Boyle-Mariotte law

Physics	Mechanics	Mechanics of liquids & gases
Physics	Thermodynamics	Kinetic gas theory & gas laws
Chemistry	General Chemistry	Stoichiometry

Difficulty level	Group size	Preparation time	Execution time
easy	1	10 minutes	10 minutes

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Teacher information

Application

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Experimental setup for the investigation of Boyle-Marriote's law

The Boyle-Marriotte law is named after the physicists Robert Boyle and Edme Mariotte. They discovered the law independently of each other.

The law states that the pressure of an ideal gas at constant temperature and amount of substance is inversely proportional to its volume.

$$p \sim \frac{1}{V}$$

If you increase the pressure on an ideal gas, its volume is reduced. If you lower the pressure again, it expands.

$$p \cdot V = const. \qquad \frac{p_1}{p_2} = \frac{V_2}{V_1}$$

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Other teacher information (1/2)

Prior knowledge

Students should have already learned basic pressure and volume.

Scientific principle

The principle developed in this experiment is also known as Boyle-Mariotte's law. It is based on the fact that the pressure exerted by an ideal gas at constant temperature is inversely proportional to its volume. In other words, the molecules of the gas repel each other more strongly at constant temperature when the volume is reduced.

Other teacher information (2/3)

Learning objective

Using a U-tube made from a hose and glass tubing, have students prove that for a closed volume of gas, the product of pressure and volume is a constant.

Tasks

To do this, they are to measure the difference in height between the water levels when the prevailing pressure changes and illustrate the relationship by calculation and graphical representation.

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Other teacher information (3/3)

Notes

- Numerically, the air pressure in hPa is equal to the specification in $mbar$. The indication in hPa or N/m^2 corresponds to the SI system: $1\,Pa = 1\,N/m^2$.
- The result $p \cdot V = const.$, the statement of Boyle-Mariotte's law, is only valid at constant temperature (e.g. constant room temperature).
- The height difference to the floor must be used in both cases. Only then do the pressure and volume changes become large enough to really prove Boyle-Mariotte's law.
- The atmospheric pressure p_0 should be read by the students themselves from an existing barometer or given by the teacher. If both are not possible, the value of $p_0 = 1013\,hPa$ can be specified.

Safety instructions

The general instructions for safe experimentation in science lessons apply to this experiment.

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Student Information

Motivation

Bicycle front tyre

To inflate a tire on your bike, you fill the tube of the tire with air using a pump. This tube has a certain maximum volume and at a certain point it becomes noticeably more difficult to pump more air into the tyre, as the pressure in the tyre continues to rise. The pressure increases because the volume of the tube is limited and the air must be compressed. Before this, however, the volume in the pump must be compressed so strongly that the current pressure in the tube behind the valve is exceeded.

In this experiment you will investigate the relationship between the pressure and the volume of a gas.

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Tasks

In this experiment, you will study what is called Boyle-Mariotte's Law.

To do this, you will change the pressure on a volume of air enclosed in a U-tube and measure the resulting displacement of the liquid columns.

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Equipment

Position	Material	Item No.	Quantity
1	Support base, variable	02001-00	1
2	Support rod, l = 600 mm, d = 10 mm, split in 2 rods with screw threads	02035-00	1
3	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
4	Glass tubes,l.250 mm, pkg.of 10	36701-68	1
5	PVC tubing, inner dia. = 7 mm, l = 1 m	03985-00	2
6	Glass tube holder with tape measure clamp	05961-00	1
7	Beaker, 100 ml, plastic (PP)	36011-01	1
8	Syringe 20ml, Luer, 100 pcs	02591-10	1
9	Nozzle for glass screwthread	43903-01	1
10	Measuring tape, l = 2 m	09936-00	1
11	Vernier calliper, plastic	03011-00	1

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Set-up (1/4)

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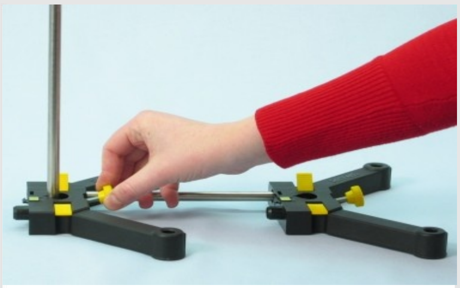
Connect the two halves of the support base with the 250 mm long support rod and fix them.

