2.2 Helium 4(NIST-ITS 1990)

Equations for thermodynamic properties have been cited from reference [1] and [2].

2.2.1 Temperature Scale

International temperature scale 1990 (ITS-1990)

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

Name of Substance:	Helium 4
Library File for UNIX:	libjhe4i90.a
Library File for DOS,Windows95/NT:	JHE4I90.LIB
Single Shot Program for UNIX:	he4i90ss
Single Shot Program for DOS,Windows95/NT:	HE4I90SS.EXE

2.2.3 Important Constants and Others

Molecular Formula:	He
Relative Molecular Mass:	4.0026
Gas Constant:	2077.2 J/(kg·K)

Critical Constants:

Critical Pressure:	0.22746×10^6Pa (2.2746 bar)
Critical Temperature:	5.1953 K (−267.9547°C)
Critical Specific Volume:	0.014360 m^3/kg

Triple Point:

Pressure:	5.0418×10^3 Pa (0.05040 bar)
Temperature:	2.1768 K (−270.9732°C)

Reference State:

At temperature of 0.8K and density of 146.15 kg/m^3, 4.515 J/(kg·K) and -0.606 J/kg are assigned to the specific entropy and the specific Hermholtz free energy, respectively.

2.2.4 Formula

Equation of State:

Equation (7) in a function form of A=$A(v,T)$ in reference [1], and equation (3) in a form of $p(T,v)$ in reference [2]. Here A=specific Helmholtz free energy, v=specific volume , T=temperature and p=pressure.

Vapor Pressure:

Equation(2) in reference[3].

Pressure and Temperature on λ-Line:

Equation(3) in reference [4]

References

[1] V. D. Arp, J. Low Temp. Phys., vol.79, (1990), p.93
[2] R. D. McCarty and V. D. Arp, Adv. Cryogenic Eng., vol. 35, (1990), p.1465.
[3] M.Durieux and R.L.Rusby, Metrologia, vol.19, (1983), p.67
[4] H.A.Kierstead, Phys. Rev., vol.162, (1967), p.153

