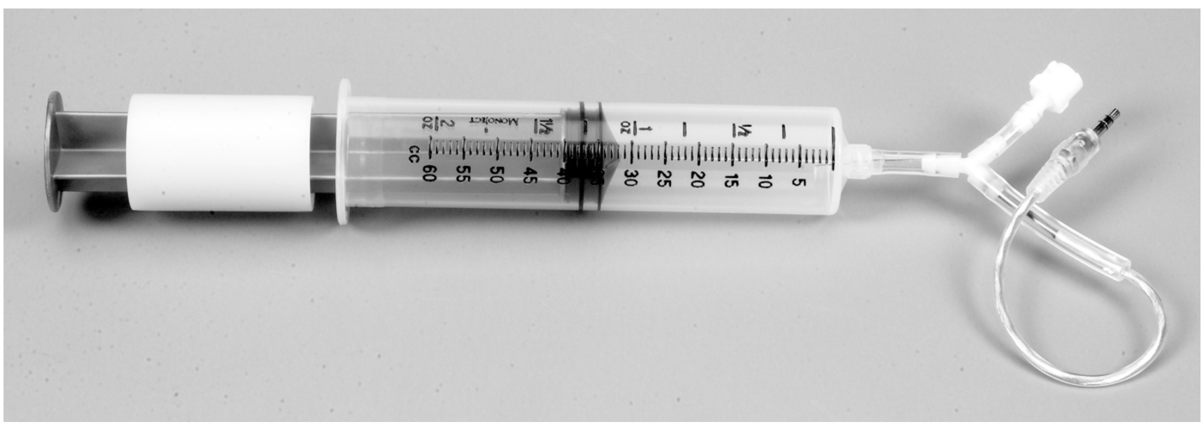
Instructions
Experiments

Instruction Manual

No. 012-08842B

Ideal Gas Law Syringe

TD-8596



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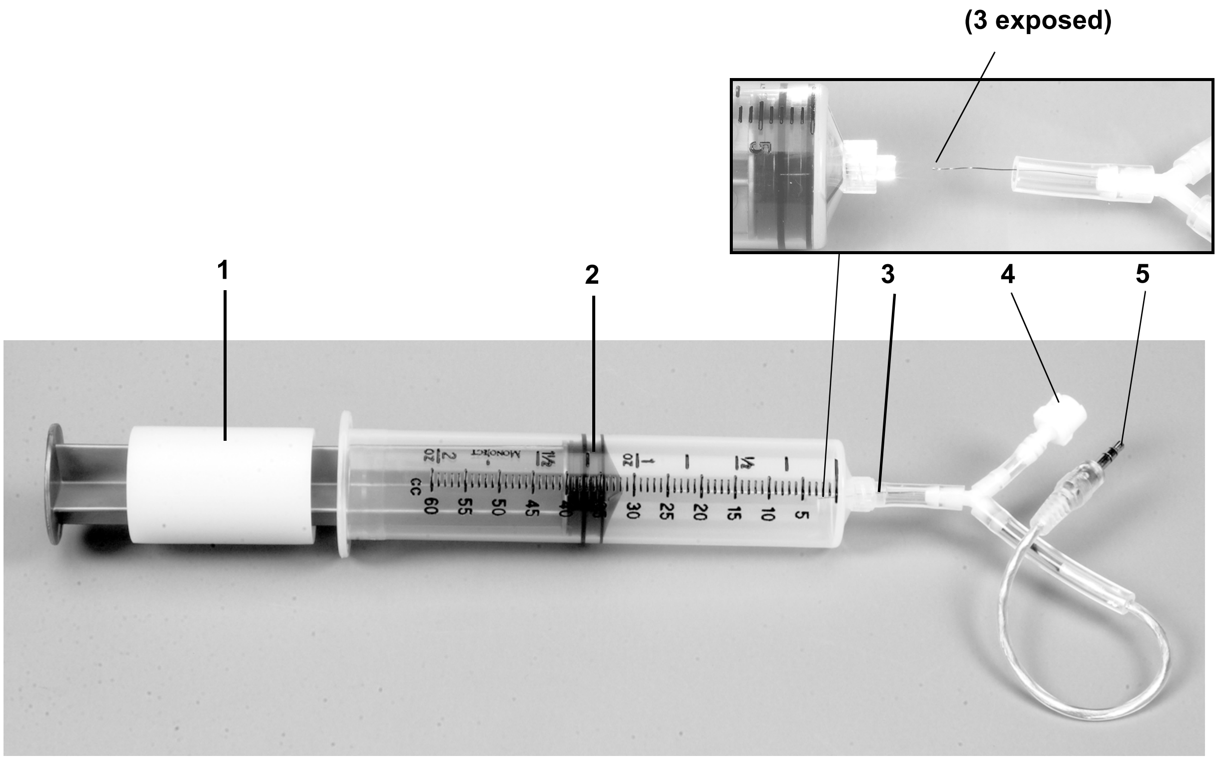
Ideal Gas Law Syringe

