Equation of State for an Ideal Gas

By Vincent Edwards

Lab Partner: Gina Herrera

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1. Results

Table 1 contains various quantities, both measured and given, that were relevant to the analysis. They are collected in a table to assist with lookup.

T is the temperature of the room measured using a digital thermometer. The temperature was initially measured as $71\,°\mathrm{F}$, then converted to kelvins as show in Equation 1.

$$T = \left(\frac{5}{9}(71 - 32) + 273.15\right)\,\mathrm{K} = 294.82\,\mathrm{K} \tag{1}$$

P_0 is the atmospheric pressure measured using a digital barometer. The pressure was initially measured as $28.93\,\mathrm{in\ Hg}$, then converted to pascals as shown in Equation 2.

$$P_0 = (28.93\,\mathrm{in\ Hg}) \cdot \frac{25.4\,\mathrm{mm\ Hg}}{1\,\mathrm{in\ Hg}} \cdot \frac{101\,325\,\mathrm{Pa}}{760\,\mathrm{mm\ Hg}} = 97\,968\,\mathrm{Pa} \tag{2}$$

m_p is the mass of the piston & platform, taken from the label on the gas law apparatus. D is the piston diameter, taken from the label on the gas law apparatus.

Some constants that were needed in the analysis were the universal gas constant R and the acceleration due to gravity g. Both values were taken from the lab manual. Note that the value of g used is for the science building, where the experiment was performed.

Table 1: Miscellaneous Quantities

Quantity	Value
T	$294.82\,\mathrm{K}$
P_0	$97\,968\,\mathrm{Pa}$
m_p	$35.0\,\mathrm{g}$
D	$32.5\,\mathrm{mm}$
R	$8.314\,\mathrm{J\,mol^{-1}\,K^{-1}}$
g	$9.7955\,\mathrm{m\,s^{-2}}$

Table 2 contains the measurements of the mass put on the piston platform m and the resulting length of the column of air in the cylinder L. 7 samples were collected all together. The piston-holding thumbscrew was used to keep the piston in place at the top of the cylinder while connecting the cylinder to the 2-liter bottle. After the connection was made, the thumbscrew was released and the piston dropped down slightly. If the piston continued to slide down, without stopping, it would have indicated that air was escaping from the cylinder, tubing, or bottle. After finding the location of the leak and patching it, the piston would need to be reset to its highest position and the bottle reconnected. However, a small amount of air leakage was unavoidable. Thus, care was

taken to quickly measure L after placing the slotted masses on the platform, only waiting a few seconds for the reading to stabilize before moving on to the next sample.

Table 2: Samples of Mass Added and Air Column Length

Sample	m (g)	L (mm)
1	0	94
2	20	87
3	40	80
4	60	72
5	80	65
6	100	57
7	120	48

2. Analysis

The cross-sectional area of the cylinder A is given by Equation 3. Substituting in the diameter D yields an area of $0.000\,830\,\mathrm{m}^2$, as shown in Equation 4.

$$A = \pi\left(\frac{D}{2}\right)^2 \tag{3}$$

$$A = \pi\left(\frac{32.5\,\mathrm{mm}}{2} \cdot \frac{1\,\mathrm{m}}{1000\,\mathrm{mm}}\right)^2 = 0.000\,830\,\mathrm{m}^2 \tag{4}$$

Table 3 contains various quantities involved in finding the pressure of the gas P and its reciprocal P^{-1} at each sample. M is the combined mass of the piston, platform, and the slotted masses put on the platform, calculated using Equation 5.

$$M = m + m_p \tag{5}$$

Sample Calculation (Sample 2 M)

$$M = (20\,\mathrm{g}) + (35.0\,\mathrm{g}) \tag{6}$$

$$M = 55\,\mathrm{g} \tag{7}$$

F_g is the force of gravity on the combined mass M, calculated using equation Equation 8.

$$F_g = Mg \tag{8}$$

Sample Calculation (Sample 2 F_g)

$$F_g = \left(55\,\text{g} \cdot \frac{1\,\text{kg}}{1000\,\text{g}}\right)(9.7955\,\text{m}\,\text{s}^{-2}) \tag{9}$$

$$F_g = 0.54\,\text{N} \tag{10}$$

P is the total pressure exerted on the gas, calculated using equation Equation 11. P^{-1} is the reciprocal of the pressure P, calculated using equation Equation 12.

$$P = P_0 + \frac{F_g}{A} \tag{11}$$

$$P^{-1} = \frac{1}{P} \tag{12}$$

Sample Calculation (Sample 2 P & P^{-1})

$$P = (97\,968\,\text{Pa}) + \frac{(0.54\,\text{N})}{(0.000\,830\,\text{m}^2)} \tag{13}$$

$$P = 98\,618\,\text{Pa} \tag{14}$$

$$P^{-1} = \frac{1}{(98\,618\,\text{Pa})} \tag{15}$$

$$P^{-1} = 1.0140 \times 10^{-5}\,\text{Pa}^{-1} \tag{16}$$

Table 3: Quantities Calculated to Find Pressure and its Reciprocal

Sample	M (g)	F_g (N)	P (Pa)	P^{-1} (Pa^{-1})
1	35	0.34	98 381	1.0165×10^{-5}
2	55	0.54	98 618	1.0140×10^{-5}
3	75	0.73	98 854	1.0116×10^{-5}
4	95	0.93	99 090	1.0092×10^{-5}
5	115	1.13	99 326	1.0068×10^{-5}
6	135	1.32	99 562	1.0044×10^{-5}
7	155	1.52	99 798	1.0020×10^{-5}