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
1	AIPPT(P,T)		
94	AJTPT(P,T)	AJTPT: Joule-Thomson Coefficient [K/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^{3}\leq P\leq2.5328\times10^{6}$ [Pa] $0.8\leq T\leq1500$ [K] $2.5328\times10^{6}<P\leq100\times10^{6}$ [Pa] TMLP(P)≤T≤1500 [K] $50.418\times10^{-3}\leq P\leq25.328$ [bar] $-272.35\leq T\leq1226.85$ [°C] 25.328<P≤1000 [bar] TMLP(P)≤T≤1226.85 [°C]
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^{3}\leq P\leq2.5328\times10^{6}$ [Pa] $0.8\leq T\leq1500$ [K] $2.5328\times10^{6}<P\leq100\times10^{6}$ [Pa] TMLP(P)≤T≤1500 [K] $50.418\times10^{-3}\leq P\leq25.328$ [bar] $-272.35\leq T\leq1226.85$ [°C] 25.328<P≤1000 [bar] TMLP(P)≤T≤1226.85 [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$1.47515\leq P\leq0.216454\times10^{6}$ [Pa] $14.7515\times10^{-6}\leq P\leq2.16454$ [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	$0.8\leq T\leq5.13$ [K] $-272.35\leq T\leq-268.02$ [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$1.47515\leq P\leq0.216454\times10^{6}$ [Pa] $14.7515\times10^{-6}\leq P\leq2.16454$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	$0.8\leq T\leq5.13$ [K] $-272.35\leq T\leq-268.02$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$47.04\times10^{3}<P\leq0.216454\times10^{6}$ [Pa] 0.4704<P≤2.16454 [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$47.04\times10^{3}<P\leq0.216454\times10^{6}$ [Pa] 0.4704<P≤2.16454 [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^{3}\leq P\leq10.485\times10^{6}$ [Pa] 3.5<T≤1500 [K] $10.485\times10^{6}<P\leq100\times10^{6}$ [Pa] TMLP(P)≤T≤1500 [K] $50.418\times10^{-3}\leq P\leq104.85$ [bar] $-269.65<T\leq1226.85$ [°C] 104.85<P≤1000 [bar] TMLP(P)≤T≤1226.85 [°C]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	3.5<T≤5.13 [K] $-269.65<T\leq-268.02$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	3.5<T≤5.13 [K] $-269.65<T\leq-268.02$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	$47.04\times10^{3}<P\leq0.216454\times10^{6}$ [Pa] 0.4704<P≤2.16454 [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	$47.04\times10^{3}<P\leq0.216454\times10^{6}$ [Pa] 0.4704<P≤2.16454 [bar]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^{3}\leq P\leq10.485\times10^{6}$ [Pa] $3.5<T\leq1500$ [K] $10.485\times10^{6}<P\leq100\times10^{6}$ [Pa] $TMLP(P)\leq T\leq1500$ [K] $50.418\times10^{-3}\leq P\leq104.85$ [bar] $-269.65<T\leq1226.85$ [°C] $104.85<P\leq1000$ [bar] $TMLP(P)\leq T\leq1226.85$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	$3.5<T\leq5.13$ [K] $-269.65<T\leq-268.02$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	$3.5<T\leq5.13$ [K] $-269.65<T\leq-268.02$ [°C]
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^{3}\leq P\leq2.5328\times10^{6}$ [Pa] $0.8\leq T\leq1500$ [K] $2.5328\times10^{6}<P\leq100\times10^{6}$ [Pa] $TMLP(P)\leq T\leq1500$ [K] $50.418\times10^{-3}\leq P\leq25.328$ [bar] $-272.35\leq T\leq1226.85$ [°C] $25.328<P\leq1000$ [bar] $TMLP(P)\leq T\leq1226.85$ [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^{3}\leq P\leq2.5328\times10^{6}$ [Pa] $0.8\leq T\leq1500$ [K] $2.5328\times10^{6}<P\leq100\times10^{6}$ [Pa] $TMLP(P)\leq T\leq1500$ [K] $50.418\times10^{-3}\leq P\leq25.328$ [bar] $-272.35\leq T\leq1226.85$ [°C] $25.328<P\leq1000$ [bar] $TMLP(P)\leq T\leq1226.85$ [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^{3}\leq P\leq2.5328\times10^{6}$ [Pa] $0.8\leq T\leq1500$ [K] $2.5328\times10^{6}<P\leq100\times10^{6}$ [Pa] $TMLP(P)\leq T\leq1500$ [K] $50.418\times10^{-3}\leq P\leq25.328$ [bar] $-272.35\leq T\leq1226.85$ [°C] $25.328<P\leq1000$ [bar] $TMLP(P)\leq T\leq1226.85$ [°C]
