

2.21 Ammonia (Tillner–Roth, Harms–Watzenberg and Baehr)

Equations for thermodynamic properties are based on Tillner–Roth, Harms–Watzenberg and Baehr [1]. The Equation for viscosity has been cited from Fenghour, Wakeham, Vesovic, Watson, Millat and Vogel [2], that for thermal conductivity from Yata [3], and that for surface tension from Liley and Desai [4].

2.21.1 Temperature Scale

International temperature scale 1990 (ITS-1990)

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

Name of Substance:	Ammonia
Library File for UNIX:	libjnh32.a
Library File for DOS,Windows95/NT:	JNH32.LIB
Single Shot Program for UNIX:	nh32-ss
Single Shot Program for DOS,Windows95/NT:	NH32-SS.EXE

2.21.3 Important Constants and Others

Molecular Formula:	NH ₃
Relative Molecular Mass:	17.03026
Gas Constant:	488.189 J/(kg·K)

Critical Constants:

Critical Pressure:	11.36×10 ⁶ Pa (113.6 bar)
Critical Temperature:	405.40 K (132.25°C)
Critical Specific Volume:	4.444×10 ⁻³ m ³ /kg

Triple Point:

Pressure:	6.063×10 ³ Pa (0.06063 bar)
Temperature:	195.495 K (−77.655°C)

Reference State:

At 273.15 K (0°C), 200 kJ/kg and 1 kJ/(kg·K) are assigned to the specific enthalpy and specific entropy of saturated liquid, respectively.

2.21.4 Formula

Equation of State:

Equations (1)–(4) in a function form of $\Phi = \Phi(\tau, \delta)$ in reference [1]. Here Φ =specific helmholtz free energy, $\tau = 405.40/T$, $\delta = \rho/225$, T = temperature (K), ρ = density (kg/m³).

Properties at Vapor-Liquid Equilibrium:

The properties at Vapor–Liquid Equilibrium are calculated by Phase–equilibrium condition (Maxwell criterion). All of those have been cited from reference [1].

Transport Properties:

Viscosiy, thermal conductivity and surface tension are cited from reference [2], [3] and [4], respectively.

References

- [1] R. Tillner–Roth, F. Harms–Watzenberg and H. D. Baehr, Eine neue Fundamentalgleichung für Ammoniakm, Proc. 20th DKV–Tagung Heidelberg, Germany, Vol. II, (1993), pp.167
- [2] A. Fenghour, W. A. Wakeham, V. Vesovic, J. T. R. Watson, J. Millat and E. Vogel, J. Phys. Chem. Ref. Data, Vol. 24, 5, (1995), pp.1649.
- [3] J. Yata, Private communication.
- [4] P. E. Liley and P. D. Desai, Thermophysical Properties of Refrigerants (Inch–Pound Edition), American Society of Heating, Refrigerating and Air-Conditioning Engineers, (1993), pp.204.

Table II-2.21-1 Ammonia 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]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
5	ALHT(T)	ALHT: Latent Heat of Vaporization [J/kg] T*: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
6	ALMPD(P)	ALMPD: Thermal Conductivity of Saturated Liquid [W/(m·K)]	$40.8339 \times 10^3 \leq P \leq 10.4652 \times 10^6$ [Pa] $0.408339 \leq P \leq 104.652$ [bar]
7	ALMPDD(P)	ALMPDD: Thermal Conductivity of Saturated Vapor [W/(m·K)]	$40.8339 \times 10^3 \leq P \leq 9.71034 \times 10^6$ [Pa] $0.408339 \leq P \leq 97.1034$ [bar]
8	ALMPT(P,T)	ALMPT: Thermal Conductivity [W/(m·K)] P*: Pressure [Pa], [bar] T*: Temperature [K], [°C]	$0 < P \leq 50.0 \times 10^6$ [Pa] $223.15 \leq T \leq 573.15$ [K] $0 < P \leq 500$ [bar] $-50.0 \leq T \leq 300$ [°C] out of range: $395.0 < T < 430.0$ [K] $112.5 < \rho < 337.5$ [kg/m ³]
9	ALMTD(T)	ALMTD: Thermal Conductivity of Saturated Liquid [W/(m·K)] T*: Temperature [K], [°C]	$223.15 \leq T \leq 401.064$ [K] $-50.0 \leq T \leq 127.914$ [°C]
10	ALMTDD(T)	ALMTDD: Thermal Conductivity of Saturated Vapor [W/(m·K)] T*: Temperature [K], [°C]	$223.15 \leq T \leq 396.8669$ [K] $-50.0 \leq T \leq 123.7169$ [°C]
11	AMUPD(P)	AMUPD: Coefficient of Viscosity of Saturated Liquid [Pa·s] P*: Pressure [Pa], [bar]	$6.06 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $6.06 \times 10^{-2} \leq P \leq 113.6$ [bar]
12	AMUPDD(P)	AMUPDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] P*: Pressure [Pa], [bar]	$6.06 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $6.06 \times 10^{-2} \leq P \leq 113.6$ [bar]
13	AMUPT(P,T)	AMUPT: Coefficient of Viscosity [Pa·s] P*: Pressure [Pa], [bar] T*: Temperature [K], [°C]	$0 < P \leq 50.0 \times 10^6$ [Pa] $196.0 \leq T \leq 700.0$ [K] $0 < P \leq 500$ [bar] $-77.15 \leq T \leq 426.85$ [°C]
14	AMUTD(T)	AMUTD: Coefficient of Viscosity of Saturated Liquid [Pa·s] T*: Temperature [K], [°C]	$196.0 \leq T \leq 405.40$ [K] $-77.15 \leq T \leq 132.25$ [°C]
15	AMUTDD(T)	AMUTDD: Coefficient of Viscosity of Saturated Vapor [Pa·s] T*: Temperature [K], [°C]	$196.0 \leq T \leq 405.40$ [K] $-77.15 \leq T \leq 132.25$ [°C]
92	BPPT(P,T)		
90	BSPT(P,T)		
91	BTPT(P,T)		
93	BVPT(P,T)		
16	CPPD(P)		
17	CPPDD(P)		
18	CPPT(P,T)		
19	CPTD(T)		
20	CPTDD(T)		

