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Problem 25.29 (RHK)

The molar atomic mass of iodine is 127 g. *A standing wave in a tube filled with iodine gas at* 400 K *has nodes that are* 6.77 cm *apart when the frequency is* 1000 Hz. *We have to determine from these data whether iodine gas is monatomic or diatomic.*

Solution:

We will first determine the speed of sound from the data on the standing waves set up in a tube filled with the gas the iodine gas. It is given that the standing waves have nodes that are 6.77 cm. Therefore, the wavelength of the sound waves of frequency 1000 Hz is

$$\lambda = 2\times 6.77 \text{ cm} = 13.54\times 10^{-2} \text{ m.}$$

Frequency of the sound waves is

$$\nu = 1000 \text{ Hz.}$$

Therefore, the speed of sound in the iodine gas is

$$V = \nu\lambda = 13.54\times 10^{-2}\times 10^{3} \text{ m s}^{-1} = 135.4 \text{ m s}^{-1}.$$

Speed of sound is a macroscopic thermodynamic property of molecules. It depends on the ratio of specific heats, γ, temperature, *T*, and the molar mass of the molecules, *M*, and is given by the relation

$$V = \sqrt{\frac{\gamma RT}{M}}.$$

As the molar mass of the iodine is 127 g, the molar mass of the iodine gas will be

$$M = 127 \times 10^{-3} \times n \text{ kg},$$

where $n = 1$ if the gas is monatomic, and $n = 2$ if the gas is diatomic. We calculate the value of γ from the data,

$$\gamma = \frac{MV^2}{RT} = \frac{135.4^2 \times 127 \times 10^{-3} \times n}{8.315 \times 400} = 0.70 \times n.$$

We know use the property that for monatomic gas

$\gamma = 5/3 = 1.67$,

and for diatomic gas

$\gamma = 7/5 = 1.4$.

We have found that γ for the iodine gas is $0.70 \times n$, therefore $n = 2$ and the gas is of diatomic iodine molecules.