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^{3}\leq P\leq2.5328\times10^{6}$ [Pa] $0.8\leq T\leq1500$ [K] $2.5328\times10^{6}<P\leq100\times10^{6}$ [Pa] $TMLP(P)\leq T\leq1500$ [K] $50.418\times10^{-3}\leq P\leq25.328$ [bar] $-272.35\leq T\leq1226.85$ [°C] $25.328<P\leq1000$ [bar] $TMLP(P)\leq T\leq1226.85$ [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.47515\leq P\leq0.216454\times10^{6}$ [Pa] $14.7515\times10^{-6}\leq P\leq2.16454$ [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.47515\leq P\leq0.216454\times10^{6}$ [Pa] $14.7515\times10^{-6}\leq P\leq2.16454$ [bar]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^3\leq P\leq2.5328\times10^6$ [Pa] $0.8\leq T\leq1500$ [K] $2.5328\times10^6<P\leq100\times10^6$ [Pa] $TMLP(P)\leq T\leq1500$ [K] $50.418\times10^{-3}\leq P\leq25.328$ [bar] $-272.35\leq T\leq1226.85$ [°C] $25.328<P\leq1000$ [bar] $TMLP(P)\leq T\leq1226.85$ [°C]
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	$0.8\leq T\leq5.13$ [K] $-272.35\leq T\leq-268.02$ [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$0.8\leq T\leq5.13$ [K] $-272.35\leq T\leq-268.02$ [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 21.948×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 0.22746×10^6 [Pa], 2.2746 [bar] Pressure S: 'A'='S': 5.7685×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 5.1953 [K], −267.9547 [°C] Temperature V: 'A'='V': 0.014360 [m^3/kg] Specific Volume	one of 'H', 'P', 'S', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)	CVPDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$1.47515\leq P\leq0.216454\times10^6$ [Pa] $14.7515\times10^{-6}\leq P\leq2.16454$ [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^3\leq P\leq2.5328\times10^6$ [Pa] $0.8\leq T\leq1500$ [K] $2.5328\times10^6<P\leq100\times10^6$ [Pa] $TMLP(P)\leq T\leq1500$ [K] $50.418\times10^{-3}\leq P\leq25.328$ [bar] $-272.35\leq T\leq1226.85$ [°C] $25.328<P\leq1000$ [bar] $TMLP(P)\leq T\leq1226.85$ [°C]
7B	CVTD(T)		
78	CVTDD(T)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	$0.8\leq T\leq5.13$ [K] $-272.35\leq T\leq-268.02$ [°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': 4.0026 Relative Molecular Mass R: 'A'='R': 2077.2 [J/(kg·K)] Gas Constant	one of 'M' and 'R'
9A	GAMPD(P)		
96	GAMPDD(P)	GAMPDD: Ratio of Specific Heat of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	$1.47515\leq P\leq0.216454\times10^6$ [Pa] $14.7515\times10^{-6}\leq P\leq2.16454$ [bar]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heat [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^{3}\leq P\leq2.5328\times10^{6}$ [Pa] $0.8\leq T\leq1500$ [K] $2.5328\times10^{6}<P\leq100\times10^{6}$ [Pa] $TMLP(P)\leq T\leq1500$ [K] $50.418\times10^{-3}\leq P\leq25.328$ [bar] $-272.35\leq T\leq1226.85$ [°C] $25.328<P\leq1000$ [bar] $TMLP(P)\leq T\leq1226.85$ [°C]
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heat of Saturated Vapor [–] T∗: Temperature [K], [°C]	$0.8\leq T\leq5.13$ [K] $-272.35\leq T\leq-268.02$ [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.47515\leq P\leq0.216454\times10^{6}$ [Pa] $14.7515\times10^{-6}\leq P\leq2.16454$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.47515\leq P\leq0.216454\times10^{6}$ [Pa] $14.7515\times10^{-6}\leq P\leq2.16454$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$5.0418\times10^{3}\leq P\leq2.5328\times10^{6}$ [Pa] $SPT(P,0.8K)\leq S\leq$ SPT(P,1500K) [J/(kg·K)] $2.5328\times10^{6}<P\leq100\times10^{6}$ [Pa] $SPT(P,TMLP(P))\leq S\leq$ SPT(P,1500K) [J/(kg·K)] $50.418\times10^{-3}\leq P\leq25.328$ [bar] $SPT(P,-272.35°C)\leq S\leq$ SPT(P,1226.85°C) [J/(kg·K)] $25.328<P\leq1000$ [bar] $SPT(P,TMLP(P))\leq S\leq$ SPT(P,1226.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^{3}\leq P\leq2.5328\times10^{6}$ [Pa] $0.8\leq T\leq1500$ [K] $2.5328\times10^{6}<P\leq100\times10^{6}$ [Pa] $TMLP(P)\leq T\leq1500$ [K] $50.418\times10^{-3}\leq P\leq25.328$ [bar] $-272.35\leq T\leq1226.85$ [°C] $25.328<P\leq1000$ [bar] $TMLP(P)\leq T\leq1226.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.47515\leq P\leq0.216454\times10^{6}$ [Pa] $14.7515\times10^{-6}\leq P\leq2.16454$ [bar] $0\leq X\leq1.0$ [–]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	$0.8\leq T\leq5.13$ [K] $-272.35\leq T\leq-268.02$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	$0.8\leq T\leq5.13$ [K] $-272.35\leq T\leq-268.02$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	$0.8\leq T\leq5.13$ [K] $-272.35\leq T\leq-268.02$ [°C] $0\leq X\leq1.0$ [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'HE' Molecular Formula S: 'A'='S': 'HELIUM 4(NIST-ITS 1990)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