Model No. TD-8596



Included Equipment	Replacement Part Number
1. Mechanical stop	
2. Syringe and plunger	
3. Thermistor	
4. Pressure connector	
5. Temperature connector	
6. DataStudio Workbook CD (not shown)	013-08980

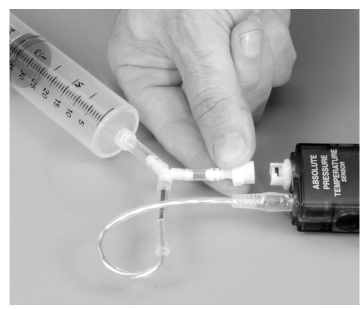
Additional Equipment Required or Recommended (*)	Model Number
PASPORT interface w/DataStudio	
Pressure/Temp sensor or	PS-2146 or
Pressure sensor and Temperature sensor	PS-2125 and PS-2107
(*) PASPORT extension cable	PS-2500

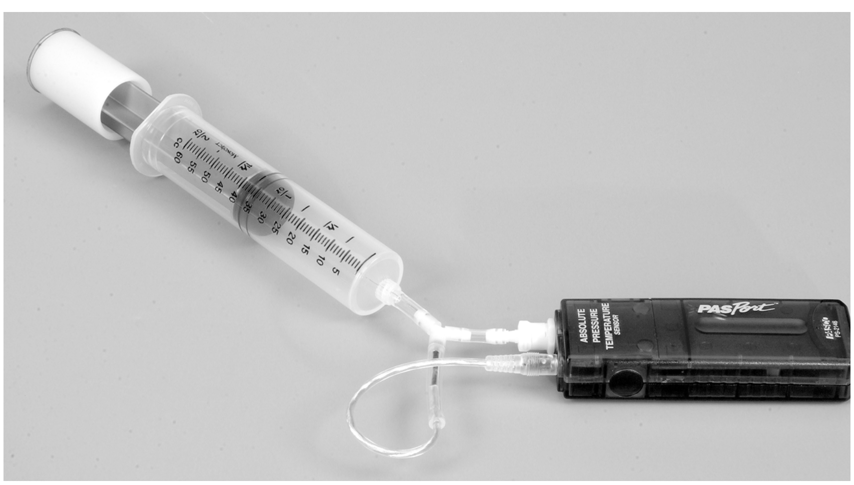
Introduction

The Ideal Gas Law Syringe allows simultaneous measurements of temperature and pressure of a gas as it is compressed. A low thermal mass thermistor is built into the end of the syringe to measure temperature changes inside the syringe. The response time is around a half of a second. The plunger is equipped with a mechanical stop that protects the thermistor, and also allows for a quick, predetermined change in volume. The temperature connector, a mini stereo jack, connects directly to a temperature sensor, and the pressure connector, a tubing coupler, connects directly to a pressure sensor. As the plunger of the syringe is depressed, the volume decreases while pressure and temperature increase.

