

Gases: Dalton's Law

INSTRUCTOR RESOURCES

By Dale A. Hammond, PhD

LEARNING OBJECTIVES

- introduce the concept of ideal gases.
- experimentally determine the relationship between pressure and amount of gas, using the *MicroLAB* interface system to collect and analyze the data.
- experimentally determine how the addition of different gases affects Dalton's law, using the *MicroLAB* interface system to collect and analyze the data.

Procedure Overview

Effect of added amounts of the same gas

- interface and syringe assembly set up and calibrated.
- Erlenmeyer flask assembly evacuated repeatedly using the 60 ml syringe.
- pressure/amount data pairs taken by addition of 5 ml increments up to about 1200 torr.
- data analyzed and graphed, and questions answered.

Effect of added amounts of the different gases

- pressure/amount data pairs taken at a minimum of five additions each of at least three different gases to the suction flask.
- data analyzed and graphed, and questions answered.

GASES: DALTON'S LAW

Report Sheet

The pressure-volume data are stored under the file names you gave in each section of the Dalton's Law program.

The effect of additions of the same gas to the total pressure in the container.

- Using the **Analysis** function, calculate the First Order (Linear) curve fit of the data for the pressure in the flask versus the added volumes, then "click-drag" the function to **Column C** and to the **Y2 Axis**. **Be sure** to record the slope and intercept values in your lab notes.
- Use the Add Formula button to construct a formula to subtract the initial pressure in the flask from all of the other pressures, i.e., P-Po, then "click-drag" this formula to **Column D**. This will give you the pressure increments between volume additions.
- Again use the Add Formula button to construct a formula to divide all of the data in **Column D** (i.e., P-Po) by the second value in **Column D**, then change the digits of precision for that column to **0**.
- Print out this screen as follows:
 - Simultaneously press the **Ctrl** and **Print Screen** keys to capture the **Main Screen** image.
 - Click successively the following sequence: **Start > All Programs > Accessories > WordPad**.
 - With **Wordpad** open, simultaneously press the **Ctrl - V** keys to save the Screen image into **WordPad**.
 - Simultaneously press **Ctrl - P** to print the page. This should print the entire Main Screen for your Dalton's Law experiment.
- Use this information to show the validity of Dalton's law of partial pressures.

- In your graph, why is the volume of gas added graphed on the *X-axis* and pressure is graphed on the *Y-axis*? Print this graph with the appropriate descriptive title, including your initials.

The effect of additions of different gases to the total pressure in the container.

- Repeat steps 1 through 4 for the second part of the experiment
- Show mathematically how Dalton's Law can be derived from this data.

- Does it matter whether the amount of gases added consist of the same gas, or different gases? Explain.

GASES: DALTON'S LAW

Tips and Traps

Dalton's Law

1. It is imperative that an absolute pressure transducer be used in this experiment, rather than a differential transducer. This is due to the fact that a range of approximately 40 torr to about 1200 torr is covered. Experience has shown that differential transducers do not calibrate well across the positive to negative pressure range.
2. It is also imperative that the connecting tubing fit tightly at all connections, and the valves close tightly. Very poor results will be obtained without this, and very good results will be obtained with it.
3. Care should be taken in the selection of the 50 ml Erlenmeyer flasks. They should be thick walled and have no cracks, stars or chips, and **MUST** be carefully wrapped in clear plastic shipping tape to prevent flying glass in case of collapse.
4. The Luer valves can be obtained from **S17 Science Supplies and Services Co. Ltd, Secure Storage, Unit I 12, LPO 163, 1755 Factory Outlet Blvd., Niagara Falls, NY 14304, USA.** Web access at www.s17science.com, email at irwin@s17science.com, phone at 800-288-7151 and fax at 905-709-2040
5. Students should get graphs in which the data points form good straight lines and should be able to validate Dalton's Law with careful work. See the following images.