66	PLDT(T)	PLDT∗: Pressure on Lambda-line [Pa], [bar] T∗: Temperature [K], [°C]	1.7673≤T≤2.1768 [K] −271.383≤T≤−270.973 [°C]
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	0.8≤T≤13.8943 [K] −272.35≤T≤−259.256 [°C]
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	47.04×10^3≤P≤0.216454×10^6 [Pa] 0.4704≤P≤2.16454 [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	47.04×10^3≤P≤0.216454×10^6 [Pa] 0.4704≤P≤2.16454 [bar]
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	5.0418×10^3≤P≤10.485×10^6 [Pa] 3.5<T≤1500 [K] 10.485×10^6<P≤100×10^6 [Pa] TMLP(P)≤T≤1500 [K] 50.418×10^{-3}≤P≤104.85 [bar] −269.65<T≤1226.85 [°C] 104.85<P≤1000 [bar] TMLP(P)≤T≤1226.85 [°C]
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	3.5<T≤5.13 [K] −269.65<T≤−268.02 [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	3.5<T≤5.13 [K] −269.65<T≤−268.02 [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	0.8≤T≤5.1953 [K] −272.35≤T≤−267.9547 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	1.47515≤P≤0.216454×10^6 [Pa] 14.7515×10^{-6}≤P≤2.16454 [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	1.47515≤P≤0.216454×10^6 [Pa] 14.7515×10^{-6}≤P≤2.16454 [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	1.47515≤P≤0.216454×10^6 [Pa] 14.7515×10^{-6}≤P≤2.16454 [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	5.0418×10^3≤P≤2.5328×10^6 [Pa] 0.8≤T≤1500 [K] 2.5328×10^6<P≤100×10^6 [Pa] TMLP(P)≤T≤1500 [K] 50.418×10^{-3}≤P≤25.328 [bar] −272.35≤T≤1226.85 [°C] 25.328<P≤1000 [bar] TMLP(P)≤T≤1226.85 [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	1.47515≤P≤0.216454×10^6 [Pa] 14.7515×10^{-6}≤P≤2.16454 [bar] 0≤X≤1.0 [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C] 0≤X≤1.0 [–]
67	TLDP(P)	TLDP∗: Temperature on Lambda-line [K], [°C] P∗: Pressure [Pa], [bar]	5.0418×10^{3}≤P≤3.0134×10^{6} [Pa] 50.418×10^{-3}≤P≤30.134 [bar]
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	2.5328×10^{6}≤P≤100×10^{6} [Pa] 25.328≤P≤1000 [bar]
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	5.0418×10^{3}≤P≤2.5328×10^{6} [Pa] HPT(P,0.8K)≤H≤ HPT(P,1500K) [J/kg] 2.5328×10^{6}<P≤100×10^{6} [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,1500K) [J/kg] 50.418×10^{-3}≤P≤25.328 [bar] HPT(P,−272.35°C)≤H≤ HPT(P,1226.85°C) [J/kg] 25.328<P≤1000 [bar] HPT(P,TMLP(P))≤H≤ HPT(P,1226.85°C) [J/kg]
6H	TPH2(P,H)		
65	TPS(P,S)	TPS∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	5.0418×10^{3}≤P≤2.5328×10^{6} [Pa] SPT(P,0.8K)≤S≤ SPT(P,1500K) [J/(kg·K)] 2.5328×10^{6}<P≤100×10^{6} [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1500K) [J/(kg·K)] 50.418×10^{-3}≤P≤25.328 [bar] SPT(P,−272.85°C)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] 25.328<P≤1000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1226.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] T∗: Temperature [K], [°C]	0.2275×10^{6}<P≤50×10^{6} [Pa] 2.275<P≤500 [bar]
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	5.0418×10^{3}≤P≤2.5328×10^{6} [Pa] VPT(P,TLDP(P))≤V≤ VPT(P,1500K) [m^3/kg] 2.5328×10^{6}<P≤100×10^{6} [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,1500K) [m^3/kg] 50.418×10^{-3}≤P≤25.328 [bar] VPT(P,TLDP(P))≤V≤ VPT(P,1226.85°C) [m^3/kg] 25.328<P≤1000 [bar] VPT(P,TLDP(P))≤V≤ VPT(P,1226.85°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 5.0418×10^{3} [Pa], 50.418×10^{-3} [bar] Pressure T∗: 'A'='T': 2.1768 [K], −270.9732 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	1.47515≤P≤0.22746×10^{6} [Pa] 14.7515×10^{-6}≤P≤2.2746 [bar]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.216454 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.16454$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.216454 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.16454$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$5.0418 \times 10^3 \leq P \leq 2.5328 \times 10^6$ [Pa] SPT(P,0.8K)≤S≤ SPT(P,1500K) [J/(kg·K)] $2.5328 \times 10^6 < P \leq 100 \times 10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1500K) [J/(kg·K)] $50.418 \times 10^{-3} \leq P \leq 25.328$ [bar] SPT(P,−272.85°C)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] 25.328<P≤1000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1226.