Equipment Setup

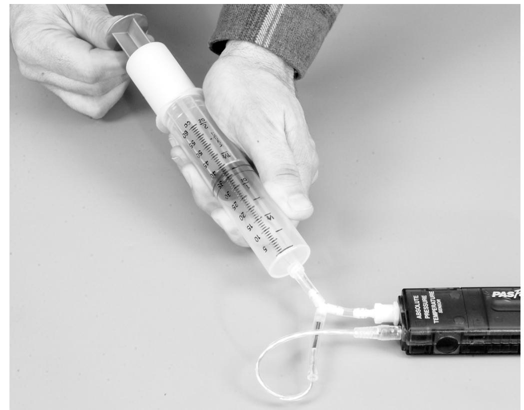
Plug the mini stereo jack into the temperature sensor. Connect the tubing coupler to the pressure port as shown. This white plastic connector can be disconnected and re-connected during the experiment to allow for different initial plunger positions. All of the clear plastic fittings are glued in place and cannot be removed.





Experiment 1: Ideal Gas Law

Procedure



1. With the pressure coupling disconnected, push the plunger all the way in so that the stop is bottomed out. Record the volume reading on the syringe. It should be around 20 cc.
2. Set the plunger for a volume of 40 cc. Connect the pressure coupling, and make sure the temperature jack is also plugged in.
3. Open the DataStudio file "Ideal Gas Law."
4. Click **Start**. Fully compress the plunger quickly so that the stop is bottomed out. Hold this position until the temperature and pressure have equalized and are no longer changing. It should take less than 30 seconds for the temperature to return to room temperature.
5. Release the plunger and allow it to expand back out on its own. (It may not go back to 40 cc.) Wait again until the temperature and pressure have equalized and are no longer changing. Record the final volume reading on the syringe.
6. Click **Stop**.

Analysis

Constant Temperature

1. Highlight an area (click and drag) on the pressure graph at the beginning of the run before you compressed the air. You should see that data highlighted in the Data Table. Record the initial pressure (P_1) in Table 1.
2. Highlight an area on the pressure graph at the point just before you released the plunger. Note that the temperature should be back down to almost room temperature again. Record the final pressure (P_2) in Table 1. Record the volume (V_2) of the syringe when the plunger is fully compressed. It should be around 20 cc

Table 1: Constant Temperature

	Volume (cc)	Pressure (kPa)
1	40.0	
2		

3. For constant temperature, the Ideal Gas Law reduces to $P_1V_1 = P_2V_2$, or

$$\frac{V_1}{V_2} = \frac{P_2}{P_1} \qquad (1)$$

4. Take the ratio of the final pressure over the initial pressure P_2 / P_1. Take the ratio of the initial volume over the final volume V_1 / V_2. Are they equal? Why not? There is actually a small consistent error in the volume that you can account for. The calibration on the syringe does not include the volume of air in the tubing. If we call this unknown, additional volume V_o, the equation (1) above can be more correctly written as

$$\frac{V_1 + V_0}{V_2 + V_0} = \frac{P_2}{P_1} \qquad (2)$$

Using your measured values of V_1, V_2, .P_1 and P_2, algebraically solve for and calculate the volume V_o.

Varying Temperature

1. Highlight an area on the temperature graph at the beginning of the run before you compressed the air, as you did before. It does not matter if it is the same pressure point or not. Record both the initial pressure (P_1) and initial temperature (T_1), in Table 2.

2. Record the initial volume (V_1), including your calculated value of V_o . Note: $V_1 \neq 40$ cc

3. Highlight the area on the temperature graph where it peaks. Pick the place where the temperature has peaked, not the pressure. It takes the temperature sensor about 1/2 second to respond. Record the peak temperature (T_2) and the corresponding pressure (P_2) for that time in Table 2. You want two values that occurred at the same time.

