

Tait Equation for Liquid Ammonia

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The Tait equation parameter B evaluated from experimental PVT data for liquid ammonia decreases with increasing temperature and can be reasonably extrapolated to the value of $-P_c$ (P_c is the critical pressure) for the critical temperature. The Tait equation parameter C is nearly constant in the temperature range from -20 to 50 °C and decreases with increasing temperature at temperatures higher than 50 °C.

Various equations of state of liquids have been proposed by many investigators (5, 16, 19–22, 26, 27, 29, 31). Among these the Tait equation has been used to describe most of the PVT data. The differential form of this equation is

$$(\partial V/\partial P)_T = -C/(B + P) \quad (1)$$

The integrated form of Equation 1 may be written as

$$V_p = V_0[1 - C \ln(B + P)/(B + P_0)] \quad (2)$$

where the parameter $C = C'/V_0$.

The Tait equation has been applied, not only to the experimental data of a number of liquids, but also those of solids (14) and gases (2, 25) with some modifications. Further, the physical meaning of parameters B and C of this equation has been discussed by several workers (9, 11, 13, 23, 24). The temperature dependence of the parameters, however, has not been fully discussed because few experimental PVT data have been provided over a wide range of temperature and pressure.

The purpose of this study is to obtain the Tait parameters for liquid ammonia and to express them as a function of temperature by using the PVT data obtained over a wide range of temperature and pressure.

Temperature Dependence of Tait Parameters B and C

The correlation of parameter B vs. temperature was first attempted by Wohl (30) for ether. The following relation was obtained:

$$B = (a/T_r) - b \quad (3)$$

Carl (4) showed the same relation was also applicable to the experimental data reported by Amagat and by Bridgman. Gibson and Kincaid (9) used the following equation to represent B values

$$B = \alpha + \beta T + \gamma T^2 \quad (4)$$

Atanov (7) expressed parameter B as a function of temperature for 11 kinds of liquids by the following equation:

$$B = 3 P_c \exp[-\chi(T - T_c)] \quad (5)$$

and Golik et al. (15) also used the same relation for alkanes for correlation of parameter B vs. temperature. According to Equation 5, Atanov showed that parameter B was $3 P_c$ for the critical temperature. It is equal to the internal pressure derived from van der Waals' equation at the critical point. On the other hand, Ginell (13) reported that from Equation 1 and the critical condition $(\partial P/\partial V)_T = 0$, parameter B for the critical temperature should be equal to $-P_c$ and that the value

obtained by extrapolating the experimental B values of liquid helium I to the critical temperature was equal to $-P_c$.

Parameter C has been regarded as being independent of temperature for many substances (6, 8–10, 12), although a slight temperature dependence of C has been reported for some substances (3, 30).

It is not known, however, whether the relationships between parameters and temperature presented above are valid or not for a wide range of temperature and pressure, especially in the neighborhood of the critical temperature.

Tait Parameters B and C for Liquid Ammonia

The Tait parameters B and C for liquid ammonia were evaluated by a least-squares method using the experimental PVT data (7, 18, 28). In this evaluation the specific volume at the saturated vapor pressure P_0 was chosen as V_0 . The results are shown in Table I and Figure 1. The solid lines in Figure 1 were obtained by use of the equations described later. The Tait equation, using B and C given in Table I, reproduces the measured values of the specific volume with a deviation not exceeding 0.4%. Figure 1 shows that parameter B decreases with increasing temperature, and its value at the critical temperature is $-P_c$, and not $3 P_c$, and that parameter C is nearly constant in the low-temperature range and decreases with increasing temperature in the high-temperature range.

Parameter B can be represented as the linear function of the reciprocal of the temperature in the low-temperature range, but cannot be represented by the relation similar to that described above at the temperatures higher than 100 °C. Accordingly, parameter B was presented in the polynomial of temperature with the aid of a least-squares method using the values given in Table I. Here, $B = -P_c$ at the critical temperature [$P_c = 111.3$ atm, and $T_c = 405.45$ K (17)] was assumed, and the B value obtained using data of Date (7) at 25 °C was rejected because of its great deviation from the

Table I. Tait Equation Parameters B and C for Liquid Ammonia

T , K	Pressure range, atm	B , atm	C	A_v dev., ^a %	Data ref.
253.15	283–1587	1330	0.1103	0.09	18
273.15	283–1587	1015	0.1088	0.07	18
298.15	50–500	883	0.1403	0.01	7
	95–1774	714	0.1109	0.07	18
313.15	283–1742	557	0.1102	0.10	18
323.15	50–500	447	0.1151	0.04	7
	1500–10000	454	0.1105	0.14	28
348.15	50–500	189	0.0993	0.02	7
373.15	75–500	26.3	0.0923	0.05	7
	1500–10000	33.6	0.0980	0.08	28
398.15	100–500	-87.6	0.0820	0.13	7