SAMPLE DATA

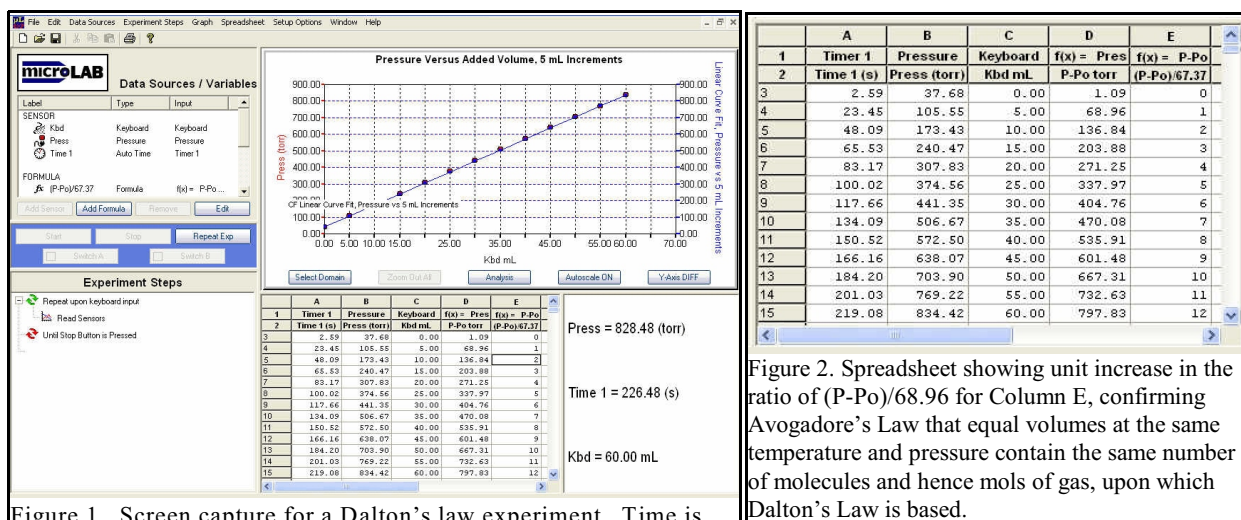


Figure 1. Screen capture for a Dalton's law experiment. Time is selected as a sensor even though it is not used in the experiment in order to evaluate the time the students took to take a set of data.

Figure 2. Spreadsheet showing unit increase in the ratio of (P-Po)/68.96 for Column E, confirming Avogadore's Law that equal volumes at the same temperature and pressure contain the same number of molecules and hence mols of gas, upon which Dalton's Law is based.

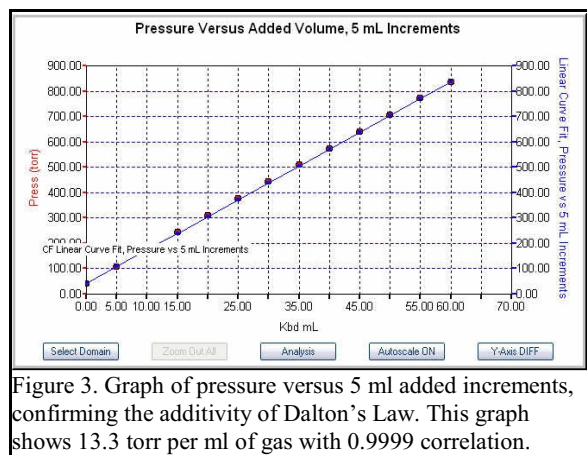


Figure 3. Graph of pressure versus 5 ml added increments, confirming the additivity of Dalton's Law. This graph shows 13.3 torr per ml of gas with 0.9999 correlation.

GASES: DALTON'S LAW

Report Sheet

The pressure-amount data are stored under the file names you gave in each section of the Dalton's Law program and recorded in your lab notes.

The effect of additions of the same gas to the total pressure in the container.

