 K (152.01°C)
Critical Specific Volume:	4.41×10 ⁻³ m ³ /kg

Triple Point:

Pressure:	0.6738 Pa (6.738×10 ⁻⁶ bar)
Temperature:	134.86 K (-138.29°C)

Reference State:

Zero is assigned to the specific internal energy at the triple point.

2.29.4 Formula

Equation of State:

Equation (6) in a function form of $P = P(\rho, T)$ in reference [1]. Here P = pressure, ρ = density and T = temperature.

Vapor Pressure:

Equation (2) in reference [1].

Properties at Vapor-Liquid Equilibrium:

Equation (3) for specific volume of saturated liquid and equation (4) for specific volume of saturated vapor, equations (13) and (17) for specific entropy, equations (14) and (17) for specific enthalpy, and equation (15) for isobaric specific heat, respectively. All of these have been cited from reference [1].

Pressure and Temperature on Melting Line:

Equation (1) in reference [1].

References

- [1] R.D.Goodwin, Normal Butane: Provisional Thermodynamic Functions from 135 to 700K at Pressures to 700 bar, National Bureau of Standards, NBSIR 79-1621 (September 1979)

Table II-2.29-1 n-Butane Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)		
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)		
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)		
3	ALAPT(T)		
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P*: Pressure [Pa], [bar]	$0.6738 \leq P \leq 3.79612 \times 10^6$ [Pa] $6.738 \times 10^{-6} \leq P \leq 37.9612$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T*: Temperature [K], [°C]	$134.86 \leq T \leq 425.16$ [K] $-138.29 \leq T \leq 152.01$ [°C]
6	ALMPD(P)		
7	ALMPDD(P)		
8	ALMPT(P,T)		
9	ALMTD(T)		
10	ALMTDD(T)		
11	AMUPD(P)		
12	AMUPDD(P)		
13	AMUPT(P,T)		
14	AMUTD(T)		
15	AMUTDD(T)		
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P*: Pressure [Pa], [bar]	$0.6738 \leq P \leq 3.79612 \times 10^6$ [Pa] $6.738 \times 10^{-6} \leq P \leq 37.9612$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P*: Pressure [Pa], [bar]	$0.6738 \leq P \leq 3.79612 \times 10^6$ [Pa] $6.738 \times 10^{-6} \leq P \leq 37.9612$ [bar]
18	CPPT(P,T)	Isobaric Specific Heat [J/(kg·K)] P*: Pressure [Pa], [bar] T*: Temperature [K], [°C]	$0.6738 \leq P \leq 70 \times 10^6$ [Pa] $TMLP(P) \leq T \leq 700$ [K] $6.738 \times 10^{-6} \leq P \leq 700$ [bar] $TMLP(P) \leq T \leq 426.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T*: Temperature [K], [°C]	$134.86 \leq T \leq 425.16$ [K] $-138.29 \leq T \leq 152.01$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T*: Temperature [K], [°C]	$134.86 \leq T \leq 425.16$ [K] $-138.29 \leq T \leq 152.01$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 783.5×10^3 [J/kg] Specific Enthalpy P*: 'A'='P': 3.79612×10^6 [Pa], 37.9612 [bar] Pressure S: 'A'='S': 5.129×10^3 [J/(kg·K)] Specific Entropy T*: 'A'='T': 425.16 [K], 152.01 [°C] Temperature V: 'A'='V': 4.41×10^{-3} [m ³ /kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'