Screw together the split 600 mm long support rod.

Place the 600 mm long support rod in the front half of the support base and screw it tight.

Assembling the support base

Screwing the support rods



Fastening with the aid of the screw plug

Set-up (2/4)

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Attach the glass tube holder to the support rod

Clamp the glass tube holder to the long support rod.

Then clamp the measuring tape into the glass tube holder.

Attach the measuring tape to the glass tube holder

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Set-up (3/4)

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Structure of a U-tube

Build a U-tube with the glass tubes and the silicone tubing. The tube length should be more than 1.5 m.

- Attach the U-tube as high as possible to the support pole.
- If necessary, use some glycerine to connect the glass tubes to the tubing.

Using a syringe, fill the U-tube with water (without the plunger, as a funnel) until the two glass tubes are half full.

Fill U-pipe with water

Set-up (4/4)

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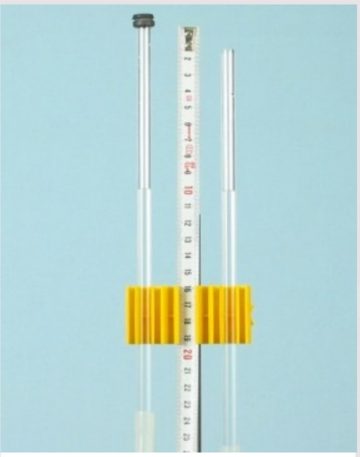

Place the rubber cap on the U-tube

Firmly place a rubber cap on the left glass tube.

Adjust the U-tube so that the water in both legs is at the same level again.

Mark the water level in the left glass tube with a felt-tip pen.

Marking the water level

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Procedure (1/3)

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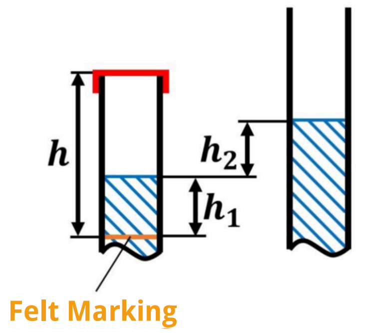
Measuring the inner diameter d_i

- Measure the inner diameter of the glass tubes with the caliper gauge d_i.
- Measure the air pressure p_0 or have your teacher give it to you. If necessary, use $p_0 = 1013\,hPa$.
- Measure the height h of the air column above the mark in the left glass tube.
- Record the measured values in the log.



Measuring the height h of the air column

Procedure (2/3)

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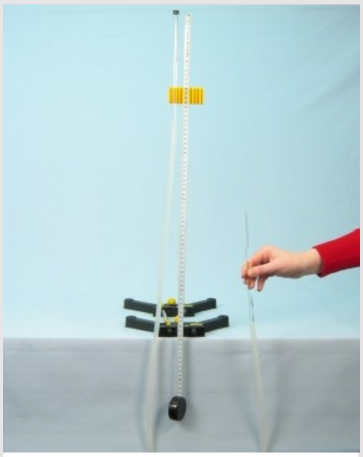

Lowering the right glass tube

Pressure reduction in the closed volume:

- Take the right glass tube out of the holder and gradually lower it to the floor.
- Note for each height h_1 (distance of the water level in the left glass tube from the mark) the height h_2 (distance between the water levels in the right and left glass tubes).
- Measure 6 pairs of values and record them in Table 2 in the protocol.

