# INITIAL DENSITY DEPENDENCE OF VISCOSITY OF NONPOLAR-POLAR GASEOUS MIXTURES

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The initial density dependence of gas viscosity, $\alpha'=\eta_0^{-1}(\partial\eta/\partial\rho)_{\rho\to0}$, of nonpolarpolar mixtures was determined from $\alpha'$ of the pure components of the mixture, where $\eta$ is gas viscosity, $\rho$ density, and $\eta_0$ the viscosity extrapolated to zero density. The calculated $\alpha'$-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 $\eta$ depends on pressure $P$ or density $\rho$ and can be expressed as follows:

$$\eta=\eta_0(1+\alpha P+\cdots) \qquad (1)$$

or

$$\eta=\eta_0(1+\alpha'\rho+\cdots) \qquad (2)$$

where $\eta_0$ is the viscosity extrapolated to zero pressure (or density), $\alpha=\eta_0^{-1}(\partial\eta/\partial P)_{P\to0}$ the initial pressure dependence of viscosity, and $\alpha'=\eta_0^{-1}(\partial\eta/\partial\rho)_{\rho\to0}$ the initial density dependence of viscosity[1].

In the previous paper[2], a theoretical equation about $\alpha$ derived by Stogryn and Hirschfelder[3] was studied and $\alpha'$ of a nonpolar and polar gas were semi-empirically introduced. The calculated $\alpha'$-values represented well the experimental ones obtained from viscosity data.

The object of this report is to determine $\alpha'$ of nonpolar-polar gaseous mixtures from $\alpha'$ of the pure components of the mixture. As the compressibility factor $z$ is expressed in a power series expansion in density[4]

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

where V: volume; T: temperature; R: gas constant; and B and C: second and third virial coefficient, the coefficient of $\rho$ in Eq. (2), $\alpha'$, corresponds to the second virial coefficient. As mentioned in the previous paper[5], it was seen that the correlation between $\alpha'$ and the reduced temperature Tr was similar to that between the reduced second virial coefficient and the reduced temperature T*. The following equation was introduced, consequently, to $\alpha'$ of gaseous mixtures.

$$\alpha'_{\mathrm{mix}}=\sum_{a=1}^{2}\sum_{b=1}^{2}\alpha'_{\mathrm{ab}}x_{\mathrm{a}}x_{\mathrm{b}} \qquad (4)$$

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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 spacies. Further, by considering the experimental results that the larger the molecular weight of nonpolar gases is, the stronger the effect on $\alpha'$ of ammonia is, and that the higher the temperature is, the smaller the $\alpha'$ is, the final expression was obtained as follows:

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

where $M_{np}=x_nM_n+(1-x_n)M_p$; $b_\circ=2\pi N\sigma^3/3$; $T_{np}^*=T/\varepsilon_{np}k^{-1}$; $M$: molecular weight; subscripts np denotes nonpolar-polar mixture and n and p denote nonpolar and polar gas. $(M_n\alpha'/b_\circ)_n$ and $(M_p\alpha'/b_\circ)_p$ 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.

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

$$\varepsilon_{np}/k=(\sqrt{\varepsilon_n\varepsilon_p}/k)\xi^2(\sqrt{z_{cn}}+\sqrt{z_{cp}})^{-2} \qquad (7)$$

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

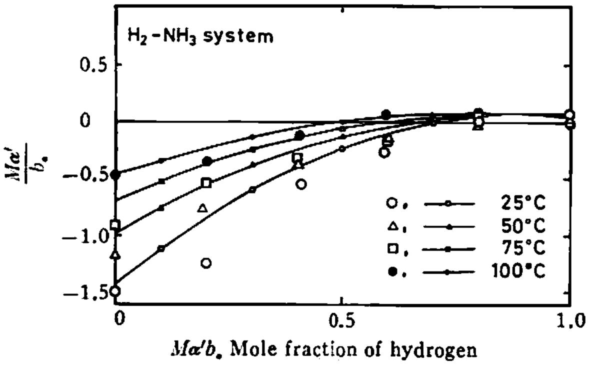

Fig. 1 Comparison of experimental value of $M\alpha'/b_\circ$ with calculated one obtained from Eq. (8) for hydrogen-ammonia system

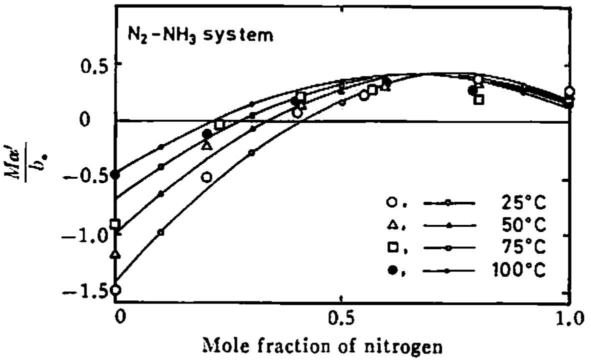

Fig. 2 Comparison of experimental value of $M\alpha'/b_\circ$ with calculated one obtained from Eq. (8) for nitrogen-ammonia system

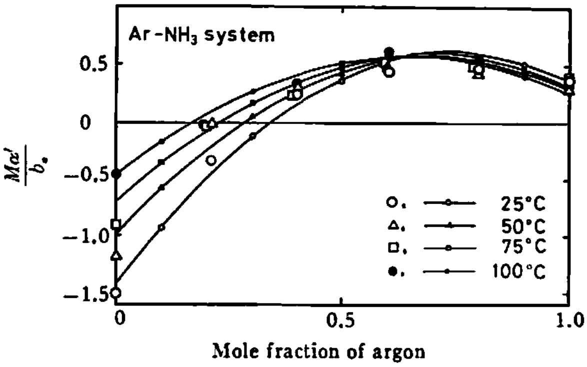

Fig. 3 Comparison of experimental value of $M\alpha'/b_o$ with calculated one obtained from Eq. (8) for argon-ammonia system

Figures 1~3 show the calculated value of $(M_{np}\alpha'/b_o)_{np}$ 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 system[6], the nitrogen-ammonia system[1], and the argon-ammonia system[5]. 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)