Speed of Sound in Gases at Room Temperature

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Abstract

We review the results of our experiment to find out how the speed of sound differs in various gases and how mass and the structure of the gas molecules plays a role in the phenomenon. It is predicted that both the molar mass and molecules' degrees of freedom in motion affect the speed at which sound propagates. First, we used a function generator and an oscilloscope to experimentally measure the speed of sound in a tube filled with gas and fitted with speaker and microphone. The speed of sound was found to be proportionate to the slope of the line of best fit on a graph that plotted the number of antinodes for a resonant frequency (measured by the oscilloscope) against the source frequency (from the function generator). Our results showed that the speed of sound is slower in denser gas–gas with greater molecular mass–as well as in gases with more complex molecular structure. This conclusion is in agreement with the theoretical predictions.

Theory

Speed of waves is affected by the density and stiffness of the medium.

$$\text{Velocity of Sound Wave} \longrightarrow v = \sqrt{\frac{\text{bulk modulus}}{\text{density}}} = \sqrt{\frac{k}{\rho}}$$

Sound waves are produced adiabatically and their speed in an ideal gas is given by:

$$v_{sound} = \sqrt{\frac{\gamma RT}{M}}$$

Where γ is the ratio of specific heats of gas, R is the molar gas constant, T is temperature in Kelvin, and M is molar mass of gas. The above equation assumes that the gas involved behaves like an ideal gas and the process is adiabatic. Ideal gas molecules occupy near zero volume and do not interact electrostatically with each other at low density and at high temperatures.

Experiment

Speed of wave is given by: $v = f\lambda$

Resonance occurs when: $L = n\frac{\lambda}{2}$

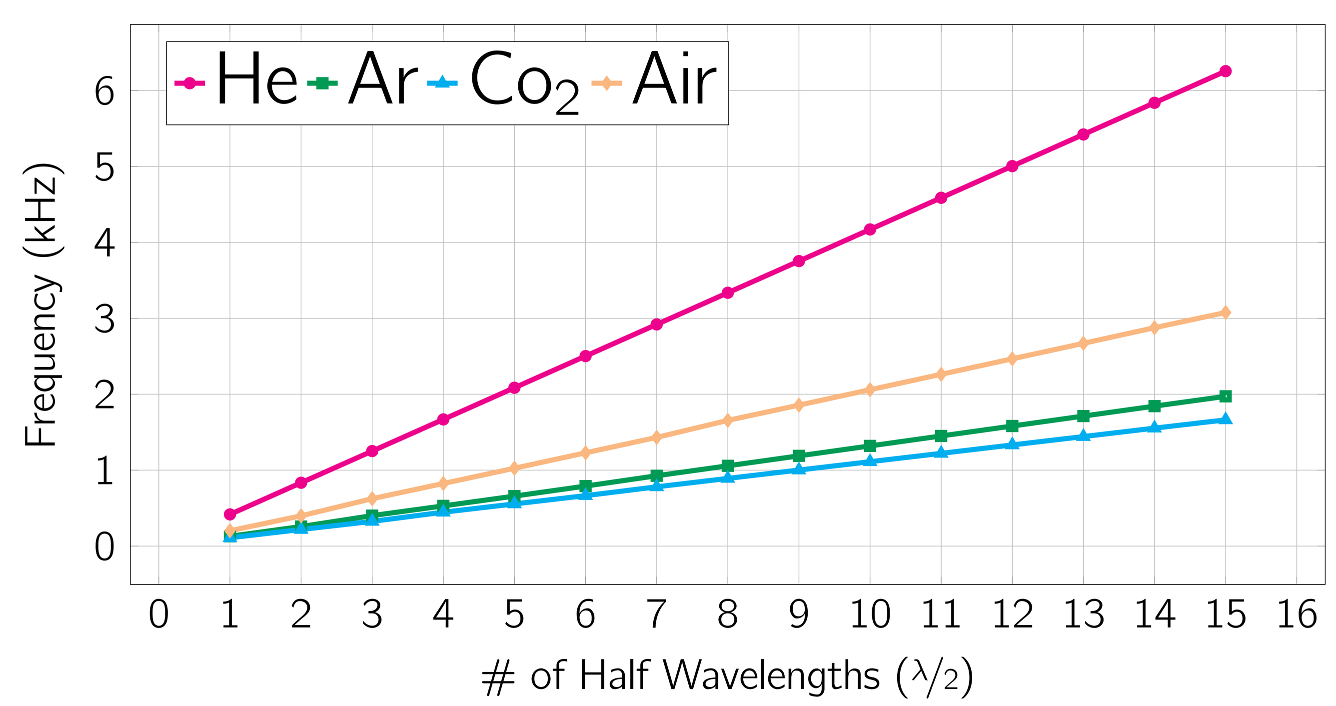
(Where f is frequency, λ is the wavelength, L is length of the system, and n is # of half-wave lengths).

Combining the above equations..

$$f = \frac{v}{2L} \times n \implies \mathbf{v = \frac{f}{n} \times 2L}$$

$\therefore$ Velocity of sound in gas mediums can be found by measuring the rate of change of resonant frequency with respect to change in number of half wavelengths $^{\Delta f}/_{\Delta n}$ and multiplying it with twice the length of the pathway ($2L$)

Data



Final Results

Here are the final results showing experimental measurements in agreement with theoretical predictions of how fast sound propogates in four different gas mediums during our experiments

	Experimental Velocity $^{m}/_{s}$	Theoretical Velocity $^{m}/_{s}$	
Gas	$v_{ex} \pm \sigma_{ex}$	$v_{th} \pm \sigma_{th}$	$^{\Delta}/_{\sigma}$
Helium	1013.8 ± 4.2	1012.75 ± 0.86	0.245
Argon	320.0 ± 1.3	320.66 ± 0.27	0.497
Carbon Dioxide	270.1 ± 1.1	269.55 ± 0.23	0.489
Air	346.2 ± 2.1	346.72 ± 0.29	0.245

Conclusion

1. Sound travels slowest in linear triatomic gases in comparison with diatomic or monoatomic gases.
   - Monoatomic: He, Ar } *Faster*
   - Diatomic: Air } *Faster*
   - Linear Triatomic: Co_2 } *Slower*
2. Molecular mass of the gas molecules is inversely related to the speed of sound in the gas.
   - Lighter: He, } *Faster*
   - Heavier: Air, Ar, Co_2 } *Slower*