Table 2: Varying Temperature

	Volume (cc)	Pressure (kPa)	Temperature (K)
1			
2			

4. Record the volume (V_2), (including V_o) of the fully compressed plunger.

5. The Ideal Gas Law states that the quantity.

$$\frac{PV}{T} = \text{Constant.}$$

Use your values to calculate the ratio

$$\frac{P_1V_1}{T_1}$$

Use your values to calculate the ratio

$$\frac{P_2V_2}{T_2}$$

6. Compare these two ratios. Are they about the same? Calculate the percent difference between them.

$$\text{Percent Difference} = \frac{\text{Value \#2 - Value \#1}}{\text{Value \#1}} \text{ x } 100\ (\%)$$

Questions

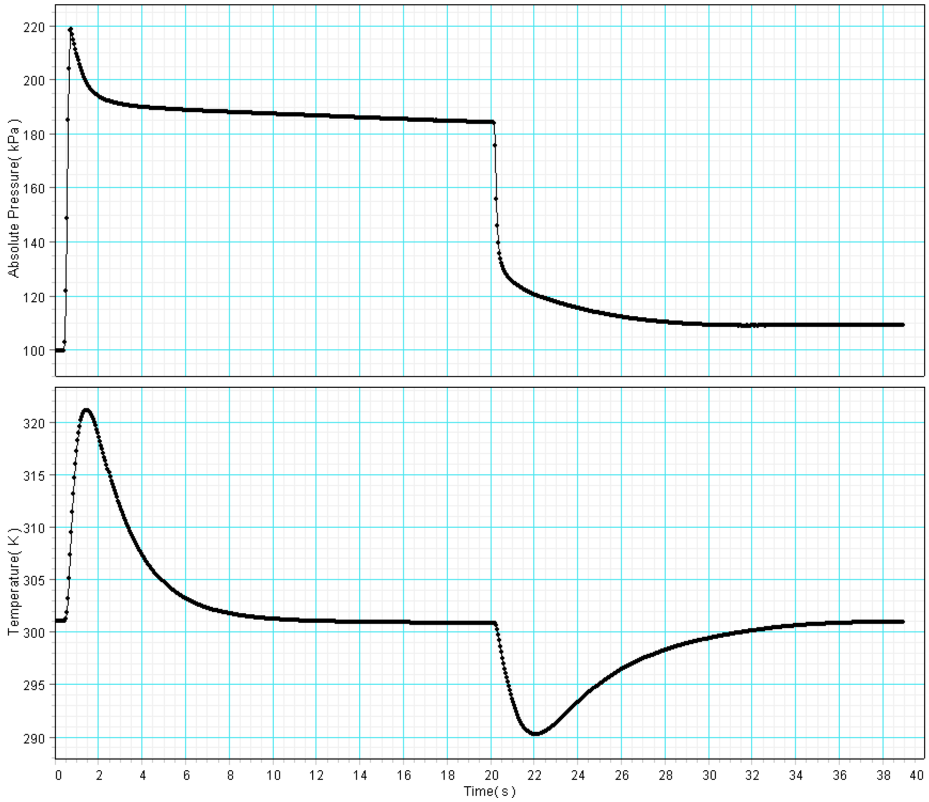
1. When the syringe volume is suddenly cut in half, the pressure changes by more than a factor of 2. Why does it momentarily spike above 200 kPa?

2. When the syringe volume is suddenly cut in half, both the temperature and the pressure go up. After a short time, the temperature approaches room temperature, but the pressure approaches some new, higher value. Why doesn't the pressure decrease back to its original value like the temperature does?

3. When the plunger is released in the last part of the data run, what happens to the temperature? Why?

Experiment 1:

Teacher's Notes—Ideal Gas Law



Constant Temperature, Sample Data and Analysis

Table 1: Constant Temperature

	Volume (cc)	Pressure (kPa)
1	40.0	99.76
2	20.0	184.17

$$V_0 = \frac{P_2V_2 - P_1V_1}{P_1 - P_2}$$

$V_0 = 3.6$ cc

Among different lab groups or over several trials you may find that calculated values of V_0 vary by 1 cc or more. This may look like a very large uncertainty, but, since it is *added* the total volume of gas (40 to 60 cc) the absolute uncertainty, rather than the relative uncertainty, should be considered.

