

INITIAL DENSITY DEPENDENCE OF VISCOSITY OF NONPOLAR-POLAR GASEOUS MIXTURES

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The initial density dependence of gas viscosity, $\alpha' = \eta_0^{-1}(\partial\eta/\partial\rho)_{P \rightarrow 0}$, of nonpolar-polar mixtures was determined from α' of the pure components of the mixture, where η is gas viscosity, ρ density, and η_0 the viscosity extrapolated to zero density. The calculated α' -values expressed mostly those obtained from the experimental data for the hydrogen-ammonia system, the nitrogen-ammonia system, and the argon-ammonia system.

The gas viscosity η depends on pressure P or density ρ and can be expressed as follows:

$$\eta = \eta_0 (1 + \alpha P + \dots) \quad (1)$$

or

$$\eta = \eta_0 (1 + \alpha' \rho + \dots) \quad (2)$$

where η_0 is the viscosity extrapolated to zero pressure (or density), $\alpha = \eta_0^{-1}(\partial\eta/\partial P)_{P \rightarrow 0}$ the initial pressure dependence of viscosity, and $\alpha' = \eta_0^{-1}(\partial\eta/\partial\rho)_{P \rightarrow 0}$ the initial density dependence of viscosity¹⁾.

In the previous paper²⁾, a theoretical equation about α derived by Stogryn and Hirschfelder³⁾ was studied and α' of a nonpolar and polar gas were semi-empirically introduced. The calculated α' -values represented well the experimental ones obtained from viscosity data.

The object of this report is to determine α' of nonpolar-polar gaseous mixtures from α' of the pure components of the mixture. As the compressibility factor z is expressed in a power series expansion in density⁴⁾

$$z = PV/RT = 1 + B\rho + C\rho^2 + \dots \quad (3)$$

where V : volume; T : temperature; R : gas constant; and B and C : second and third virial coefficient, the coefficient of ρ in Eq. (2), α' , corresponds to the second virial coefficient. As mentioned in the previous paper⁵⁾, it was seen that the correlation between α' and the reduced temperature T_r was similar to that between the reduced second virial coefficient and the reduced temperature T^* . The following equation was introduced, consequently, to α' of gaseous mixtures.

$$\alpha'_{\text{mix}} = \sum_{a=1}^2 \sum_{b=1}^2 \alpha'_{ab} x_a x_b \quad (4)$$

1) M. Hongo and H. Iwasaki, *This Journal*, **47**, 90 (1977)

2) M. Hongo, *ibid.*, **49**, 1 (1979)

3) D. E. Stogryn and J. O. Hirschfelder, *J. Chem. Phys.*, **31**, 1545 (1959)

4) J. O. Hirschfelder, C. F. Curtiss and R. B. Bird, "Molecular Theory of Gases and Liquids", John Wiley & Sons, Inc., New York (1954)

5) M. Hongo, *This Journal*, **48**, 63 (1978)

where x is mole fraction and a and b denote molecular species. Further, by considering the experimental results that the larger the molecular weight of nonpolar gases is, the stronger the effect on α' of ammonia is, and that the higher the temperature is, the smaller the α' is, the final expression was obtained as follows:

$$\left(\frac{M_{np}\alpha'}{b_o}\right)_{np} = x_n^2 \left(\frac{M_n\alpha'}{b_o}\right)_n + 2x_n(1-x_n) \left(\frac{M_n}{M_p}\right)^{1/2} (T_{np}^*)^{-1/2} + (1-x_n)^2 \left(\frac{M_p\alpha'}{b_o}\right)_p \quad (5)$$

where $M_{np} = x_n M_n + (1-x_n) M_p$; $b_o = 2\pi N \sigma^3 / 3$; $T_{np}^* = T / \epsilon_{np} k^{-1}$; M : molecular weight; subscripts np denotes nonpolar-polar mixture and n and p denote nonpolar and polar gas. $(M_n\alpha'/b_o)_n$ and $(M_p\alpha'/b_o)_p$ are calculated from Eq. (11) for a nonpolar gas and from Eq. (12) for a polar gas in Ref. 2. The force constants of the Lennard-Jones potential and of the modified Stockmayer potential were used for a nonpolar and polar gas, respectively. The following combination rules were applied for nonpolar-polar interactions⁶.

