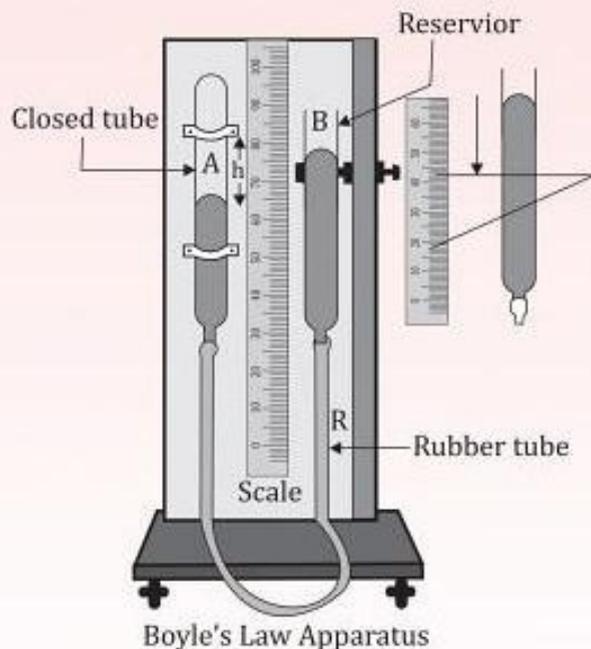# EXPERIMENT

AIM

To study the variation in volume (V) with pressure (P) for a sample of air at constant temperature by plotting the graphs between P and V, and also between P and $\frac{1}{V}$.

MATERIAL REQUIRED

Fortin's barometer, Boyle's law apparatus Vernier calipers, thermometer, plumbline, a pair of set square and spirit level.

DIAGRAM

Boyle's Law Apparatus

THEORY

The given apparatus is named as Boyle's law which consists of two glass tubes about 25 cm long and 0.5 cm in diameter. It's one tube A is closed at one end while another tube B is opened.

These two tubes are drawn into fine opening at the other ends A and B. The ends of both the tubes are connected by a thick-walled rubber tube. The tube is fixed vertically along the meter scale and the other tube can be moved vertically along a vertical rod and can be fixed to it at any altitude with the help of the screw.

Both the tubes and the rubber tubing are filled with mercury. The height of mercury in both the tubes is measured by the vertical scale with the help of set square. The closed end tube has some air trapped in it. Due to this, the volume of air is proportional to the length of air column because it is of uniform cross-

section. The whole apparatus is fixed on a horizontal platform with a horizontal stand provided with levelling screws.

Boyle's Law

According to this law, "At a constant temperature, the pressure exerted by an enclosed of is inversely proportional to its volume."

i.e.;

$$P \propto \frac{1}{V} \Rightarrow P = \frac{K}{V}$$

It means that at constant temperature, the volume of the given mass of a gas varies inversely with its pressure. So, it signifies that the graph between P and $\frac{1}{V}$ will be a curve, i.e., a rechange, hyperbola and between P and $\frac{1}{V}$ will be a straight line.

PROCEDURE

A. MEASUREMENT OF PRESSURE

The pressure of the enclosed air in tube AB is measured by noting the difference (h) in the mercury level (X and Y) in the two tubes AB and CD with the help of set square by setting one of its edges tangential to the curved surface of the mercury and other parallel to the vertical scale. Since liquid in interconnected vessels have same pressure at any horizontal level,

