Qualitative study of speed of sound and heat capacity in constant volume under various temperatures of gases using oscillator.

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Supporting Information Placeholder

ABSTRACT: (Word Style "BD_Abstract"). All manuscripts must be accompanied by an abstract. The abstract should briefly state the problem or purpose of the research, indicate the theoretical or experimental plan used, summarize the principal findings, and point out the major conclusions. The optimal length is one paragraph.

Results

Observed frequencies of in-phases and out-phases using oscillator were recorded. It was analyzed it using Error Fit (Version 1.0) program that utilizes Monte-Carlo linear regression accounting for errors in the dependent variable to provide various information regarding a set of data including regression line (1). Then, using OpenOffice Spreadsheet, graphs of the data including regression line were acquired. It was noted that the instrument has 9% error for each data point (1). It is expressed in vertical error bar presented for each data point. Multiple experiments were conducted per medium to prove reproducibility of the experiments and to provide statistical tools to assess each experiment. One most representative experiment per medium is presented in graph drawn using OpenOffice Spreadsheet. Following work was inspired by instructions from A.J. Pounds (2).

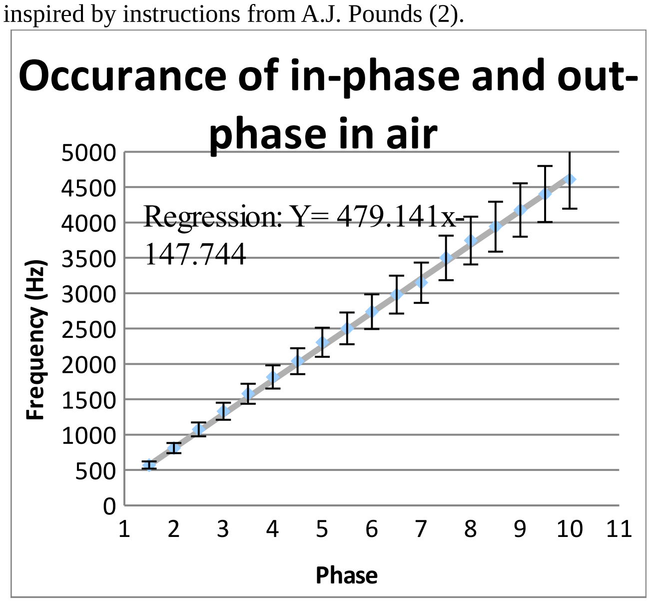

Fig 1. Frequencies of observed in-phases and out-phases using oscillator under air in 21.2 Celsius

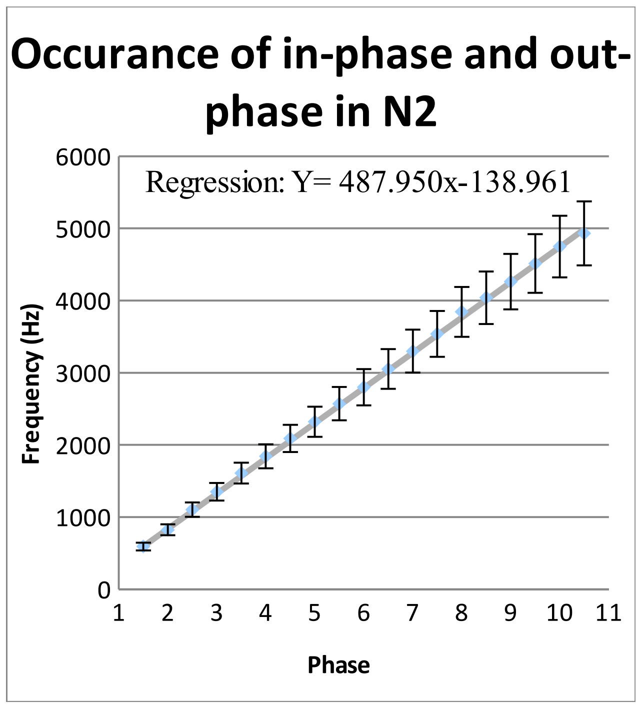

Fig 2. Frequencies of observed in-phases and out-phases using oscillator under nitrogen in 22.2 Celsius

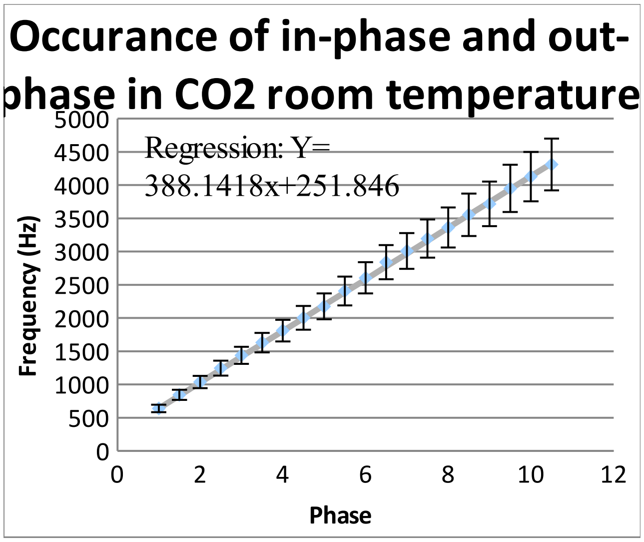

Fig 3. Frequencies of observed in-phases and out-phases using oscillator under carbon dioxide in 21.5 Celsius

