Indian J. Phys. **44**, 141–142 (1970)

Application of Rao's rule to liquified inert gases

By A. Qadeer, M. N. Sharma and A. S. Varma

Physics Department, Lucknow University, Lucknow-7, India

(*Received* 21 *July* 1970)

A considerable amount of work has been done on the propagation of ultrasonic waves in organic liquids and liquid mixtures by Parthasarthy (1935). Mikhaylov (1949), Kudryavtsev (1951) and Bergmann (1956) However. no attempt has been made to investigate the propagation of ultrasonic waves at the liquefaction temperature of the inert and polar gases On the basis of experimental data Rao (1940) has suggested an empirical relation connecting the temperature coefficient of velocity of sound α_c and the temperature ocoefficient of volume α_v and may be written as

$$\frac{\alpha_c}{\alpha_v} = -\lambda \qquad \ldots \quad (1)$$

where λ is a constant known as Rao's empirical constant and has been found to be practically equal to $+3$ for most of the organic liquids.

In the present investigation, the authors have verified the Rao's rule in the case of liquid helium and argon at their liquefaction temperature on the basis of the interaction-potential approach. Various potential energy functions have been suggested for the interaction between the atoms or molecules The simplest of them is the inverse form of the overlap interaction. In terms of volume the inverse potential form may be written as

$$\phi(v) = -\alpha v^{-\mu} + \beta v^{-\nu} \qquad \ldots \quad (2)$$

where α, β, μ and ν are constants of the potential energy functions and v is the molar volume.

The equation of state of a gas for the condensed system may be expressed as

$$p = \frac{kT}{v} - \frac{\partial \phi}{\partial v} \qquad \ldots \quad (3)$$

Using equation (3) the following relation for λ the Rao's constant has been obtained

$$\lambda = -\frac{\alpha_c}{\alpha_v} = 1 - K\,\frac{\nu+2}{2} \qquad \ldots \quad (4)$$

where

$$K = \frac{1 - \dfrac{k\left(\dfrac{1}{\alpha_v} - 2T\right)}{\beta\nu(\nu+1)(\nu+2)v^{-\nu}} - \dfrac{\alpha\mu(\mu+1)(\mu+2)v^{\nu-\mu}}{\beta\nu(\nu+1)(\nu+2)}}{1 + \dfrac{kT}{\beta\nu(\nu+1)(\nu+2)v^{-\nu}} - \dfrac{\alpha\mu(\mu+1)\nu^{\nu-\mu}}{\beta\nu(\nu+1)}}$$

The computed values of λ employing equation (4) for liquid helium and liquid argon are presented in table 1 These values of λ have been utilized to derive the following equations for the velocity of sound at the temperature of liquefaction

$$\frac{MC^{\frac{1}{2}}}{d} = R \text{ for helium} \qquad \dots \quad (5)$$

$$\frac{MC^{1/3}}{d} = R \text{ for argon} \qquad \dots \quad (6)$$

where M is the molecular weight, C the velocity of ultrasonic waves in the substance d the density of the substance and R is an additive constant which depends upon chemical constitution of the substance but is independent of temperature. For other liquified gases the work is in progress and will be published shortly.

TABLE 1. Values of λ for liquid helium and liquid argon.

Substance	Temperature in °K	Using equations (4) and (5)
Liquid helium	4.2	2.0724
Liquid argon	87	3.0012

REFERENCES

Bergmann, L. 1956 *Ultrasonics, IL*

Kudryavtsev, B. B. 1962 *Applications of Ultrasonic Methods to Physico-Chemical Studies*, Gostekhizdat.

Mikhaylov, I. G. 1949 *The Propagation of Ultrasonic Waves in Liquids*, Gostekhizdat.

Parthasarathy 1935 *Proc. Indian Acad. Sci.* **A2**, 497.

Rao, Rama 1940 *Indian J. Phys.*, **14**, 109.