1. Using the **Analysis** function, calculate the First Order (Linear) curve fit of the data for the pressure in the flask versus the added volumes, then "click-drag" the function to **Column C** and to the **Y2 Axis**. **Be sure** to record the slope and intercept values in your lab notes.
2. Use the Add Formula button to construct a formula to subtract the initial pressure in the flask from all of the other pressures, i.e., $P - P_0$, then "click-drag" this formula to **Column D**. This will give you the pressure increments between volume additions.
3. Again use the Add Formula button to construct a formula to divide all of the data in **Column D** (i.e., $P - P_0$) by the second value in **Column D**, then change the digits of precision for that column to **0**.
4. Print out this screen as follows:
 - a. Simultaneously press the **Ctrl** and **Print Screen** keys to capture the **Main Screen** image.
 - b. Click successively the following sequence: **Start > All Programs > Accessories > WordPad**.
 - c. With **Wordpad** open, simultaneously press the **Ctrl - V** keys to save the Screen image into **WordPad**.
 - d. Simultaneously press **Ctrl - P** to print the page. This should print the entire Main Screen for your Dalton's Law experiment.
5. Use this information to show the validity of Dalton's law of partial pressures.

*Because the derivative is linear, this indicates that each addition of gas changed the total pressure at the same rate, therefore the total pressure equals the sum of the pressure each volume increment added. In addition, after the procedures performed in steps 2 and 3, the ratios obtained in **Column D** all have unit increments, within experimental error. Both of these validate Dalton's Law as*

$$P_T = k \sum_{i=1}^n P_i$$

6. In your graph, why is the volume of gas added graphed on the *X-axis* and pressure is graphed on the *Y-axis*? Print this graph with the appropriate descriptive title, including your initials.

The volume of gas added is the independent variable, because that is the variable determined by the experimenter. Therefore it should be placed on the X-axis, which typically is used to graph the independent variable. Pressure is graphed on the Y-axis because it is the dependent variable.

The effect of additions of different gases to the total pressure in the container.

7. Repeat steps 1 through 4 for the second part of the experiment
8. Show mathematically how Dalton's Law can be derived from this data.

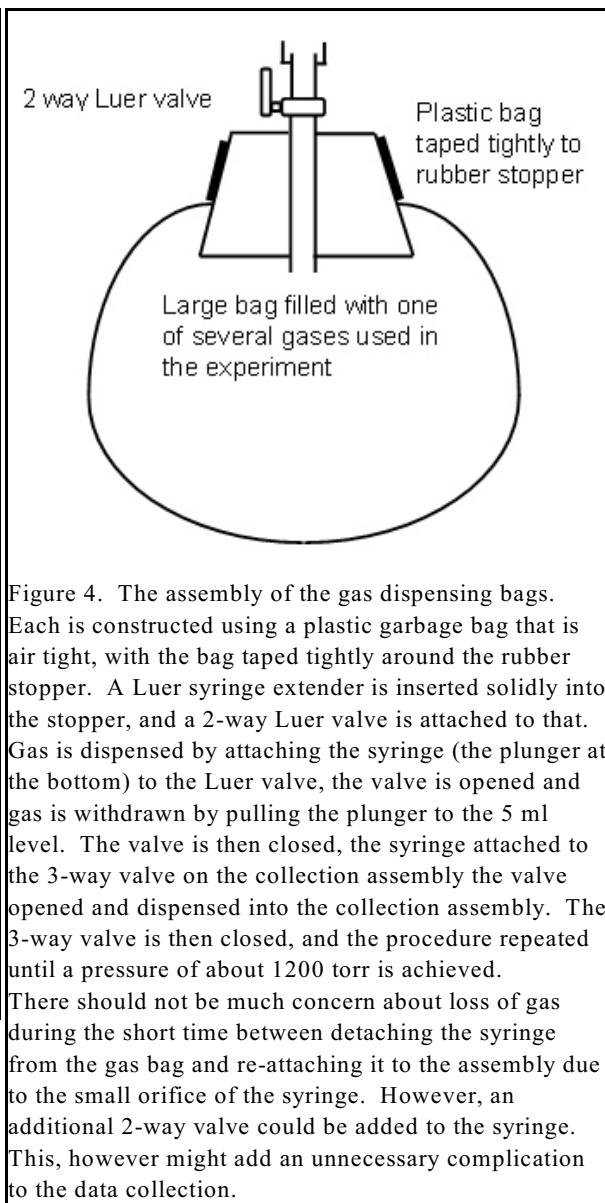
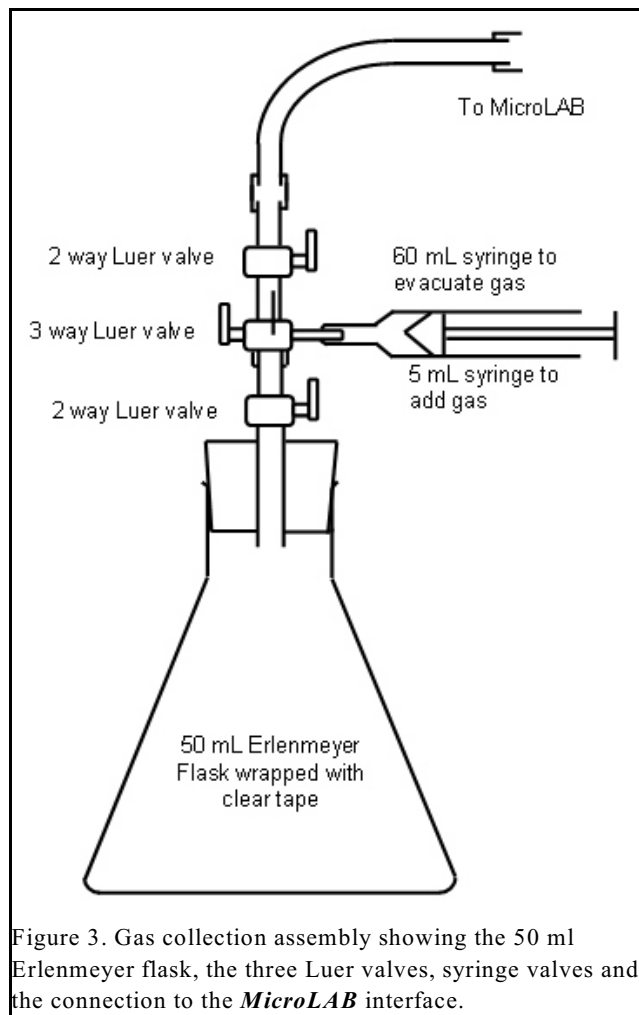
Answer should be similar to question 5 above.
9. Does it matter whether the amount of gases added consist of the same gas, or different gases? Explain.

