Experiment 7

Boyle's Law

1- Objects of the experiment

- Measuring the pressure P of the trapped air at room temperature for different heights of mercury.
- Verifying Boyle's Law.

2- 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 pressure 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 and Mariotte states that:

$$PV = const. \qquad (1)$$

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:

$$PV = nRT \qquad (2)$$

where $R = 8.341 J.mol^{-1}.K^{-1}$, 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 changing the height of mercury level, while simultaneously measuring the pressure P of the enclosed air.

3- List of Equipments

J-tube

Vernier callipers

Meter stick

4- Setup

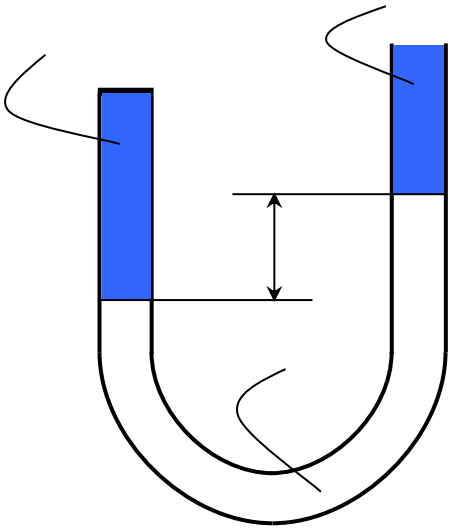

Fig. 1. J-tube apparatus

The apparatus consists of a J-tube containing a quantity of mercury as pictured in Figure (1) one arm of the J-tube is a glass tube open to the air. The other arm is a glass tube closed at the top and holding a quantity of air trapped above the mercury. The bottom portion of the J-tube is made of flexible tubing. The two arms of the J-tube can be moved up and down so that the trapped air can

be compressed or expanded into different volumes. A meter stick is mounted on the apparatus so that the height of the mercury in the two columns can be measured. You are interested in two quantities: the volume (V) of the trapped gas in the closed tube and the total pressure (P) on this gas.

5- Carrying out the experiment

Pressure: The total pressure on the air trapped in the column is the sum of:

(1) Atmospheric pressure (P_{atm}), which is transmitted from the open tube through the mercury to the trapped air.

$$P_{atm} = 1.013 \times 10^5 \text{ Pa} \qquad (3)$$

(2)The pressure due to the difference in the level of the mercury on the two sides of the J-tube. The difference in the heights of the two mercury columns is found by subtracting the level of the mercury in the closed column, from the level of the mercury in the open column (See Figure 1). Note the sign of this difference.

$$P_{Hg} = \rho_{Hg} g.\Delta h \qquad (4)$$

Where ρ is the density of the mercury in kg/m^3 ($\rho_{Hg} = 13540 kg/m^3$), g is the acceleration due to gravity in m/s^2 ($g = 9.81 m/s^2$), and Δh is the difference in height of the mercury in the two columns in meters. So the total pressure is:

$$P = \rho_{Hg} g.\Delta h + P_{atm} \qquad (5)$$

Volume: Use a vernier callipers to measure the inside diameter (d) of the open tube. This tube has the same diameter as the closed tube containing the trapped air. Measure the height of the column of trapped air (h_{air}) with a meter stick.

$$V = \pi r^2 h_{air} \qquad (6)$$

where $r = \frac{d}{2}$ the radius of the open colomn

- Insert the data in Table (1)

Table 1: Measurement of the difference in height Δh of mercury, and height h of the trapped air.

Δh (m)	h (m)	P (Pa)	V (m^3)	$\frac{1}{V}(m^{-3})$

- Prepare a sheet of graph paper for plotting P versus $\frac{1}{V}$. You should make P the vertical axis and $\frac{1}{V}$ the horizontal axis. Each axis should be labeled and appropriate units indicated. The graph should have a title.

- Plot your data on the graph.

- Determine the slope and the y-intercept point by using the least square method (see appendix).

- Draw best fit line to the points on your graph.

- Discuss your results