2. Individual Sustance and Formulation

2.1 Helium 4(IUPAC-IPTS 1968)

Equations for thermodynamic properties have been cited from the IUPAC Table[1], and those for transport properties from McCarty et al.[2] and Hands et al.[3].

2.1.1 Temperature Scale

International practical temperature scale 1968 (IPTS-1968)

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

Name of Substance:	Helium 4
Library File for UNIX:	libjhe4.a
Library File for DOS,Windows95/NT:	JHE4.LIB
Single Shot Program for UNIX:	he4-ss
Single Shot Program for DOS,Windows95/NT:	HE4–SS.EXE

2.1.3 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:	5.2014 K (−267.9486°C)
Critical Specific Volume:	0.014360 m^3/kg

Triple Point:

Pressure:	5.040×10^3 Pa (0.05040 bar)
Temperature:	2.1773 K (−270.9727°C)

Reference State:

At 1.01325 bar(1 atm) and 25°C(298.15 K)(ideal gas state) 126.039 J/(mol·K) and 6197 J/mol are assigned to the specific entropy and the specific enthalpy, respectively.

2.1.4 Formula

Equation of State:

Equation (14) in a function form of P=$P(\rho, T)$ in reference [1]. Here P=pressure, ρ=density and T=temperature. However, n_{50}, n_{51}, n_{60}, n_{61}, n_{62}, n_{70}, n_{71}, n_{72} in table I in the same reference have been corrected as n_{60}, n_{61}, n_{62}, n_{70}, n_{71}, n_{72}, n_{50}, n_{51}, respectively.

Vapor Pressure:

Equation(7) in reference[1]. However 1.2774706525×10^2 in table J in the same reference have been corrected as 1.4127497598×10^2.

Properties at Vapor-Liquid Equilibrium:

Equations (7), (8) and (14) for specific volume, equation (7) and the equation given on page 39 for specific entropy, and equation (7) and the equation given on page 40 for specific enthalpy, and equations (7) and (23) for isosbaric specific heat, respectively. All of these have been cited from reference[1].

Pressure and Temperature on λ-Line:

Equation (3) in reference [1]

Pressure and Temperature on Melting Line:
Equations (5) and (6) in reference [1]

Transport Properties:
Viscosity from reference[2] and thermal conductivity from reference[3]. Both are valid in the temperature range of T<173.15 °C(100 K).

References

[1] S.Angus and K.M.de Reuck, Helium International Thermodynamic Table of the Fluid State, IUPAC, (1977).
[2] R.D.McCarty, N.B.S. Technical Note 631, (Nov., 1972), p.9.
[3] B.A.Hands and V.D.Arp, Cryogenics, vol.21, (1981), p.697.

