

Boyle's Law: Balloon in a Vacuum

Preparer's Version

Introduction

In this demonstration, a partially inflated balloon is placed inside a vacuum chamber and the air is slowly evacuated. As the external pressure decreases, the balloon visibly expands in size, despite no additional air being added. This striking behavior illustrates Boyle's Law, which describes the inverse relationship between the pressure and volume of a gas at constant temperature. The mathematical equation for expressing Boyle's Law is shown below, where P is pressure and V is volume. As pressure decreases, volume increases proportionally, provided that the temperature and the amount of gas remain constant.

$$P_1V_1 = P_2V_2$$

The balloon contains a fixed quantity of gas molecules. Under normal atmospheric pressure, these gas molecules exert an internal pressure that is balanced by the atmospheric pressure outside the balloon. When the vacuum pump reduces the external pressure, the internal pressure of the gas inside the balloon becomes greater than the surrounding pressure. To restore equilibrium, the gas expands, increasing the balloon's volume until the internal and external pressures are balanced once again. This expansion occurs without a change in the number of gas molecules or a significant change in temperature, making it a direct application of Boyle's Law.

Safety Hazards

- Personal Protective Equipment:
 - Safety glasses/goggles
 - Nitrile gloves
 - Chemical & flame retardant lab coat
- Physical Hazards
 - Vacuum chambers present several physical hazards due to the negative pressure they create, including potential implosions, flying debris, and pressure surges.

- Chemical Hazards
 - None.

Materials

- 11" balloon
- Nalgene vacuum chamber
- Vacuum pump
- Extension cord

Safety Data Sheet(s)

- None.



Procedure

1. Take an 11" balloon and inflate it just a little bit. It should be as small as it can be while still having enough air to be round.
2. Place the balloon in the center of the vacuum plate.
3. Place the top of the vacuum chamber on the plate and press down, slightly twisting to create a seal.
4. Securely attach the hose of the vacuum pump to the hose connector on the vacuum plate.
5. Plug the vacuum pump into the extension cord.

Tips & Tricks

- None.

Clean-Up Procedures

1. None.