Table II-2.29-1 n-Butane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P*: Pressure [Pa], [bar]	$0.6738 \leq P \leq 3.79612 \times 10^6$ [Pa] $6.738 \times 10^{-6} \leq P \leq 37.9612$ [bar]
77	CVPT(P,T)	Isochoric Specific Heat [J/(kg·K)] P*: Pressure [Pa], [bar] T*: Temperature [K], [°C]	$0.6738 \leq P \leq 70 \times 10^6$ [Pa] TMLP(P) $\leq T \leq 700$ [K] $6.738 \times 10^{-6} \leq P \leq 700$ [bar] TMLP(P) $\leq T \leq 426.85$ [°C]
7B	CVTD(T)		
78	CVTDD(P)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T*: Temperature [K], [°C]	$134.86 \leq T \leq 425.16$ [K] $-138.29 \leq T \leq 152.01$ [°C]
2A	EPSPD(P)		
2B	EPSPDD(P)		
22	EPSPT(P,T)		
2C	EPSTD(T)		
2D	EPSTDD(T)		
89	FC('A')	FC: Fundamental Constants M: 'A'='M': 58.1243 Relative Molecular Mass R: 'A'='R': 143.05 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)		
95	GAMPT(P,T)		
9B	GAMTD(T)		
97	GAMTDD(T)		
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P*: Pressure [Pa], [bar]	$0.6738 \leq P \leq 3.79612 \times 10^6$ [Pa] $6.738 \times 10^{-6} \leq P \leq 37.9612$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P*: Pressure [Pa], [bar]	$0.6738 \leq P \leq 3.79612 \times 10^6$ [Pa] $6.738 \times 10^{-6} \leq P \leq 37.9612$ [bar]
71	HPS(P,S)		
25	HPT(P,T)	Specific Enthalpy [J/kg] P*: Pressure [Pa], [bar] T*: Temperature [K], [°C]	$0.6738 \leq P \leq 70 \times 10^6$ [Pa] TMLP(P) $\leq T \leq 700$ [K] $6.738 \times 10^{-6} \leq P \leq 700$ [bar] TMLP(P) $\leq T \leq 426.85$ [°C]
26	HPX(P,X)		
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T*: Temperature [K], [°C]	$134.86 \leq T \leq 425.16$ [K] $-138.29 \leq T \leq 152.01$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T*: Temperature [K], [°C]	$134.86 \leq T \leq 425.16$ [K] $-138.29 \leq T \leq 152.01$ [°C]
29	HTX(T,X)		
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'CH3CH2CH2CH3' Molecular Formula S: 'A'='S': 'N-BUTANE' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)		
68	PMLT(T)	PMLT*: Pressure on Melting Curve [Pa], [bar] T*: Temperature [K], [°C]	$134.86 \leq T \leq 146.05$ [K] $-138.29 \leq T \leq -127.10$ [°C]
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		

Table II-2.29-1 n-Butane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST*: Saturation Pressure [Pa], [bar] T*: Temperature [K], [°C]	134.86 ≤ T ≤ 425.16 [K] -138.29 ≤ T ≤ 152.01 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)		
32	SIGT(P)		
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P*: Pressure [Pa], [bar]	0.6738 ≤ P ≤ 3.79612 × 10 ⁶ [Pa] 6.738 × 10 ⁻⁶ ≤ P ≤ 37.9612 [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P*: Pressure [Pa], [bar]	0.6738 ≤ P ≤ 3.79612 × 10 ⁶ [Pa] 6.738 × 10 ⁻⁶ ≤ P ≤ 37.9612 [bar]
35	SPT(P,T)	Specific Entropy [J/(kg·K)] P*: Pressure [Pa], [bar] T*: Temperature [K], [°C]	0.6738 ≤ P ≤ 70 × 10 ⁶ [Pa] TMLP(P) ≤ T ≤ 700 [K] 6.738 × 10 ⁻⁶ ≤ P ≤ 700 [bar] TMLP(P) ≤ T ≤ 426.85 [°C]
36	SPX(P,X)		
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T*: Temperature [K], [°C]	134.86 ≤ T ≤ 425.16 [K] -138.29 ≤ T ≤ 152.01 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T*: Temperature [K], [°C]	134.86 ≤ T ≤ 425.16 [K] -138.29 ≤ T ≤ 152.01 [°C]
39	STX(T,X)		
67	TLDP(P)		
69	TMLP(P)	TMLP*: Temperature on Melting Curve [K], [°C] P*: Pressure [Pa], [bar]	0.6738 ≤ P ≤ 70 × 10 ⁶ [Pa] 6.738 × 10 ⁻⁶ ≤ P ≤ 700 [bar]
64	TPH(P,H)		
6H	TPH2(P,H)		
65	TPS(P,S)		
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)		
41	TRPL('A')	TRPL*: Properties at Triple Point P*: 'A'='P': 0.6738 [Pa], 6.738 × 10 ⁻⁶ [bar] Pressure T*: 'A'='T': 134.86 [K], -138.29 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP*: Saturation Temperature [K], [°C] P*: Pressure [Pa], [bar]	0.6738 ≤ P ≤ 3.79612 × 10 ⁶ [Pa] 6.738 × 10 ⁻⁶ ≤ P ≤ 37.9612 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P*: Pressure [Pa], [bar]	0.6738 ≤ P ≤ 3.79612 × 10 ⁶ [Pa] 6.738 × 10 ⁻⁶ ≤ P ≤ 37.9612 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P*: Pressure [Pa], [bar]	0.6738 ≤ P ≤ 3.79612 × 10 ⁶ [Pa] 6.738 × 10 ⁻⁶ ≤ P ≤ 37.9612 [bar]
79	UPS(P,S)		
44	UPT(P,T)	Specific Internal Energy [J/kg] P*: Pressure [Pa], [bar] T*: Temperature [K], [°C]	0.6738 ≤ P ≤ 70 × 10 ⁶ [Pa] TMLP(P) ≤ T ≤ 700 [K] 6.738 × 10 ⁻⁶ ≤ P ≤ 700 [bar] TMLP(P) ≤ T ≤ 426.85 [°C]