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) 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]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C] exclude the critical region shown in Fig.II-2-2
8A	AKPD(P)		
8B	AKPDD(P)		
82	AKPT(P,T)	AKPT: Isentropic Exponent [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]
8C	AKTD(T)		
8D	AKTDD(T)		
2	ALAPP(P)	ALAPP: Laplace Coefficient [m] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.218797\times10^6$ [Pa] 0.0504≤P≤2.18797 [bar]
3	ALAPT(T)	ALAPT: Laplace Coefficient [m] T∗: Temperature [K], [°C]	2.1773≤T≤5.15 [K] −270.9727≤T≤−268 [°C]
4	ALHP(P)	ALHP: Latent Heat of Vaporization [J/kg] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)] P∗: Pressure [Pa], [bar]	$46.99\times10^3\leq P\leq0.219\times10^6$ [Pa] 0.4699≤P≤2.19 [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	$46.99\times10^3\leq P\leq0.219\times10^6$ [Pa] 0.4699≤P≤2.19 [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3\leq P<10.397\times10^6$ [Pa] 3.5≤T≤300 [K] $10.397\times10^6\leq P\leq70\times10^6$ [Pa] TMLP(P)≤T≤300 [K] 0.0504≤P<103.97 [bar] −269.65≤T≤26.85 [°C] 103.97≤P≤700 [bar] TMLP(P)≤T≤26.85 [°C] exclude the critical region shown in Fig.II-2-1
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T∗: Temperature [K], [°C]	3.5≤T≤5.15 [K] −269.65≤T≤−268 [°C]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T∗: Temperature [K], [°C]	3.5≤T≤5.15 [K] −269.65≤T≤−268 [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P∗: Pressure [Pa], [bar]	46.99×10^3≤P≤0.22746×10^6 [Pa] 0.4699≤P≤2.2746 [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P∗: Pressure [Pa], [bar]	46.99×10^3≤P≤0.22746×10^6 [Pa] 0.4699≤P≤2.2746 [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	5.04×10^3≤P<10.397×10^6 [Pa] 3.5≤T≤300 [K] 10.397×10^6≤P≤70×10^6 [Pa] TMLP(P)≤T≤300 [K] 0.0504≤P<103.97 [bar] −269.65≤T≤26.85 [°C] 103.97≤P≤700 [bar] TMLP(P)≤T≤26.85 [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T∗: Temperature [K], [°C]	3.5≤T≤5.2014 [K] −269.65≤T≤−267.9486 [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T∗: Temperature [K], [°C]	3.5≤T≤5.2014 [K] −269.65≤T≤−267.9486 [°C]
92	BPPT(P,T)	BPPT: Volumetric Coefficient of Expansion [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	5.04×10^3≤P<3.013×10^6 [Pa] TLDP(P)≤T≤1400 [K] 3.013×10^6≤P≤70×10^6 [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]
90	BSPT(P,T)	BSPT: Isentropic Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	5.04×10^3≤P<3.013×10^6 [Pa] TLDP(P)≤T≤1400 [K] 3.013×10^6≤P≤70×10^6 [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]
91	BTPT(P,T)	BTPT: Isothermal Compressibility [1/Pa] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	5.04×10^3≤P<3.013×10^6 [Pa] TLDP(P)≤T≤1400 [K] 3.013×10^6≤P≤70×10^6 [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
93	BVPT(P,T)	BVPT: Pressure Coefficient [1/K] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]
16	CPPD(P)	CPPD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.219\times10^6$ [Pa] 0.0504≤P≤2.19 [bar]
17	CPPDD(P)	CPPDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.219\times10^6$ [Pa] 0.0504≤P≤2.19 [bar]
18	CPPT(P,T)	CPPT: Isobaric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C] exclude the critical region shown in Fig.II-2-2
19	CPTD(T)	CPTD: Isobaric Specific Heat of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	2.1773≤T≤5.15 [K] −270.9727≤T≤−268 [°C]
20	CPTDD(T)	CPTDD: Isobaric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	2.1773≤T≤5.15 [K] −270.9727≤T≤−268 [°C]
21	CRP('A')	CRP: Critical Constants H: 'A'='H': 6.7406×10^3 [J/kg] Specific Enthalpy P∗: 'A'='P': 0.22746×10^6 [Pa], 2.2746 [bar] Pressure S: 'A'='S': 5.6988×10^3 [J/(kg·K)] Specific Entropy T∗: 'A'='T': 5.2014 [K], −267.9486 [°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]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar]
