Ideal gas laws and the determination of absolute zero

M. Crescimanno,[1,**], **K. Accetta, M. delFraino,**

[1] *Dept. of Physics and Astronomy, Youngstown State University, Youngstown, OH 44555*

[**] *Corresponding author: mcrescim@cc.ysu.edu*

Compiled February 9, 2009

Using a mercury manometer, and taking a series of pressure -vs- volume measurements at two different temperatures, we were able to test various components of the ideal gas laws and use our data to estimate a temperature (which approximates "absolute zero") at which the pressure-volume product for the gas would be zero. This was done for both air and natural gas, yielding an estimated "absolute zero" of -275 ± .6 ^{o}C (as computed with air).

Introduction: Real gasses behave as ideal gasses in the limit of high temperature and low density. In this laboratory we used a U-shaped tube (a "manometer", after a fashion) filled with mercury. One side had a valve into which a quantity of has could be introduced above the mercury. The valve was then sealed, trapping a fixed quantity of gas. The manometers' inside diameter was 3mm.

A revervoir of mercury at the bottom of the manometer allowed one to selectively increase or decrease the pressure of the gas by pushing enough mercury into manometer so that a desired height difference in the two columns could be obtained (note that the side without the valve was open to the atmosphere).

The conditions in the laboratory during the day of the experiment were intially ambient pressure of 737.0mm Hg and 24.6 degrees (C) inside and some -8 degrees outside (where the apparatus was taken for a temperature change). Air was the first gas introduced into the apparatus under these conditions. The following data set was collected for air, and the accompanying graph is in Figure 1, with the line being the best fit using the ideal gas law,

$$PV = \text{const.} \quad (T + T_0) \tag{1}$$

with P the pressure as measure in the column height differences of mercury and V the volume of the gas. Here T_0 is an offset temperature, in essence, we think of as representing the (negative) temperature at which the naive gas law above would give a zero PV product.

During the second segment, the valve was opened, and the reservior was pushed in so that very nearly all the air was expelled from the manometer. Then Methane (Natural gas) was slowly introduced in to the manometer, and after a given quantity of that gas was introduced, the valve was again sealed and the experimental determination of a pressure-volume trajectory at room temperature and outside was repeated. Note that during this second phase of the experiment the room temperature was found to 22 ^{o}C and the atmospheric pressure had increased to 737.2mm (determined to this accuracy with a barometer that had a vernier).

Table 1. **Air**, room temp (RT) and outside (O), Mercury Column Heights (cm)

air side (RT)	open side (RT)	air side (O)	open side (O)
21.4	22.4	28.2	47.0
21.5	23.4	27.9	44.7
21.8	24.4	27.5	42.5
22.2	25.9	27.2	41.0
22.4	27.1	26.8	38.8
22.8	28.5	26.5	37.3
23.0	29.5	26.0	34.7
23.5	31.7	25.6	32.6
23.9	33.6	25.3	30.8
24.2	34.9	25.0	29.3
24.4	36.1	24.7	28.3
24.6	37.2	24.3	26.1
24.8	38.2	23.8	24.3
25.3	40.7	23.5	22.9
25.5	41.6	23.3	21.8
25.8	43.3	22.8	20.1
26.0	44.4	22.4	18.5
26.3	46.1	22.0	16.9
26.6	47.7	21.8	16.1
26.9	49.5	21.5	14.8

In detail, the air data shown above in Figure 1 (each trace is a different temperature, the points are data and the lines are the fits) was fit with the single relation, $P = A/V$ for a single constant A. For the two temperatures, this single parameter fit gave

And finally we extrapolate these data back to the temperature at which the constant 'A' would be zero to find that would happen at a temperature of -275 ± .6 ^{o}C.

We now complete the same ideal gas fit with the methane data. There appears to be issues with these data for methane, and we were not able to get a reasonable estimate for the constants that we would then use in estimating absolute zero.

Conclusion: Using air the data was very regular, fit well

Table 2. **Methane**, room temp (22) and outside (O), Mercury Column Heights (cm)

air side (22)	open side (22)	air side (O)	open side (O)
29.63	30.3	25.0	25.5
29.6	31.6	25.3	26.4
29.9	33.0	25.7	27.2
30.3	34.2	26.1	27.8
30.7	35.6	26.6	28.2
31.1	37.1	27.3	28.6
31.9	40.4	27.6	28.9
32.4	42.4	28.0	29.5
33.8	44.7	28.5	29.9
34.5	46.5	29.0	30.6
35.1	48.5	29.3	30.7
		29.7	30.7
		30.2	31.6
		30.6	32.4
		31.0	32.7
		31.5	33.1
		32.0	33.9
		32.4	34.5
		33.1	35.3
		33.6	35.7