Table II-2.21-1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
21	CRP('A')	CRP: Critical Constants P*: 'A'='P': 11.36×10^6 [Pa], 113.6 [bar] Pressure T*: 'A'='T': 405.4 [K], 132.25 [°C] Temperature V: 'A'='V': 4.444×10^{-3} [m ³ /kg] Specific Volume	one of 'P', 'T' and 'V'
7A	CVPD(P)		
76	CVPDD(P)		
77	CVPT(P,T)		
7A	CVTD(T)		
78	CVTDD(T)		
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': 17.03026 Relative Molecular Mass R: 'A'='R': 488.189 [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]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
24	HPDD(P)	HPDD: Specific Enthalpy of Saturated Vapor [J/kg] P*: Pressure [Pa], [bar]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
71	HPS(P,S)	HPS: Specific Enthalpy [J/kg] P*: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0 < P \leq 1000 \times 10^6$ [Pa] SPT(P,196K) $\leq S \leq$ SPT(P,700K) [J/(kg·K)] $0 < P \leq 10000$ [bar] SPT(P, -77.15°C) $\leq S \leq$ SPT(P, 426.85°C) [J/(kg·K)]
25	HPT(P,T)	HPT: Specific Enthalpy [J/kg] P*: Pressure [Pa], [bar] T*: Temperature [K], [°C]	$0 < P \leq 1000 \times 10^6$ [Pa] $196 \leq T \leq 700$ [K] $0 < P \leq 10000$ [bar] $-77.15 \leq T \leq 426.85$ [°C]
26	HPX(P,X)	HPX: Specific Enthalpy of Mixture [J/kg] P*: Pressure [Pa], [bar] X: Dryness Fraction [-]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] $0 \leq X \leq 1.0$ [-]
27	HTD(T)	HTD: Specific Enthalpy of Saturated Liquid [J/kg] T*: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
28	HTDD(T)	HTDD: Specific Enthalpy of Saturated Vapor [J/kg] T*: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
29	HTX(T,X)	HTX: Specific Enthalpy of Mixture [J/kg] T*: Temperature [K], [°C] X: Dryness Fraction [-]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C] $0 \leq X \leq 1.0$ [-]
84	IDENTF('A')	IDENTF: CHARACTER TYPE FUNCTION for Package Identification (Length 20) C: 'A'='C': 'NH3' Molecular Formula S: 'A'='S': 'AMMONIA' Name of Substance V: 'A'='V': '10.1' Version Number	one of 'C', 'S' and 'V'