77	CVPT(P,T)	CVPT: Isochoric Specific Heat [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]
7B	CVTD(T)		
78	CVTDD(P)	CVTDD: Isochoric Specific Heat of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
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]	$5.04\times10^3\leq P\leq0.219\times10^6$ [Pa] $0.0504\leq P\leq2.19$ [bar]
95	GAMPT(P,T)	GAMPT: Ratio of Specific Heat [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] $0.0504\leq P<30.13$ [bar] TLDP(P)≤T≤1126.85 [°C] $30.13\leq P\leq700$ [bar] TMLP(P)≤T≤1126.85 [°C] exclude the critical region shown in Fig.II-2-2
9B	GAMTD(T)		
97	GAMTDD(T)	GAMTDD: Ratio of Specific Heat of Saturated Vapor [–] T∗: Temperature [K], [°C]	$2.1773\leq T\leq5.15$ [K] $-270.9727\leq T\leq-268$ [°C]
23	HPD(P)	HPD: Specific Enthalpy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] $0.0504\leq P\leq2.2746$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] $0.0504\leq P\leq2.2746$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] SPT(P,TLDP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] $0.0504\leq P<30.13$ [bar] SPT(P,TLDP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)] $30.13\leq P\leq700$ [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $0.0504\leq P<30.13$ [bar] TLDP(P)≤T≤1126.85 [°C] $30.13\leq P\leq700$ [bar] TMLP(P)≤T≤1126.85 [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] $0.0504\leq P\leq2.2746$ [bar] $0\leq X\leq1.0$ [–]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C] 0≤X≤1.0 [–]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'HE' Molecular Formula S: 'A'='S': 'HELIUM 4(IUPAC−IPTS 1968)' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'
66	PLDT(T)	PLDT∗: Pressure on Lambda-line [Pa], [bar] T∗: Temperature [K], [°C]	1.7678≤T≤2.1773 [K] −271.3822≤T≤−270.9727 [°C]
68	PMLT(T)	PMLT∗: Pressure on Melting Curve [Pa], [bar] T∗: Temperature [K], [°C]	1.7678≤T≤11.023 [K] −271.3822≤T≤−262.127 [°C]
85	PRPD(P)	PRPD: Prandtl Number of Saturated Liquid [–] P∗: Pressure [Pa], [bar]	46.99×10^3≤P≤0.219×10^6 [Pa] 0.4699≤P≤2.19 [bar]
86	PRPDD(P)	PRPDD: Prandtl Number of Saturated Vapor [–] P∗: Pressure [Pa], [bar]	46.99×10^3≤P≤0.219×10^6 [Pa] 0.4699≤P≤2.19 [bar]
81	PRPT(P,T)	PRPT: Prandtl Number [–] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	5.04×10^3≤P≤10.397×10^6 [Pa] 3.5≤T≤300 [K] 10.397×10^6≤P≤70×10^6 [Pa] TMLP(P)≤T≤300 [K] 0.0504≤P≤103.97 [bar] −269.65≤T≤26.85 [°C] 103.97≤P≤700 [bar] TMLP(P)≤T≤26.85 [°C] exclude the critical region shown in Fig.II-2-1
87	PRTD(T)	PRTD: Prandtl Number of Saturated Liquid [–] T∗: Temperature [K], [°C]	3.5≤T≤5.15 [K] −269.65≤T≤−268 [°C]
88	PRTDD(T)	PRTDD: Prandtl Number of Saturated Vapor [–] T∗: Temperature [K], [°C]	3.5≤T≤5.15 [K] −269.65≤T≤−268 [°C]
99	PSBT(T)		
30	PST(T)	PST∗: Saturation Pressure [Pa], [bar] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P∗: Pressure [Pa], [bar]	5.04×10^3≤P≤0.218797×10^6 [Pa] 0.0504≤P≤2.18797 [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T∗: Temperature [K], [°C]	2.1773≤T≤5.15 [K] −270.9727≤T≤−268 [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P∗: Pressure [Pa], [bar]	5.04×10^3≤P≤0.22746×10^6 [Pa] 0.0504≤P≤2.2746 [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P∗: Pressure [Pa], [bar]	5.04×10^3≤P≤0.22746×10^6 [Pa] 0.0504≤P≤2.2746 [bar]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar] 0≤X≤1.0 [–]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C] 0≤X≤1.0 [–]
67	TLDP(P)	TLDP∗: Temperature on Lambda-line [K], [°C] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] 0.0504≤P<30.13 [bar]