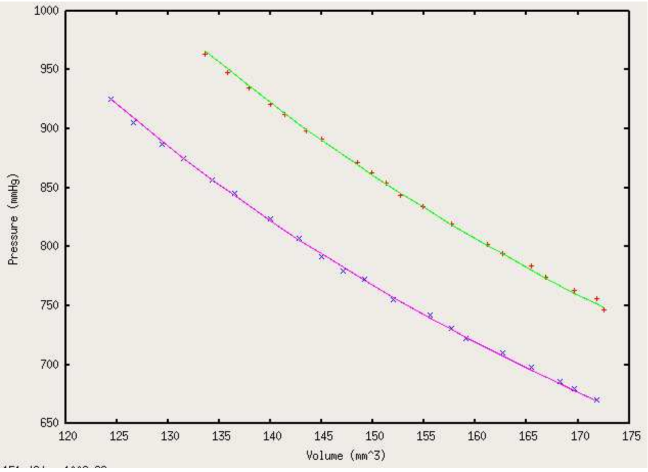

Fig. 1. Air data, for the temperatures 24.6 and -8 ^{o}C. Data is points and lines are the one parameter fit using the gas laws.

with the gas law and lead to a reasonable estimate for absolute zero of -275 ± .6 ^{o}C. We have many reasons to believe that there are large systematic errors which are not accounted for in this analysis.

Our data for the natural gas were problematic. it is possible that there was a slow leak of the gas, and there may have been other issues that we are not aware of and were unable to quantify. As a result those data were essentially unusable.

Table 3. **Air**, the constants -vs- temperature

Temperature (C)	constant A	± error	(percent)
24.6	129000	± 67	.06%
-8	115000	± 65	.05%

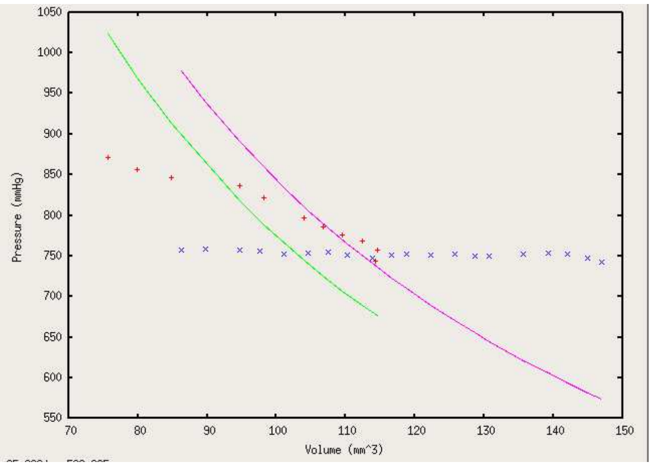

Fig. 2. Methane data.

References

1. K. Rzazewski, B. Stone, and M. Wilkens, “Laser-noise-induced intensity fluctuations in resonance flourescence,” *Phys. Rev. A* **40**, 2788-2791 (1989).
2. T. Yabuzaki, T. Mitsui, U. Tanaka, ”New type of high-resolution spectroscopy with a diode laser,” *Phys. Rev. Lett.* **67**, 2453-2457 (1991).
3. Th. Haslwanter, H. Ritsch, J. Cooper, and P. Zoller, “Lasernoise-induced population fluctuations in two- and threelevel systems,” *Phys. Rev. A* **38**, 5652-5659 (1988).
4. B. J. Dalton and P. L. Knight, “The effects of laser field fluctuations on coherent population trapping,” *J. Phys. B* **15**, 3997-4015 (1982).
5. M. Fleischhauer and T. Richter, ”Pulse matching and correlation of phase fluctuations in a Λ system,” *Phys. Rev. A* **51** 2430-2442 (1995).
6. R. Walser and P. Zoller, ”Laser-noise-induced polarization fluctuations as a spectroscopic tool”, *Phys. Rev. A* **49**, 5067-5077 (1994).
7. M. Martinelli, P. Valente, H. Failache, D. Felinto, L.S. Cruz, P. Nussenzveig, A. Lezama, Phys. Rev.A 69, 043809 (2004)
8. L.S. Cruz, D. Felinto, J.G. Aguirre Gomez, M. Martinelli, P. Valente, A. Lezama, and P. Nussenzveig, ”Laser-noise-induced correlations and anti-correlations in electromagnetically induced transparency,” *Eur. Phys. J.* D **41**, 531-539 (2007).
9. V.A. Sautenkov, Y.V. Rostovtsev, M.O. Scully, ” ,” *Phys. Rev. A* **72**, 065801 (2005), quant-ph/0508026.
10. G.O. Ariunbold, V.A. Sautenkov, Y.V. Rostovtsev, M.O. Scully, ” ,” arXiv:quant-ph/0603025 (2005).