Table II-2.21-1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
66	PLDT(T)		
68	PMLT(T)		
85	PRPD(P)		
86	PRPDD(P)		
81	PRPT(P,T)		
87	PRTD(T)		
88	PRTDD(T)		
99	PSBT(T)		
30	PST(T)	PST*: Saturation Pressure [Pa], [bar] T*: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
72	PSTD(T)		
73	PSTDD(T)		
31	SIGP(P)	SIGP: Surface Tension [N/m] P*: Pressure [Pa], [bar]	$10.8207 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $10.8207 \times 10^{-2} \leq P \leq 113.6$ [bar]
32	SIGT(T)	SIGT: Surface Tension [N/m] T*: Temperature [K], [°C]	$203.0 \leq T \leq 405.40$ [K] $-70.15 \leq T \leq 132.25$ [°C]
33	SPD(P)	SPD: Specific Entropy of Saturated Liquid [J/(kg·K)] P*: Pressure [Pa], [bar]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
34	SPDD(P)	SPDD: Specific Entropy of Saturated Vapor [J/(kg·K)] P*: Pressure [Pa], [bar]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
35	SPT(P,T)	SPT: Specific Entropy [J/(kg·K)] P*: Pressure [Pa], [bar] T*: Temperature [K], [°C]	$0 < P \leq 1000 \times 10^6$ [Pa] $196 \leq T \leq 700$ [K] $0 < P \leq 10000$ [bar] $-77.15 \leq T \leq 426.85$ [°C]
36	SPX(P,X)	SPX: Specific Entropy of Mixture [J/(kg·K)] P*: Pressure [Pa], [bar] X: Dryness Fraction [-]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] $0 \leq X \leq 1.0$ [-]
37	STD(T)	STD: Specific Entropy of Saturated Liquid [J/(kg·K)] T*: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
38	STDD(T)	STDD: Specific Entropy of Saturated Vapor [J/(kg·K)] T*: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
39	STX(T,X)	STX: Specific Entropy of Mixture [J/(kg·K)] T*: Temperature [K], [°C] X: Dryness Fraction [-]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C] $0 \leq X \leq 1.0$ [-]
67	TLDP(P)		
69	TMLP(P)		
64	TPH(P,H)	TPH*: Temperature [K], [°C] P*: Pressure [Pa], [bar] H: Specific Enthalpy [J/kg]	$0 < P \leq 1000 \times 10^6$ [Pa] $HPT(P, 196K) \leq H \leq HPT(P, 700K)$ [J/kg] $0 < P \leq 10000$ [bar] $HPT(P, -77.15^\circ C) \leq H \leq HPT(P, 426.85^\circ C)$ [J/kg]
6H	TPH2(P,H)		

Table II–2.21–1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
65	TPS(P,S)	TPS*: Temperature [K], [°C] P*: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0 < P \leq 1000 \times 10^6$ [Pa] $SPT(P, 196K) \leq S \leq SPT(P, 700K)$ [J/(kg·K)] $0 < P \leq 10000$ [bar] $SPT(P, -77.15^\circ C) \leq S \leq SPT(P, 426.85^\circ C)$ [J/(kg·K)]
6S	TPS2(P,S)		
98	TPSEUP(P)		
70	TPV(P,V)	TPV*: Temperature [K], [°C] P*: Pressure [Pa], [bar] V: Specific Volume [m ³ /kg]	$0 < P \leq 1000 \times 10^6$ [Pa] $VPT(P, 196K) \leq V \leq VPT(P, 700K)$ [m ³ /kg] $0 < P \leq 10000$ [bar] $VPT(P, -77.15^\circ C) \leq V \leq VPT(P, 426.85^\circ C)$ [m ³ /kg]
41	TRPL('A')	TRPL*: Properties at Triple Point P*: 'A'='P': 6.063×10^3 [Pa], 0.06063 [bar] Pressure T*: 'A'='T': 195.495 [K], -77.655 [°C] Temperature	one of 'P' and 'T'
100	TSBP(P)		
40	TSP(P)	TSP*: Saturation Temperature [K], [°C] P*: Pressure [Pa], [bar]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
74	TSPD(P)		
75	TSPDD(P)		
42	UPD(P)	UPD: Specific Internal Energy of Saturated Liquid [J/kg] P*: Pressure [Pa], [bar]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
43	UPDD(P)	UPDD: Specific Internal Energy of Saturated Vapor [J/kg] P*: Pressure [Pa], [bar]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
79	UPS(P,S)	UPS: Specific Internal Energy [J/kg] P*: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0 < P \leq 1000 \times 10^6$ [Pa] $SPT(P, 196K) \leq S \leq SPT(P, 700K)$ [J/(kg·K)] $0 < P \leq 10000$ [bar] $SPT(P, -77.15^\circ C) \leq S \leq SPT(P, 426.85^\circ C)$ [J/(kg·K)]
44	UPT(P,T)	UPT: Specific Internal Energy [J/kg] P*: Pressure [Pa], [bar] T*: Temperature [K], [°C]	$0 < P \leq 1000 \times 10^6$ [Pa] $196 \leq T \leq 700$ [K] $0 < P \leq 10000$ [bar] $-77.15 \leq T \leq 426.85$ [°C]
45	UPX(P,X)	UPX: Specific Internal Energy of Mixture [J/kg] P*: Pressure [Pa], [bar] X: Dryness Fraction [-]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] $0 \leq X \leq 1.0$ [-]
46	UTD(T)	UTD: Specific Internal Energy of Saturated Liquid [J/kg] T*: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
47	UTDD(T)	UTDD: Specific Internal Energy of Saturated Vapor [J/kg] T*: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]