69	TMLP(P)	TMLP∗: Temperature on Melting Curve [K], [°C] P∗: Pressure [Pa], [bar]	$3.013\times10^6\leq P\leq70\times10^6$ [Pa] 30.13≤P≤700 [bar]
64	TPH(P,H)	TPH∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] HPT(P,TLDP(P))≤H≤ HPT(P,1400K) [J/kg] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] HPT(P,TMLP(P))≤H≤ HPT(P,1400K) [J/kg] 0.0504≤P<30.13 [bar] HPT(P,TLDP(P))≤H≤ HPT(P,1126.85°C) [J/kg] 30.13≤P≤700 [bar] HPT(P,TMLP(P))≤H≤ HPT(P,1126.85°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)]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] SPT(P,TLDP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] 0.0504≤P<30.13 [bar] SPT(P,TLDP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)] 30.13≤P≤700 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)	TPSEUP: Pseudo Boiling Point [K], [°C] T∗: Temperature [K], [°C]	$0.228\times10^6<P\leq50\times10^6$ [Pa] 2.28<P≤500 [bar]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
70	TPV(P,V)	TPV∗: Temperature [K], [°C] P∗: Pressure [Pa], [bar] V: Specific Volume [m^3/kg]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] VPT(P,TLDP(P))≤V≤ VPT(P,1400K) [m^3/kg] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] VPT(P,TMLP(P))≤V≤ VPT(P,1400K) [m^3/kg] 0.0504≤P<30.13 [bar] VPT(P,TLDP(P))≤V≤ VPT(P,1126.85°C) [m^3/kg] 30.13≤P≤700 [bar] VPT(P,TMLP(P))≤V≤ VPT(P,1126.85°C) [m^3/kg]
41	TRPL('A')	TRPL∗: Properties at Triple Point P∗: 'A'='P': 5.04×10^3 [Pa], 0.0504 [bar] Pressure T∗: 'A'='T': 2.1773 [K], −270.9727 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP∗: Saturation Temperature [K], [°C] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P∗: Pressure [Pa], [bar]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] SPT(P,TLDP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] 0.0504≤P<30.13 [bar] SPT(P,TLDP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)] 30.13≤P≤700 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	$5.04\times10^3\leq P<3.013\times10^6$ [Pa] TLDP(P)≤T≤1400 [K] $3.013\times10^6\leq P\leq70\times10^6$ [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] 0.0504≤P≤2.2746 [bar] 0≤X≤1.0 [–]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C] 0≤X≤1.0 [–]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m^3/kg] P∗: Pressure [Pa], [bar]	5.04×10^3≤P≤0.22746×10^6 [Pa] 0.0504≤P≤2.2746 [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m^3/kg] P∗: Pressure [Pa], [bar]	5.04×10^3≤P≤0.22746×10^6 [Pa] 0.0504≤P≤2.2746 [bar]
80	VPS(P,S)	VPS: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	5.04×10^3≤P<3.013×10^6 [Pa] SPT(P,TLDP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] 3.013×10^6≤P≤70×10^6 [Pa] SPT(P,TMLP(P))≤S≤ SPT(P,1400K) [J/(kg·K)] 0.0504≤P<30.13 [bar] SPT(P,TLDP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)] 30.13≤P≤700 [bar] SPT(P,TMLP(P))≤S≤ SPT(P,1126.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m^3/kg] P∗: Pressure [Pa], [bar] T∗: Temperature [K], [°C]	5.04×10^3≤P<3.013×10^6 [Pa] TLDP(P)≤T≤1400 [K] 3.013×10^6≤P≤70×10^6 [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m^3/kg] P∗: Pressure [Pa], [bar] X: Dryness Fraction [–]	5.04×10^3≤P≤0.22746×10^6 [Pa] 0.0504≤P≤2.2746 [bar] 0≤X≤1.0 [–]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m^3/kg] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m^3/kg] T∗: Temperature [K], [°C]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m^3/kg] T∗: Temperature [K], [°C] X: Dryness Fraction [–]	2.1773≤T≤5.2014 [K] −270.9727≤T≤−267.9486 [°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]	5.04×10^3≤P<3.013×10^6 [Pa] TLDP(P)≤T≤1400 [K] 3.013×10^6≤P≤70×10^6 [Pa] TMLP(P)≤T≤1400 [K] 0.0504≤P<30.13 [bar] TLDP(P)≤T≤1126.85 [°C] 30.13≤P≤700 [bar] TMLP(P)≤T≤1126.85 [°C]