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418 \times 10^3 \leq P \leq 2.5328 \times 10^6$ [Pa] 0.8≤T≤1500 [K] $2.5328 \times 10^6 < P \leq 100 \times 10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418 \times 10^{-3} \leq P \leq 25.328$ [bar] −272.35≤T≤1226.85 [°C] 25.328<P≤1000 [bar] TMLP(P)≤T≤1226.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.47515 \leq P \leq 0.216454 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.16454$ [bar] 0≤X≤1.0 [–]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.22746 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.2746$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	$1.47515 \leq P \leq 0.22746 \times 10^6$ [Pa] $14.7515 \times 10^{-6} \leq P \leq 2.2746$ [bar]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$5.0418\times10^3\leq P\leq2.5328\times10^6$ [Pa] SPT(P,0.8K)≤S≤ SPT(P,1500K) [J/(kg·K)] $2.5328\times10^6<P\leq100\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1500K) [J/(kg·K)] $50.418\times10^{-3}\leq P\leq25.328$ [bar] SPT(P,−272.85°C)≤S≤ SPT(P,1226.85°C) [J/(kg·K)] 25.328<P≤1000 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1226.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^3\leq P\leq2.5328\times10^6$ [Pa] 0.8≤T≤1500 [K] $2.5328\times10^6<P\leq100\times10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418\times10^{-3}\leq P\leq25.328$ [bar] −272.35≤T≤1226.85 [°C] 25.328<P≤1000 [bar] TMLP(P)≤T≤1226.85 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$1.47515\leq P\leq0.22746\times10^6$ [Pa] $14.7515\times10^{-6}\leq P\leq2.4746$ [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	0.8≤T≤5.1953 [K] −272.35≤T≤−267.9547 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	0.8≤T≤5.1953 [K] −272.35≤T≤−267.9547 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	0.8≤T≤5.1953 [K] −272.35≤T≤−267.9547 [°C] 0≤X≤1.0 [–]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)	WPT: Velocity of Sound [m/s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.0418\times10^3\leq P\leq2.5328\times10^6$ [Pa] 0.8≤T≤1500 [K] $2.5328\times10^6<P\leq100\times10^6$ [Pa] TMLP(P)≤T≤1500 [K] $50.418\times10^{-3}\leq P\leq25.328$ [bar] −272.35≤T≤1226.85 [°C] 25.328<P≤1000 [bar] TMLP(P)≤T≤1226.85 [°C]
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$1.47515\leq P\leq0.216454\times10^6$ [Pa] $14.7515\times10^{-6}\leq P\leq2.16454$ [bar] HPD(P)≤H≤HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [–] P∗: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$1.47515\leq P\leq0.216454\times10^6$ [Pa] $14.7515\times10^{-6}\leq P\leq2.16454$ [bar] SPD(P)≤S≤SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [–] P∗: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$1.47515\leq P\leq0.216454\times10^6$ [Pa] $14.7515\times10^{-6}\leq P\leq2.16454$ [bar] UPD(P)≤U≤UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [–] P∗: Pressure [Pa], [bar] V: Specific Volume of Mixture [m^3/kg]	$1.47515\leq P\leq0.22746\times10^6$ [Pa] $14.7515\times10^{-6}\leq P\leq2.2746$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]

Table II–2.2–1 Helium 4 (NIST−ITS 1990) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C] HTD(T)≤H≤HTDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTU: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	0.8≤T≤5.13 [K] −272.35≤T≤−268.02 [°C] UTD(T)≤U≤UTDD(T) [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T∗: Temperature [K], [°C] V: Specific Volume of Mixture [m^3/kg]	0.8≤T≤5.1953 [K] −272.35≤T≤−267.9547 [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]