Table II-2.29-1 n-Butane Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
45	UPX(P,X)		
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T*: Temperature [K], [°C]	134.86 ≤ T ≤ 425.16 [K] -138.29 ≤ T ≤ 152.01 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T*: Temperature [K], [°C]	134.86 ≤ T ≤ 425.16 [K] -138.29 ≤ T ≤ 152.01 [°C]
48	UTX(T,X)		
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m ³ /kg] P*: Pressure [Pa], [bar]	0.6738 ≤ P ≤ 3.79612 × 10 ⁶ [Pa] 6.738 × 10 ⁻⁶ ≤ P ≤ 37.9612 [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m ³ /kg] P*: Pressure [Pa], [bar]	0.6738 ≤ P ≤ 3.79612 × 10 ⁶ [Pa] 6.738 × 10 ⁻⁶ ≤ P ≤ 37.9612 [bar]
80	VPS(P,S)		
51	VPT(P,T)	Specific Volume [m ³ /kg] P*: Pressure [Pa], [bar] T*: Temperature [K], [°C]	0.6738 ≤ P ≤ 70 × 10 ⁶ [Pa] TMLP(P) ≤ T ≤ 700 [K] 6.738 × 10 ⁻⁶ ≤ P ≤ 700 [bar] TMLP(P) ≤ T ≤ 426.85 [°C]
52	VPX(P,X)		
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m ³ /kg] T*: Temperature [K], [°C]	134.86 ≤ T ≤ 425.16 [K] -138.29 ≤ T ≤ 152.01 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m ³ /kg] T*: Temperature [K], [°C]	134.86 ≤ T ≤ 425.16 [K] -138.29 ≤ T ≤ 152.01 [°C]
55	VTX(T,X)		
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	Velocity of Sound [m/s] P*: Pressure [Pa], [bar] T*: Temperature [K], [°C]	0.6738 ≤ P ≤ 70 × 10 ⁶ [Pa] TMLP(P) ≤ T ≤ 700 [K] 6.738 × 10 ⁻⁶ ≤ P ≤ 700 [bar] TMLP(P) ≤ T ≤ 426.85 [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)		
57	XPS(P,S)		
58	XPU(P,U)		
59	XPV(P,V)		
60	XTH(T,H)		
61	XTS(T,S)		
62	XTU(T,U)		
63	XTV(T,V)		