Table II–2.1–1 Helium 4(IUPAC−IPTS 1968) Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [–] P∗: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] $0.0504\leq P\leq2.2746$ [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)]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] $0.0504\leq P\leq2.2746$ [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]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] $0.0504\leq P\leq2.2746$ [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]	$5.04\times10^3\leq P\leq0.22746\times10^6$ [Pa] $0.0504\leq P\leq2.2746$ [bar] VPD(P)≤V≤VPDD(P) [m^3/kg]
60	XTH(T,H)	XTH: Dryness Fraction [–] T∗: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$2.1773\leq T\leq5.2014$ [K] $-270.9727\leq T\leq-267.9486$ [°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)]	$2.1773\leq T\leq5.2014$ [K] $-270.9727\leq T\leq-267.9486$ [°C] STD(T)≤S≤STDD(T) [J/(kg·K)]
62	XTU(T,U)	XTS: Dryness Fraction [–] T∗: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$2.1773\leq T\leq5.2014$ [K] $-270.9727\leq T\leq-267.9486$ [°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]	$2.1773\leq T\leq5.2014$ [K] $-270.9727\leq T\leq-267.9486$ [°C] VTD(T)≤V≤VTDD(T) [m^3/kg]

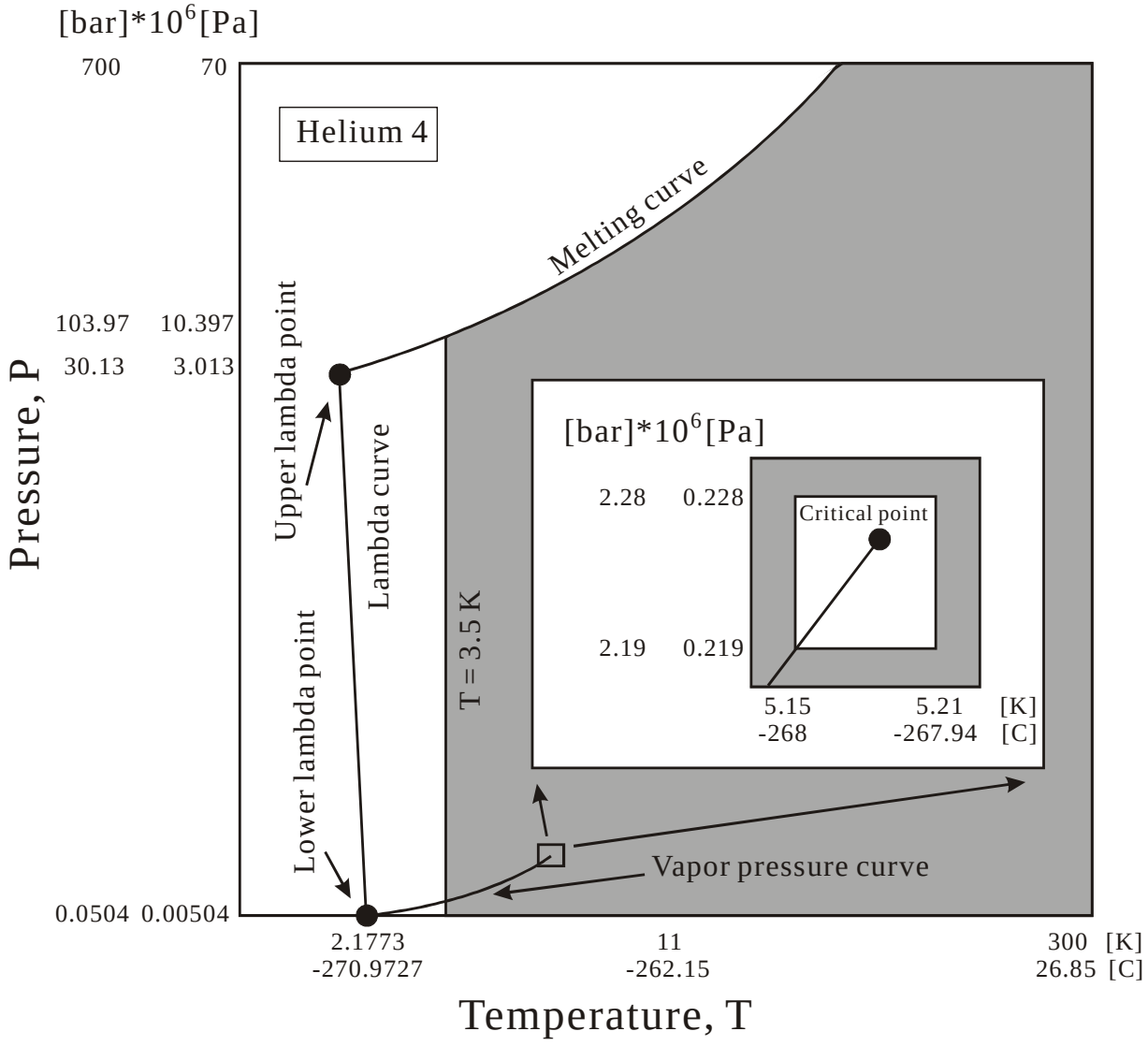

Fig.II–2.1–1 Range of Arguments(P,T) for ALMPT(P,T) and PRPT(P,T).