Because the derivatives are linear, and the ratios have unit increase for each type of experiment, this indicates that each 5 ml addition of gas changed the total pressure at the same rate, regardless of what type of gas was used, therefore the total pressure equals the sum of the pressure of each volume increment added. This validates Dalton's Law as

$$P_T = k \sum_{i=1}^n P_i$$

as well as Avogadro's law that equal volumes of gas at the same temperature and pressure contain equal numbers of molecules, and consequently equal number of moles of molecules.

SAMPLE APPARATUS SET-UPS



GASES: DALTON'S LAW

Laboratory Preparation (per student station)

Dalton's Law

- 50 ml Erlenmeyer flask, well taped with clear boxing tape, with one hole stopper and Luer valves, assembled as shown in Figure 3. Students should assemble their own and test for leakage as described in the experiment.
- Large gas bags tightly attached to rubber stoppers with Luer valves, and filled with nitrogen gas(see Figure 4)
- Several other balloons as above, filled with different gases, e.g., helium, CO₂, hydrogen, argon, etc.
- 1 each 5 ml and 60 ml syringes.
- Luer valves and extenders per student station as follows: (Students will check these for leakage)
 - 2 or 3 each 2-way valves (S17 catalog number EQ 066 singly, or EQ 067 for 10, or EQ 068 for 25).
 - 1 each 3-way valve (S17 catalog number EQ 200 singly, or EQ 250 for 10, or EQ 260 for 25).
 - 1 each Syringe Extender (S17 catalog number EQ 0077 singly, or EQ 0787 for 10, or EQ 510 for 50).
- Luer valves and extenders for each gas bag as follows: (Lab supervisor should check these for leakage.)
 - 1 each 2-way valve (S17 catalog number EQ 066 singly, or EQ 067 for 10, or EQ 068 for 25).
 - 1 each Syringe Extender (S17 catalog number EQ 077 singly, or EQ 078 for 10, or EQ 510 for 50).
- **MicroLAB** interface pressure sensor
- **MicroLAB** program which will accept volume inputs from the keyboard and read pressure values from the pressure sensor.