Gases

Matter exists in three distinct physical states: gas, liquid, and solid. Although few substances exist in the gas state under typical conditions, gases are very important. For example, we live immersed in a gaseous solution — Earth's atmosphere.

In this unit, we will look carefully at the properties of gases. Then we will construct a model to explain why gases behave as they do.

Pressure

A gas uniformly fills any container, is easily compressed, and mixes completely with any other gas. One of the most obvious properties of a gas is that it exerts pressure on its surrounding. For example, when you blow up a balloon, the air inside pushes outward against the elastic sides of the balloon causing it to expand.

The gas particles are colliding with the inside of the balloon, exerting an outward force. This outward force spread over the surface area of the balloon is called pressure. **Pressure** is defined as force per unit area.

The gases of the atmosphere also exert pressure on everything they are in contact with. The pressure exerted by the atmosphere is called **atmospheric pressure**, or **air pressure**.

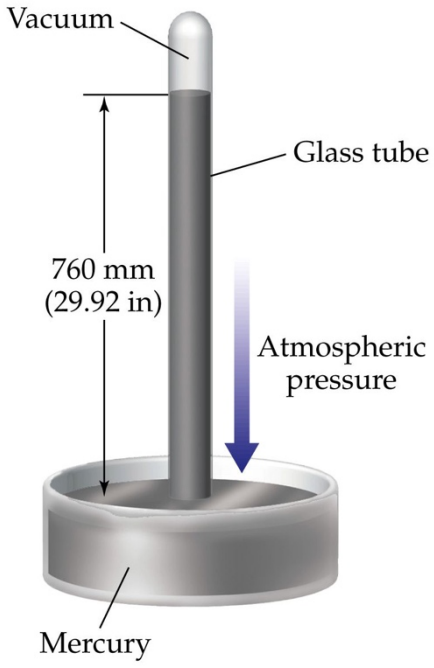
Measuring Pressure

A **barometer** is an instrument used to measure atmospheric pressure. It was invented in 1643 by Evangelista Torricelli.

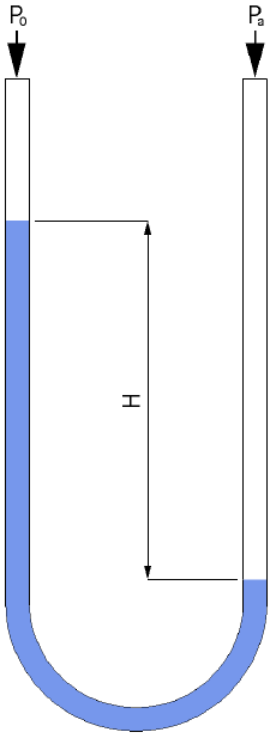
A mercury barometer has a glass tube of at least 84 *cm* in height, closed at one end, with an open mercury-filled reservoir at the base.

The weight of the mercury creates a vacuum in the top of the tube. Mercury in the tube adjusts until the weight of the mercury column balances the atmospheric force exerted on the reservoir.

The design of the barometer gave rise to the expression of atmospheric pressure in **millimeters of mercury** (aka **torr**). At normal atmospheric pressure, the height of the mercury in the tube is 760 *mm*. At lower pressure, the mercury would be lower. At higher pressure the mercury would be higher.



A **manometer** is an instrument used to measure gas pressure in a closed container. A very simple version consists of a U-shaped tube filled with mercury.



One side of the tube is connected to a known pressure (a vacuum, or possibly the atmospheric pressure), while the other side is connected to the pressure that you are attempting to determine. The mercury in the tube will be higher on the side with the lower pressure.

Based on the difference in height between the two sides, the unknown pressure can be calculated.

Units of Pressure

Pressure is defined as force per unit area.

$$Pressure = \frac{force}{area}$$

The metric unit of pressure is the **pascal** (Pa). Since pressure is a measure of force per unit area, one pascal is equivalent to one newton per square meter.

$$1\ Pa = 1\ N/m^2$$

At sea level, the average atmospheric pressure is 760 *mm Hg* when the temperature is 0℃. Atmospheric pressure is often reported in a unit called an **atmosphere** (atm). One atmosphere is equal to 760 *mm Hg* or 101.3 *kPa*.

For the purposes of converting units of pressure:

$$1\ atm = 101325\ Pa = 101.3\ kPa = 760\ mm\ Hg = 760\ torr$$

Example
The pressure of a gas is measured as 49 torr. Represent this pressure in both atmospheres and kilopascals.

Worksheet

1. Complete each of the following pressure conversions:

    a) 738 *mm Hg* to *atm*

    b) 380 *torr* to *Pa*

    c) 2.38 *atm* to *kPa*

    d) 748 *mm Hg* to *torr*

    e) 25000 *kPa* to *mm Hg*

    f) 565 *mm Hg* to *atm*

    g) 104.9 *kPa* to *mm Hg*