P (pressure of enclosed air) = $Z \pm h$ (where, Z is the atmospheric pressure)
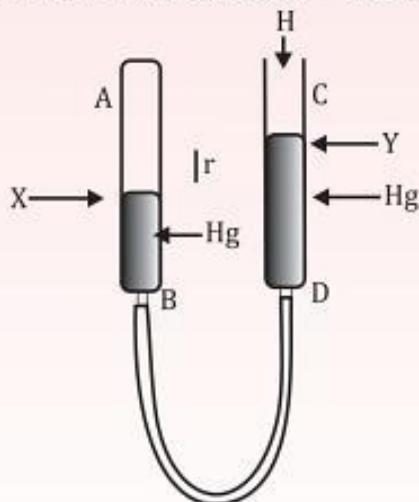
Pressure of air in tube
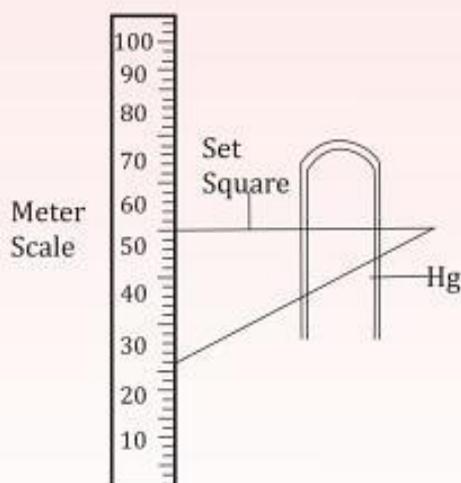
$Z \pm h$ will be considered according to the levels X and Y taking into account whether the pressure of air in tube AB is more than atmospheric pressure or less, that means these two are added algebraically.

B. MEASUREMENT OF VOLUME OF TRAPPED AIR

In case the closed tube is not graduated,

Volume of air in tube = Volume of air in length PR — Volume of air in curved portion PQ

Let r be the radius of the tube that can be easily calculated by measuring the diameter by using Vernier Caliper. Volume of curved portion is equal to the volume of the hemisphere of radius r,

$$\rightarrow \frac{1}{2} \times \frac{4}{3} \pi r^3 = \frac{2}{3} \pi r^3$$

Volume of PQ = $\pi^3 \times r = \pi r^3$

Error in volume = Volume of PQ — Volume of curved portion

$$= \pi r^3 - \frac{2}{3}\pi r^2$$
$$= \frac{1}{3}r$$

Resulting error in length $= \dfrac{\frac{1}{3}\pi r^3}{\pi r^3} = \dfrac{1}{3}r$

Correction in length $= -\dfrac{1}{3}r = -\dfrac{1}{3}PQ$

This should be subtracted from the measured length l.

C. MEASUREMENT OF VOLUME OF AIR FOR A GIVEN PRESSURE

INITIAL OBSERVATIONS

1. Firstly, set up the plank of Boyle's law apparatus vertically with the help of levelling screws and spirit level.
2. Note the room temperature by using a thermometer.
3. Note the atmospheric pressure using Fortin's barometer.
4. After measuring the air enclosed in tube AB, adjust the height of tube CD such that mercury level in both the tubes is at same level.
5. After noting down the reading of mercury levels in tube AB and CD against scale S, note down the volume of enclosed gas in graduated tube AB. The same procedure will be followed as discussed in part (ii) to measure the volume.

RAISING THE TUBE

6. Raise the tube CD upwards by about 2 cm. Mercury level in tube AB will also move upwards a little, reducing the volume of enclosed air. Note down the reduced volume.
7. Moreover, pressure of air in tube AB increases and mercury level in AB remains lower than that in CD.
8. Position of mercury level in tube CD is noted against the vertical scale using the set squares. Here, the set square is used to read the meniscus of the mercury, thereby the difference in the mercury level X and Y can be determined.
9. Now, repeat the steps 6, 7, 8 a few more times by moving the tube CD upward by 2 cm each time.

LOWERING THE TUBE

10. Also, lower the tube CD and bring the mercury level with the same horizontal line as in tube AB.
11. Move the tube CD downwards by few centimeters.
12. Notice that the mercury level in tube AB will also come down (which shows a little increase in volume of enclosed air).
13. After noting down the value of increased volume, notice that the pressure of air in tube AB decreases and mercury level in tube AB should remain higher than that in tube CD.
14. Now, repeat the above steps 11 and 12 a few more times by lowering the tube CD each time by 2 cm.
15. Note all these observations in a tabular form.