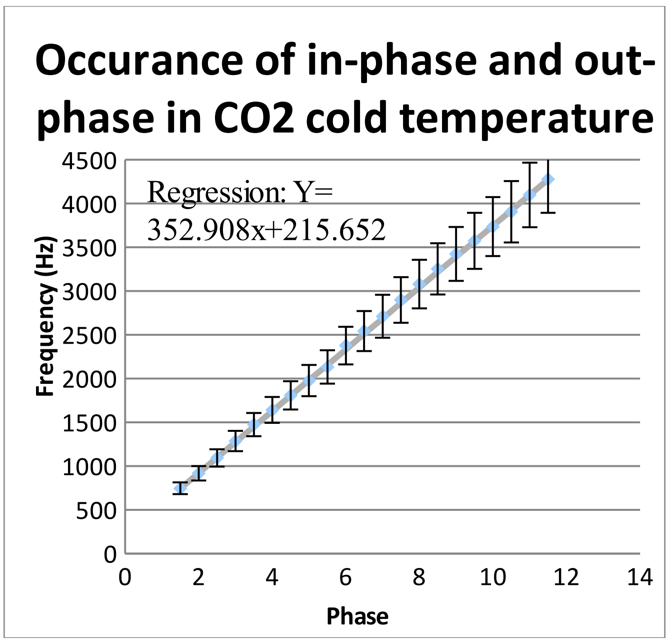

Fig 4. Frequencies of observed in-phases and out-phases using oscillator under carbon dioxide in -25.9 Celsius

Regression line and observed frequencies on dry air seem to be coherent for all experiments done in different medium. This is a good indication of precision of the acquired set of data, indicating that it may be reliable. Also, it must be noted that for regression line seems to be within the range of 9% error bar that was assigned to the data points. Meaning that there is no potential for outlier and all data points are reliable.

Assuming that gas in the tube was dry and pure, speed of sound, U, can be found by using following equation

$$U = U_i\sqrt{\frac{T}{(298.15\,K)}}$$.

	U_i (m/s)	U (m/s)
Air 294.35 K	346.3	344.1
N_2 295.2 K	334	332.3
CO_2 296.1 K	259	258.1
CO_2 247.0 K	259	235.7

Table 1. velocity of sound observed in the experiment

Since $U = \frac{df}{dn}L$, and $\frac{df}{dn}$ can be found from regression line of the the data; length of the tube used in lab was able to be calculated mathematically. Also, error for $\frac{df}{dn}$ was found using $\frac{1}{3}\sqrt{S_1^2+S_2^2+S_3^2}$ where S is the slope of error terms for regression coefficients for different trials of experiments.

	$\frac{df}{dn}$	Length (m)
Air 294.35 K	479.94±36.7	0.72
N_2 295.2 K	487.95±33.65	0.68
CO_2 296.1 K	388.14±26.49	0.66
CO_2 247.0 K	352.91±32.33	0.67

Table 2. Length of tube calculated using velocity of the sound and slope of regression line.

It is apparent that apart from experiment done in air, the lengths of the tube are rather coherent. This indicates that the most data from experiments are precise. The difference in experiment done in air may be credited to the fact that air was not dry, and had humidity of 54%, humidity may have made calculation for velocity of sound incorrect.

Theoretical C_v was found by utilizing the equation $C_v = 2.5\text{R} + C_{vibr}$. Where C_{vibr} can be found by $C_{vibr} = R\sum_1^4 \left(\frac{hcV_i}{kT}\right)^2 * \left(e^{\left(\frac{hcV_i}{kT}\right)} - 1\right)^2$. Values of V are found below in table 3.

	Frequency (1/cm)
V1	1340
V2a	667
V2b	667
V3	2349

Table 3. Normal modes of vibration (3)

	Cv theoretical (J/Kmol)
CO2 at 295.2K	21.4
CO2 at 247.1K	26.4053

Table 3. Cv theoretical found for two temperatures of CO2

Experimental C_v was found Using following equation $Cv=\frac{R^2T(C_v+R)}{U^2M}$, this equation was derived to $C_v=\frac{(R^2T)}{M_{CO2}*(U_{CO_2}/S_{CO_2})^2-RT}$ where S is slope of regression line and M is molar mass in $\frac{Kg}{mol}$. Data from CO2, even though other data seems fitting as well, because data from CO2 seemed to be most linear. Error estimate for the experimental C_v was found by using the following equation.

$$\sqrt{(\frac{dC_v}{dT})^2(a^2)+(\frac{dC_v}{dM_{CO_2}})^2(a^2)+(\frac{dC_v}{dS_{CO_2}})^2(a^2)+(\frac{dC}{dU_{C}}$$

	Cv experimental (J/K mol)	Error estimate
CO2 at 295.2 K	14.54	+- 0.09
CO2 at 247.1 K	18.00	+-0.2

Table 4. Cv experimental found for two temperatures

It is notable that experimental result and theoretical result varies greatly.

REFERENCES

(1) A. J Pounds. Mercer University, Macon, GA. Personal communication, **2011**

(2) A.J Pounds, *Experimental Determination of Gaseous Heat Capacity via Sound Velocity Measurements* **2011**.

(3) Silbey R.J, et al. *Physical Chemistry 4ed*, John Wiley & Sons: Hobken, NJ, **2005**; 487.