

TABLE A-24 Constants for the van der Waals, Redlich–Kwong, and Benedict–Webb–Rubin Equations of State1. van der Waals and Redlich–Kwong: Constants for pressure in bar, specific volume in m³/kmol, and temperature in K

Substance	van der Waals		Redlich–Kwong	
	$\text{bar} \left(\frac{\text{m}^3}{\text{kmol}} \right)^2$	$\frac{\text{m}^3}{\text{kmol}}$	$\text{bar} \left(\frac{\text{m}^3}{\text{kmol}} \right)^2 \text{K}^{1/2}$	$\frac{\text{m}^3}{\text{kmol}}$
Air	1.368	0.0367	15.989	0.02541
Butane (C ₄ H ₁₀)	13.86	0.1162	289.55	0.08060
Carbon dioxide (CO ₂)	3.647	0.0428	64.43	0.02963
Carbon monoxide (CO)	1.474	0.0395	17.22	0.02737
Methane (CH ₄)	2.293	0.0428	32.11	0.02965
Nitrogen (N ₂)	1.366	0.0386	15.53	0.02677
Oxygen (O ₂)	1.369	0.0317	17.22	0.02197
Propane (C ₃ H ₈)	9.349	0.0901	182.23	0.06242
Refrigerant 12	10.49	0.0971	208.59	0.06731
Sulfur dioxide (SO ₂)	6.883	0.0569	144.80	0.03945
Water (H ₂ O)	5.531	0.0305	142.59	0.02111

Source: Calculated from critical data.

2. Benedict–Webb–Rubin: Constants for pressure in bar, specific volume in m³/kmol, and temperature in K

Substance	<i>a</i>	<i>A</i>	<i>b</i>	<i>B</i>	<i>c</i>	<i>C</i>	α	γ
C ₄ H ₁₀	1.9073	10.218	0.039998	0.12436	3.206×10^5	1.006×10^6	1.101×10^{-3}	0.0340
CO ₂	0.1386	2.7737	0.007210	0.04991	1.512×10^4	1.404×10^5	8.47×10^{-5}	0.00539
CO	0.0371	1.3590	0.002632	0.05454	1.054×10^3	8.676×10^3	1.350×10^{-4}	0.0060
CH ₄	0.0501	1.8796	0.003380	0.04260	2.579×10^3	2.287×10^4	1.244×10^{-4}	0.0060
N ₂	0.0254	1.0676	0.002328	0.04074	7.381×10^2	8.166×10^3	1.272×10^{-4}	0.0053

Source: H. W. Cooper and J. C. Goldfrank, *Hydrocarbon Processing*, 46 (12): 141 (1967).

TABLE A-25 Thermochemical Properties of Selected Substances at 298K and 1 atm

Substance	Formula	Molar Mass, <i>M</i> (kg/kmol)	Enthalpy of Formation, \bar{h}_f° (kJ/kmol)	Gibbs Function of Formation, \bar{g}_f° (kJ/kmol)	Absolute Entropy, \bar{s}° (kJ/kmol · K)	Heating Values	
						Higher, HHV (kJ/kg)	Lower, LHV (kJ/kg)
Carbon	C(s)	12.01	0	0	5.74	32,770	32,770
Hydrogen	H ₂ (g)	2.016	0	0	130.57	141,780	119,950
Nitrogen	N ₂ (g)	28.01	0	0	191.50	—	—
Oxygen	O ₂ (g)	32.00	0	0	205.03	—	—
Carbon monoxide	CO(g)	28.01	−110,530	−137,150	197.54	—	—
Carbon dioxide	CO ₂ (g)	44.01	−393,520	−394,380	213.69	—	—
Water	H ₂ O(g)	18.02	−241,820	−228,590	188.72	—	—
Water	H ₂ O(l)	18.02	−285,830	−237,180	69.95	—	—
Hydrogen peroxide	H ₂ O ₂ (g)	34.02	−136,310	−105,600	232.63	—	—
Ammonia	NH ₃ (g)	17.03	−46,190	−16,590	192.33	—	—
Oxygen	O(g)	16.00	249,170	231,770	160.95	—	—
Hydrogen	H(g)	1.008	218,000	203,290	114.61	—	—
Nitrogen	N(g)	14.01	472,680	455,510	153.19	—	—
Hydroxyl	OH(g)	17.01	39,460	34,280	183.75	—	—
Methane	CH ₄ (g)	16.04	−74,850	−50,790	186.16	55,510	50,020
Acetylene	C ₂ H ₂ (g)	26.04	226,730	209,170	200.85	49,910	48,220
Ethylene	C ₂ H ₄ (g)	28.05	52,280	68,120	219.83	50,300	47,160
Ethane	C ₂ H ₆ (g)	30.07	−84,680	−32,890	229.49	51,870	47,480
Propylene	C ₃ H ₆ (g)	42.08	20,410	62,720	266.94	48,920	45,780
Propane	C ₃ H ₈ (g)	44.09	−103,850	−23,490	269.91	50,350	46,360
Butane	C ₄ H ₁₀ (g)	58.12	−126,150	−15,710	310.03	49,500	45,720
Pentane	C ₅ H ₁₂ (g)	72.15	−146,440	−8,200	348.40	49,010	45,350
Octane	C ₈ H ₁₈ (g)	114.22	−208,450	17,320	463.67	48,260	44,790
Octane	C ₈ H ₁₈ (l)	114.22	−249,910	6,610	360.79	47,900	44,430
Benzene	C ₆ H ₆ (g)	78.11	82,930	129,660	269.20	42,270	40,580
Methyl alcohol	CH ₃ OH(g)	32.04	−200,890	−162,140	239.70	23,850	21,110
Methyl alcohol	CH ₃ OH(l)	32.04	−238,810	−166,290	126.80	22,670	19,920
Ethyl alcohol	C ₂ H ₅ OH(g)	46.07	−235,310	−168,570	282.59	30,590	27,720
Ethyl alcohol	C ₂ H ₅ OH(l)	46.07	−277,690	174,890	160.70	29,670	26,800

Source: Based on JANAF Thermochemical Tables, NSRDS-NBS-37, 1971; *Selected Values of Chemical Thermodynamic Properties*, NBS Tech. Note 270-3, 1968; and *API Research Project 44*, Carnegie Press, 1953. Heating values calculated.