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Procedure (3/3)

Lowering the left glass tube

Pressure increase in the closed volume:

- Fix the right glass tube back in the holder, take out the left one and lower it step by step like the right one before, down to the floor.
- Note again for each height h_1 (distance of the water level in the left glass tube from the mark) the height h_2 (distance between the water levels in the right and left glass tubes).
- Again, measure 6 pairs of values and record them in Table 3 in the protocol.

Report

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Table 1

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First, write down your measurement for the experimental constants in the adjacent boxes.

$h =$ ______

$d_i =$ ______

$p_0 =$ ______

Notes to Table 2 & 3:

Calculate the volume V of the enclosed gas volume according to:

$$V = \pi \cdot r^2 \cdot (h \pm h_1) \quad \text{with } r = \frac{d_i}{2}$$

(+ for pressure reduction, − for pressure increase)

Calculate the pressure p in the sealed gas volume according to:

$$p = p_0 \mp h_2 \cdot g \cdot \rho \quad \text{with } g = 9.81\,\frac{m}{s^2},\ \rho = 1\,\frac{g}{cm^3}$$

(− for pressure reduction, + for pressure increase)

Table 2 (Pressure reduction)

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$h_1\ [cm]$	$h_2\ [cm]$	$V\ [cm^3]$	$p\ [hPa]$	$p \cdot V\ [hPa \cdot cm^3]$

Write down your measurements for the part of the experiment with the reduction in pressure in the adjacent table.

Calculate the corresponding pressures and volumes. Determine for each pair of measured values the product $p \cdot V$ and complete the table with it.

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Table 3 (Pressure increase)

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$h_1\ [cm]$	$h_2\ [cm]$	$V\ [cm^3]$	$p\ [hPa]$	$p \cdot V\ [hPa \cdot cm^3]$

Note down your measurements for the part of the experiment with the pressure increase in the table opposite.

Calculate the corresponding pressures and volumes. Determine for each pair of measured values the product $p \cdot V$ and complete the table with it.

Task 1

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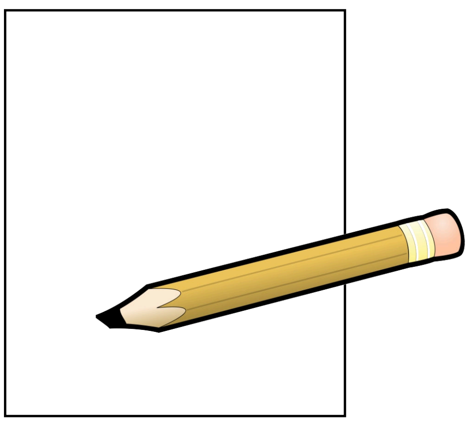

Now take a sheet of paper and create a diagram on it.

In this diagram the pressure p (y-axis) as a function of the volume V (x-axis) can be displayed.

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Task 2

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Consider the shape of the resulting curve for the diagram of the pairs of values from pressure p and volume V. What kind of function can this curve be described as?

- A parabolic function.
- A linear function.
- An exponential function.
- A constant function.

Check

Task 3

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Consider the values for $p \cdot V$ in Tables 2 and 3, what can you determine?

- The products of p and V are steadily decreasing.
- The products of p and V are steadily increasing.
- The products of p and V are always the same.

Check

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Task 4

Give the relationship between p and V in a formula.

- ○ $p \cdot V = \rho \cdot g \cdot h$
- ○ $p \cdot V = const.$
- ○ $p \cdot V = m \cdot g \cdot h$

Check

Task 5

The temperature was not changed in this experiment. What other relationship can you derive from the previous task for a closed volume filled with gas?

- ☐ $p_1/p_2 = V_2/V_1$
- ☐ $p \sim 1/V$
- ☐ $p_1/p_2 = V_1/V_2$

Check

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Slide	Score / Total
Slide 23: Type of function	0/1
Slide 24: Relationship between p and V	0/1
Slide 25: Formula p and V (1)	0/1
Slide 26: Formula p and V (2)	0/2

Total 0/5

Solutions Repeat Export text

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