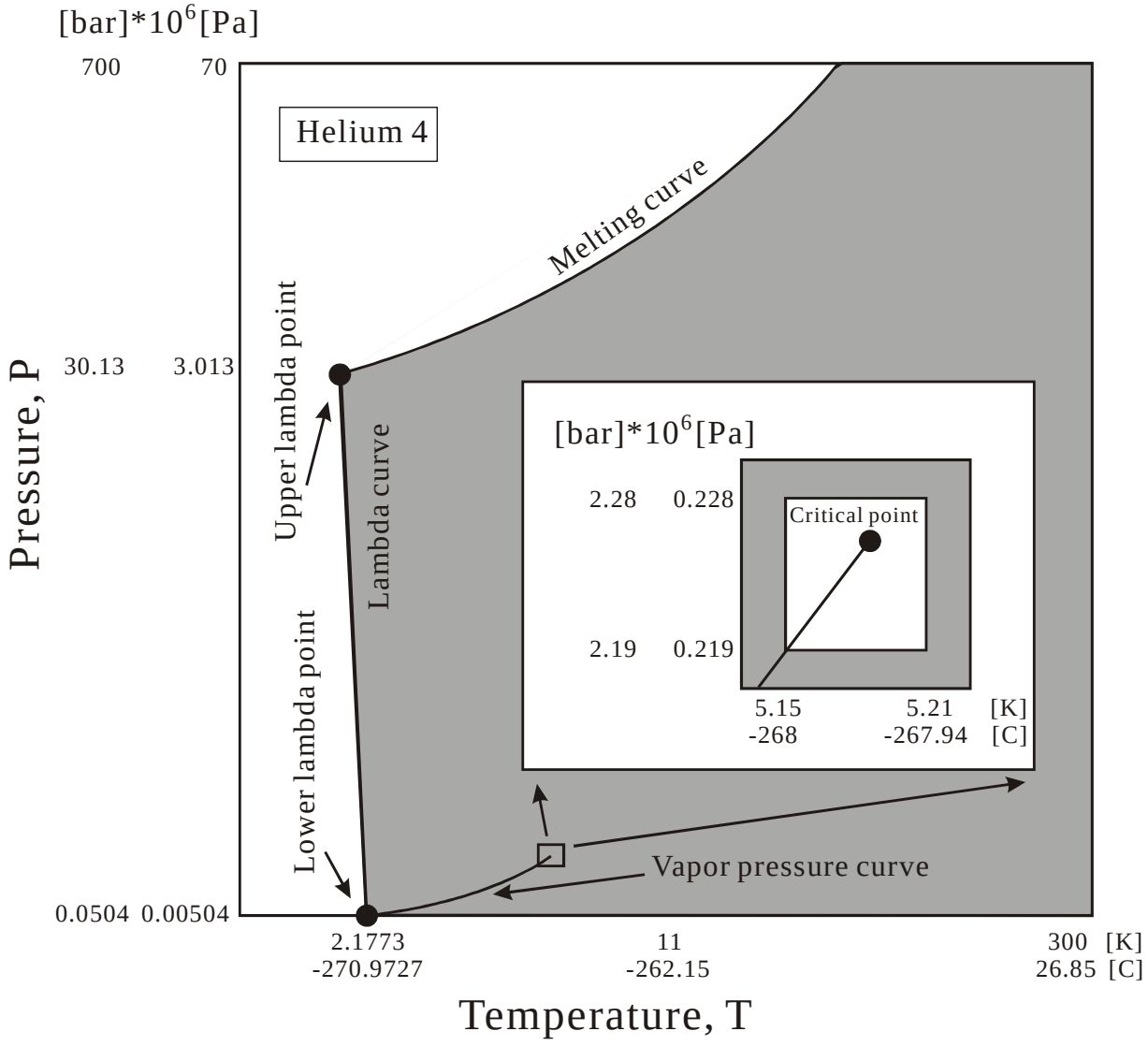

Fig.II–2.1–2 Range of Arguments(P,T) for AJTPT(P,T),CPPT(P,T) and GAMPT(P,T).