Varying Temperature, Sample Data and Analysis

Table 2: Varying Temperature

	Volume (cc)	Pressure (kPa)	Temperature (K)
1	43.6	99.76	301.04
2	23.6	199.22	321.08

$$\frac{P_1V_1}{T_1} = 14.4\ \text{kPa} \cdot \text{cc}/\text{K}$$

$$\frac{P_2V_2}{T_2} = 14.6\ \text{kPa} \cdot \text{cc}/\text{K}$$

Percent Difference = 1%

Answers to Questions

1. When the cylinder is compressed, the pressure momentarily spikes because the temperature of the gas increases. As the temperature drops back down, the pressure decreases.

2. The pressure does not return to its original value because volume has decreased while the molar quantity of gas remains the same.

3. When the pressure is released the temperature drops rapidly, then slowly returns to room temperature. The temperature drops due to sudden decompression (which is essentially adiabatic). It returns to room temperature due to heat flow from the environment into the syringe.

Experiment 2: Teacher's Notes—Ideal Gas Law Workbook

With the electronic workbook contained on the CD-ROM, students will explore the relationship between the volume, pressure and temperature of a gas. They will compare graphs of V versus T/P for two different quantities of gas, and use these graphs to calculate the number of moles in both cases.

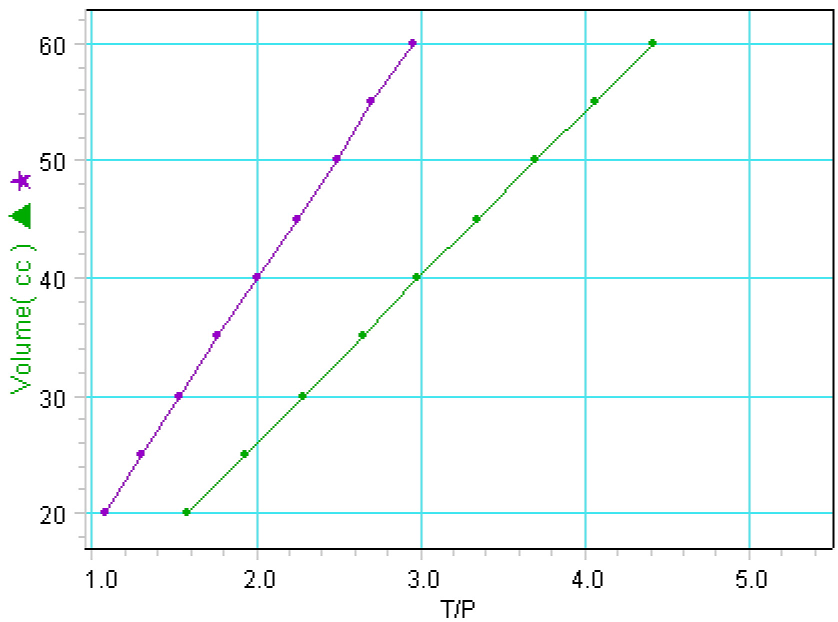


Fig. 4. Both Data Sets

Have your students open the DataStudio file "Ideal Gas Law Workbook" and follow the on-screen instructions. They will collect, graph and analyze data within the electronic workbook.

To hand in their work, students can save a copy of the file or print the workbook after they have finished.

These sample data are from the file "Workbook with data".