Table II-2.21-1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
48	UTX(T,X)	UTX: Specific Internal Energy of Mixture [J/kg] T*: Temperature [K], [°C] X: Dryness Fraction [-]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C] $0 \leq X \leq 1.0$ [-]
49	VPD(P)	VPD: Specific Volume of Saturated Liquid [m ³ /kg] P*: Pressure [Pa], [bar]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
50	VPDD(P)	VPDD: Specific Volume of Saturated Vapor [m ³ /kg] P*: Pressure [Pa], [bar]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar]
80	VPS(P,S)	VPS: Specific Volume [m ³ /kg] P*: Pressure [Pa], [bar] S: Specific Entropy [J/(kg·K)]	$0 < P \leq 1000 \times 10^6$ [Pa] SPT(P,196K) $\leq S \leq$ SPT(P,700K) [J/(kg·K)] $0 < P \leq 10000$ [bar] SPT(P, -77.15°C) $\leq S \leq$ SPT(P, 426.85°C) [J/(kg·K)]
51	VPT(P,T)	VPT: Specific Volume [m ³ /kg] P*: Pressure [Pa], [bar] T*: Temperature [K], [°C]	$0 < P \leq 1000 \times 10^6$ [Pa] $196 \leq T \leq 700$ [K] $0 < P \leq 10000$ [bar] $-77.15 \leq T \leq 426.85$ [°C]
52	VPX(P,X)	VPX: Specific Volume of Mixture [m ³ /kg] P*: Pressure [Pa], [bar] X: Dryness Fraction [-]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] $0 \leq X \leq 1.0$ [-]
53	VTD(T)	VTD: Specific Volume of Saturated Liquid [m ³ /kg] T*: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
54	VTDD(T)	VTDD: Specific Volume of Saturated Vapor [m ³ /kg] T*: Temperature [K], [°C]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C]
55	VTX(T,X)	VTX: Specific Volume of Mixture [m ³ /kg] T*: Temperature [K], [°C] X: Dryness Fraction [-]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C] $0 \leq X \leq 1.0$ [-]
8E	WPD(P)		
8F	WPDD(P)		
83	WPT(P,T)		
8G	WTD(T)		
8H	WTDD(T)		
56	XPH(P,H)	XPH: Dryness Fraction [-] P*: Pressure [Pa], [bar] H: Specific Enthalpy of Mixture [J/kg]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] HPD(P) $\leq H \leq$ HPDD(P) [J/kg]
57	XPS(P,S)	XPS: Dryness Fraction [-] P*: Pressure [Pa], [bar] S: Specific Entropy of Mixture [J/(kg·K)]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] SPD(P) $\leq S \leq$ SPDD(P) [J/(kg·K)]
58	XPU(P,U)	XPU: Dryness Fraction [-] P*: Pressure [Pa], [bar] U: Specific Internal Energy of Mixture [J/kg]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] UPD(P) $\leq U \leq$ UPDD(P) [J/kg]
59	XPV(P,V)	XPV: Dryness Fraction [-] P*: Pressure [Pa], [bar] V: Specific Volume of Mixture [m ³ /kg]	$6.063 \times 10^3 \leq P \leq 11.36 \times 10^6$ [Pa] $0.06063 \leq P \leq 113.6$ [bar] VPD(P) $\leq V \leq$ VPDD(P) [m ³ /kg]
60	XTH(T,H)	XTH: Dryness Fraction [-] T*: Temperature [K], [°C] H: Specific Enthalpy of Mixture [J/kg]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C] HPD(T) $\leq H \leq$ HPDD(T) [J/kg]
61	XTS(T,S)	XTS: Dryness Fraction [-] T*: Temperature [K], [°C] S: Specific Entropy of Mixture [J/(kg·K)]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C] SPD(T) $\leq S \leq$ SPDD(T) [J/(kg·K)]

Table II–2.21–1 Ammonia Function (cont'd)

No.	Name of Function	Function and Argument(s)	Range of Argument(s)
62	XTU(T,U)	XTU: Dryness Fraction [–] T*: Temperature [K], [°C] U: Specific Internal Energy of Mixture [J/kg]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C] $UPD(T) \leq U \leq UPDD(P)$ [J/kg]
63	XTV(T,V)	XTV: Dryness Fraction [–] T*: Temperature [K], [°C] V: Specific Volume of Mixture [m ³ /kg]	$195.495 \leq T \leq 405.4$ [K] $-77.655 \leq T \leq 132.25$ [°C] $VPD(T) \leq V \leq VPDD(T)$ [m ³ /kg]