^a average deviation = $\sum_{n=1}^n |(V_{\text{calcd}} - V_{\text{exptl}})/V_{\text{exptl}}| \times 100 / n$. n = number of data. V_{calcd} , V_{exptl} = specific volumes calculated by Tait equation with parameters B and C in Table I and experimental one, respectively, cm^3/g or cm^3/mol .

smooth curve representing B . The polynomial of second degree

$$B = 8.2418 \times 10^3 - 3.8241 \times 10 T + 4.3504 \times 10^{-2} T^2 \quad (6)$$

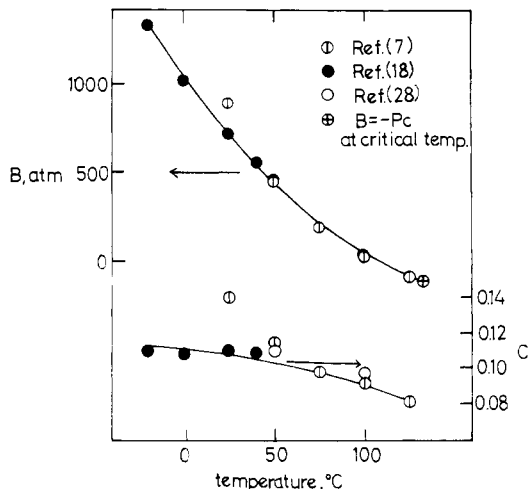


Figure 1. Temperature variation of Tait equation parameters for liquid ammonia

reproduces B values satisfactorily within the limits of accuracy of the available data, up to the critical temperature.

Parameter C was also approximated by the following empirical equation, considering the fact that C values became constant in the low-temperature range.

$$\log(0.1180 - C) = -13.0628 + 4.4657 \log T \quad (7)$$

The two curves representing B and C in Figure 1 were obtained from Equation 6 and 7, respectively.

Figure 2 represents the deviations of the specific volumes calculated by Equation 2 combined with Equations 6 and 7 from the experimental data. From Figure 2, the Tait equation with the temperature-dependent parameters B and C reproduces the experimental specific volumes with deviation not exceeding 0.6% up to the neighborhood of the critical temperature and up to 500 atm, except at extremely high pressures.

Nomenclature

a, b = coefficients in Equation 3

B, C, C' = Tait equation parameters, atm, dimensionless, and cm^3/g , respectively

P = pressure, atm. Subscript c (P_c), critical pressure; subscript 0 (P_0), pressure of reference state

T = temperature, K. Subscript c (T_c), critical temperature; subscript r (T_r), reduced temperature

V = specific volume, cm^3/g . Subscript 0 (V_0), specific volume at pressure of reference state, P_0 ; subscript P (V_P), specific volume at pressure P

α, β, γ = coefficients in Equation 4

χ = coefficient in Equation 5

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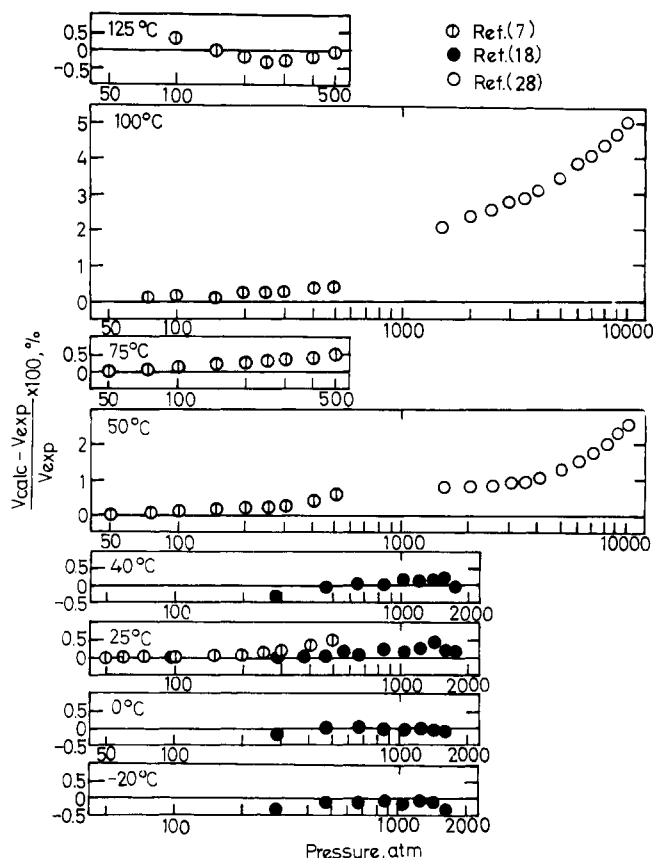


Figure 2. Deviation of experimental specific volumes from those calculated by Tait equation