Volume (cc)	Pressure (kP (kPa)	Temperature (K)	T / P (K/kPa)
60	102	300	2.95
55	111	300	2.70
50	121	302	2.49
45	135	302	2.25
40	151	303	2.00
35	172	303	1.76

Table 1: Initial Volume 60 cc

Volume (cc)	Pressure (kP (kPa)	Temperature (K)	T / P (K/kPa)
40	101	302	2.98
35	115	304	2.65
30	133	305	2.29
25	158	306	1.94
20	194	308	1.58

Table 2: Initial Volume 40 cc

Answers to Questions on Page 5 of the Workbook:

3. The slope of each line is nR. From the slope and the initial pressure and temperature on Table 1, the initial volume of gas is:

Initial Volume = nRT/P = (21.3 cc·kPa/K) × (300 K)/(102 kPa) = 62.8 cc

4. This figure is the volume of the syringe, plus the volume of the attached tubing:

Volume of tubing = 62.8 cc - 60.0 cc = 2.8 cc

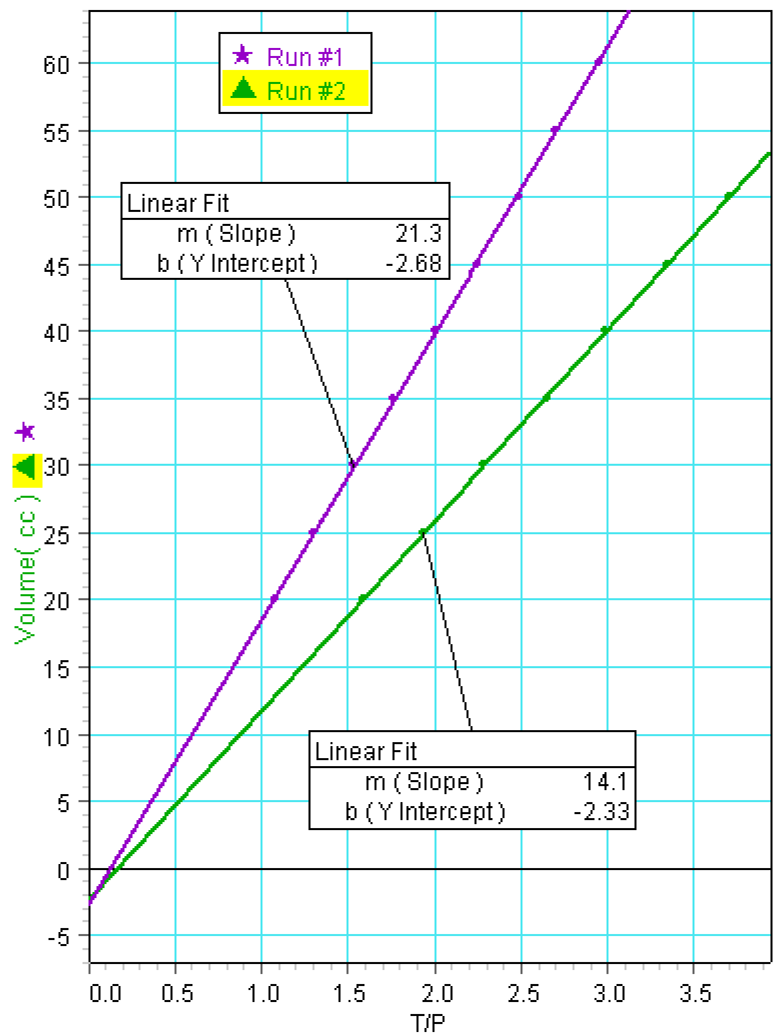
5. The y-intercept of the best-fit line, 2.68 cc, is also the volume of gas in the tubing. In this case the two values deviate by about 0.1 cc.

6. n = slope/R. Pay attention to units in this calculation.

$$n = \frac{21.3\ \text{cc} \cdot \text{kPa/K}}{8.31\ \text{J/K} \cdot \text{mol}} = \frac{0.0213\ \text{J/K}}{8.31\ \text{J/K} \cdot \text{mol}} = 2.56 \times 10^{-3}\ \text{mol}$$

7. The ratio of slopes is 1.51, close to the expected value of 1.5.

8. In theory the y-intercepts of both slopes are equal because they both represent the volume of the tubing. In this case they differ by 0.35 cc.



Safety

Read the instructions before using this product. Students should be supervised by their instructors. When using this product, follow the instructions in this manual and all local safety guidelines that apply to you.

Technical Support

For assistance with any PASCO product, contact PASCO at:

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