OBSERVATIONS

Mean of the Atmospheric Pressure:

1. During the beginning of experiment, atmospheric pressure,

$$Z_1 = \underline{\quad\quad} \text{ cm of Hg}$$

2. During the end of experiment, atmospheric pressure,

$$Z_2 = \underline{\hspace{2cm}} \text{ cm of Hg}$$

3. Therefore, mean atmospheric pressure,

$$Z = \frac{z_1 + z_2}{2} = \underline{\hspace{1cm}} \text{ cm of Hg}$$

Mean of the Room Temperature:

1. Room temperature during the beginning of experiment,

$$t_1 = \underline{\hspace{2cm}} \,°C$$

2. Room temperature at the end of the experiment,

$$t_2 = \underline{\hspace{2cm}} \,°C$$

3. Mean temperature,

$$T = \frac{t_1 + t_2}{2} = \underline{\hspace{1cm}} \,°C$$

4. Correction in the Level of Mercury due to Curved Portion of the Tube
5. Reading at the top end of the closed tube AB,

$$x_1 = \underline{\hspace{2cm}} \text{ cm}$$

6. Reading where the curved portion of tube AB begins,

$$x_2 = \underline{\hspace{2cm}} \text{ cm}$$

7. Now, correction

$$= \frac{1}{3}(x_1 - x_2) = \underline{\hspace{2cm}} \text{ cm}$$

The correction in level can also be determined with the same method as discussed in part (ii) of the procedure i.e., correction for level,

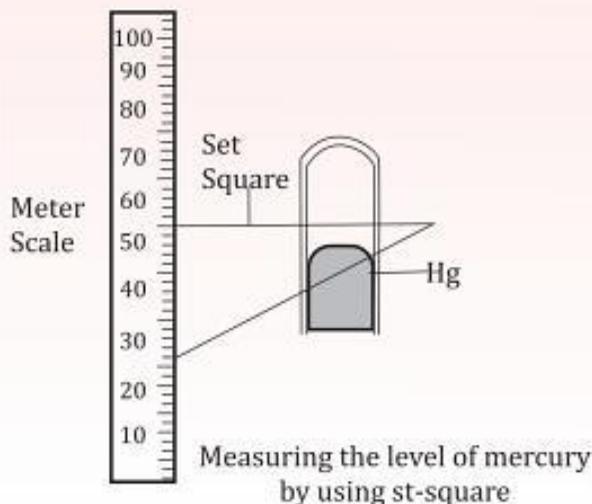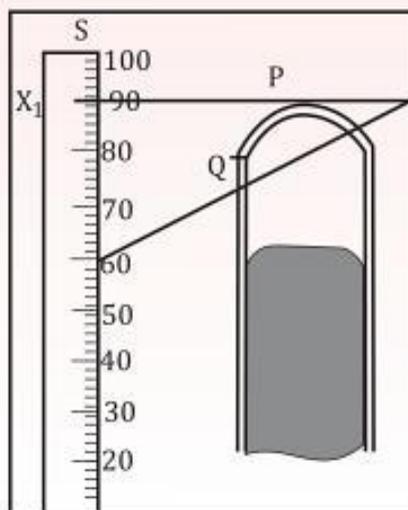$$l = \frac{1}{3r}$$

Where, r radius of the tube.

Measuring the level of mercury by using st-square

TABLE FOR MEASUREMENT OF PRESSURE AND VOLUME OF ENCLOSED AIR

S. No.	Level of mercury		Pressure difference $h = X - Y$ (cm of Hg)	Pressure of air in tube AB, $P = Z \pm h$ (cm of Hg)	Volume of air, V (cm^3)	$\frac{1}{V}$ (cm^{-3})	PV
	In tube AB (closed one) X (cm of Hg)	In tube CD (opened one) Y (cm of Hg)					
1							

|							
2							
3							
4							

NOTE: In order to achieve the aim of this experiment, you should focus on its centralized core concept, i.e., while taking the readings in the observation table, the value of V should be decreased with respect to the increasing value of while the value of should be increased with respect to the increasing value of. So, it will give you the constant value of PV, which is an ultimate result.
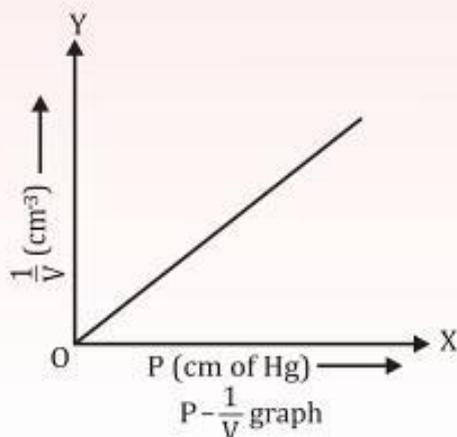
PLOTTING GRAPH

