Heat

Gas Laws

Boyle's Law

MEASUREMENTS ON AIR AT ROOM TEMPERATURE

- Measuring the pressure p of the enclosed air at room temperature for different positions s of the piston.
- Displaying the measured values for three different quantities of air in the form of a p-V diagram.
- Verifying Boyle's Law.

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BASIC PRINCIPLES

The volume of a fixed quantity of a gas depends on the pressure acting on the gas and on the temperature of the gas. If the temperature remains unchanged, the product of the volume and the temperature remains constant in many cases. This law, discovered by Robert Boyle and Edme Mariotte, is valid for all gases in the ideal state, which is when the temperature of the gas is far above the point that is called its critical temperature.

The law discovered by Boyle und Mariotte states that :

$$(1) \quad p \cdot V = \text{const.}$$

and is a special case of the more general law that applies to all ideal gases. This general law describes the relationship between the pressure p, the volume V, the temperature T referred to absolute zero, and the quantity n of the gas:

$$(2) \quad p \cdot V = n \cdot R \cdot T$$

$R = 8.314 \dfrac{J}{mol \cdot K}$ (the universal gas constant).

From the general equation (2), the special case (1) is derived given the condition that the temperature T and the quantity of the gas n do not change.

In the experiment, the validity of Boyle's Law at room temperature is demonstrated by taking air as an ideal gas. The volume V of air in a cylindrical vessel is varied by the movement of a piston, while simultaneously measuring the pressure p of the enclosed air.

The quantity n of the gas depends on the initial volume V_0 into which the air is admitted through an open valve before starting the experiment.

Fig. 1: Boyle's Law Apparatus

LIST OF APPARATUS

1   Boyle's Law Apparatus   U17210

EXPERIMENT PROCEDURE

- Set the piston at the position s_0 = 24 cm, open the valve, then close it again.

- Read off the pressure and record it.

- Change the position of the piston in steps of 1 cm. At each position read off the pressure and record it.

- Set the piston at the position s_0 = 12 cm, open the valve, then close it again.

- Start again with the piston at s_0 = 24 cm, change the position of the piston in steps of 1 cm, and at each position read off the pressure and record it.

- Set the piston at the position s = 6 cm, open the valve, then close it again.

- Start again with the piston at s_0 = 24 cm, change the position of the piston in steps of 1 cm, and at each position read off the pressure and record it.

SAMPLE MEASUREMENTS AND EVALUATION

Diameter of piston: 4 cm

Table 1: Experimental data

s / cm	V_{corr} / cm³	s_0 = 24 cm p / bars	s_0 = 12 cm p / bars	s_0 = 6 cm p / bars
24	309.3	1.02	0.52	0.28
23	296.7	1.07	0.55	0.29
22	284.1	1.11	0.58	0.30
21	271.6	1.16	0.62	0.31
20	259.0	1.22	0.63	0.32
19	246.4	1.28	0.68	0.33
18	233.9	1.34	0.71	0.35
17	221.3	1.42	0.76	0.37
16	208.7	1.50	0.78	0.39
15	196.2	1.60	0.82	0.42
14	183.6	1.72	0.88	0.45
13	171.0	1.83	0.96	0.49
12	158.5	1.99	1.02	0.51
11	145.9	2.18	1.08	0.58
10	133.3	2.38	1.18	0.62
9	120.8	2.62	1.33	0.69
8	108.2	2.96	1.46	0.78
7	95.6	3.34	1.68	0.87
6	83.1	3.90	1.97	1.00
5	70.5		2.33	1.18
4	57.9		2.90	1.45

As the cross-sectional area A of the piston is constant, the volume V of the enclosed air can easily be calculated from the distance s travelled by the piston relative to the zero-volume position. For an exact analysis, the unavoidable dead volume V_1 of the air in the manometer should also be taken into account.

Thus, the volume of air, corrected for the dead volume, is

$$V_{corr} = s \cdot \pi \cdot 4 \text{ cm}^2 + V_1$$

V_1 can be determined by finding the value that results in the best fit to the relationship $p \cdot V_{corr}$ = constant, corresponding to Equation 1. From the data given here the value is V_1 = 7.7 cm³.

The quantity of gas in the cylinder, expressed in moles (mol – or in millimoles as in the graph below), can then be calculated using Equation 2.
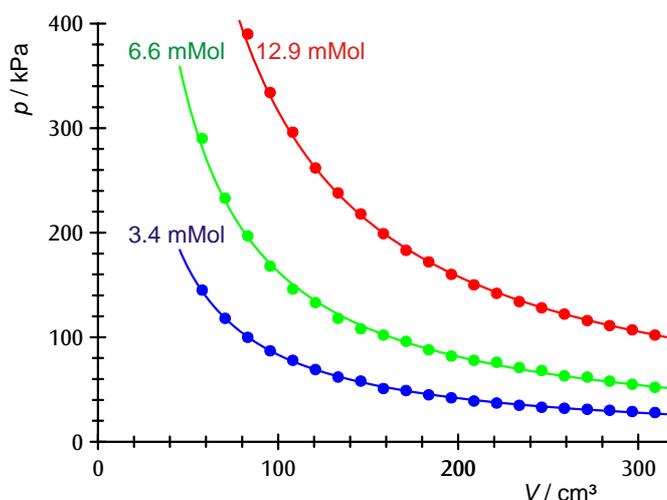

Fig. 2:   Pressure/volume diagrams for three different quantities of air at room temperature