$$\sigma_{np} = (\sigma_n + \sigma_p) \xi^{-1/6} / 2 \quad (6)$$

$$\epsilon_{np} / k = (\sqrt{\epsilon_n \epsilon_p} / k) \xi^2 (\sqrt{z_{cn}} + \sqrt{z_{cp}})^{-2} \quad (7)$$

where ξ is defined in Eq. (8.6-5) in Ref. 4 and z_c is critical compressibility factor.

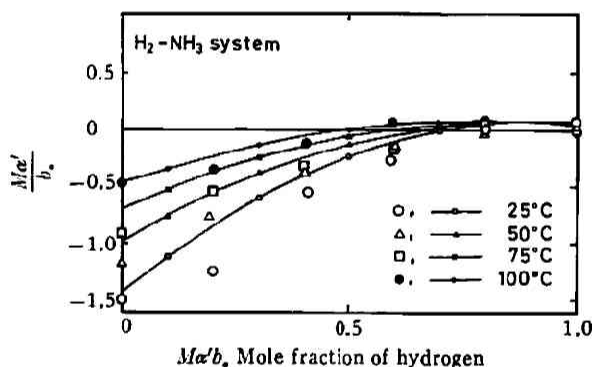


Fig. 1 Comparison of experimental value of $M\alpha'/b_o$ with calculated one obtained from Eq. (8) for hydrogen-ammonia system

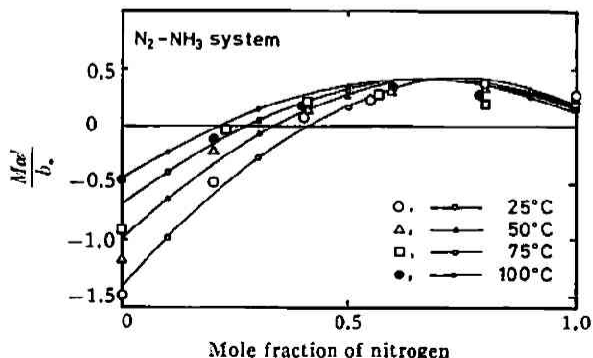


Fig. 2 Comparison of experimental value of $M\alpha'/b_o$ with calculated one obtained from Eq. (8) for nitrogen-ammonia system

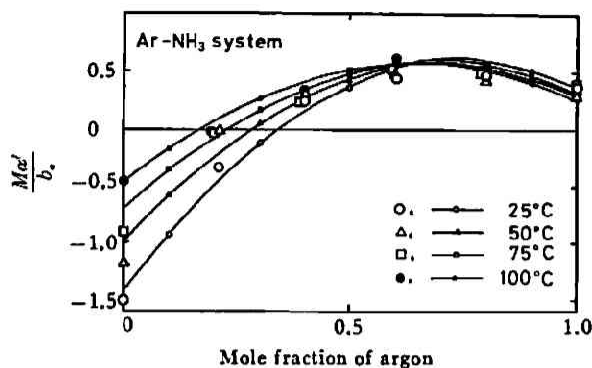


Fig. 3 Comparison of experimental value of $M\alpha'/b_+$ with calculated one obtained from Eq. (8) for argon-ammonia system

Figures 1~3 show the calculated value of $(M_{np}\alpha'/b_+)_{np}$ obtained from Eq. (5) (denoted by solid lines with small symbols), in comparison with the experimental one (denoted by large symbols) for the hydrogen-ammonia system⁶⁾, the nitrogen-ammonia system¹⁾, and the argon-ammonia system⁵⁾. As shown in the figures, the results of the calculations represented well the experimental values except the ammonia-rich region of the hydrogen-ammonia system.

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6) M. Hongo and H. Iwasaki, *This Journal.*, 48, 1 (1978)