With the help of the observation table,
1. Plot the graph between P and V by taking along X-axis and along Y axis rectangular hyperbola.

P - V graph
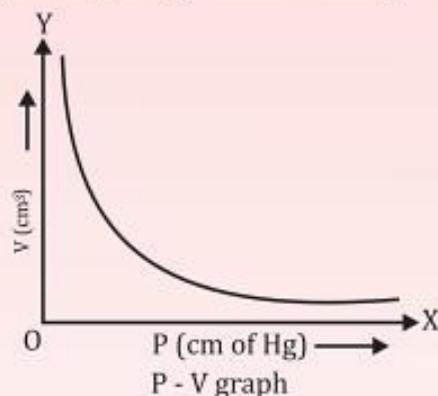
2. Plot a graph between p and $\frac{1}{v}$ by taking p along X-axis and along Y-axis. The graph will be a straight line passing through the origin.

$P - \frac{1}{V}$ graph

RESULT

1. In the observation table, the value of PV is constant.
2. Within the experimental limits, the graph between P and V is a rectangular hyperbola. i.e., PV= constant.
3. Within the experimental limits, the graph between P and $\frac{1}{v}$ is a straight line. i.e., $P \propto \frac{1}{v}$.

PRECAUTIONS

1. Before starting the experiment, apparatus should be levelled on prank gently.
2. Correction for the curved portion of the closed tube should be taken into consideration while measuring

the volume of air.

3. The open tube should be plugged with cotton when not in use.
4. The readings should be taken carefully in order to get an exact desired graph either in between P and V or in between P and $\frac{1}{v}$.
5. Mercury used should be clean and not leave any trace on the glass.
6. The apparatus should not be shifted in between observations.
7. The apparatus must be well covered when not in use to avoid any contamination.

SOURCES OF ERROR

1. The room temperature and the atmospheric pressure may change while performing the experiment.
2. The closed end of the tube AB may not be hemispherical.
3. The air in tube AB may not be dry.
4. The readings may not be taken carefully which can result in an error in the ultimate result.
5. The mercury may be oxidized due to exposure to atmosphere.
6. The diameter of the glass tubes may or may not be the same.

VIVA VOCE

Q1. State Boyle's law.

Ans. If states that the pressure (p) of an enclosed gas (i.e. for a given mass of gas) is inversely proportional to its volume (V), provided that the temperature of gas remains constant. i.e.,

$$P \propto \frac{1}{v}$$
$$\Rightarrow PV = \text{constant}$$

Q2. What can be the reason of making Boyle's law apparatus vertical?

Ans. It is necessary to make Boyle's law apparatus vertical because, if is not vertical, then the reading of mercury column will not be accurate.

Q3. Why should the air enclosed in tube AB be dry?

Ans. Air enclosed in tube AB should be dry because the behavior of water vapors at room temperature is different than the behavior of air.

Q4. While performing the experiment, what is the reason of moving the tube CD upward or downward slowly?

Ans. It is usually done because while moving the tube CD in upward direction, the pressure on the gas enclosed in tube AB increases and while moving the tube CD in downward direction, the pressure decreases.

Q5. What is the use of mercury in Boyle's law apparatus?

Ans. Since the pressure difference is in terms of difference of mercury levels in tube AB and CD. So. when this difference gets added algebraically to atmospheric pressure, it gives the pressure of air in tube AB in cm of Hg.

Q6. Name the laws which govern the gas behavior.

Ans. They are Boyles law, Charles' low, Gay-Lussac's low, Avogadro's law, Dation's law of partial pressures and Graham's low of diffusion.