Lesson 6: Gas Pressure and the Ideal Gas Law

Objectives: By the end of today's class you will be able to use the ideal gas law to relate the physical properties of a gas.

- The physical behavior of gas is determined by four properties: amount (moles), volume, temperature and **pressure**.
- What is pressure and how do we determine the pressure of a gas?

Force and Pressure

$$F = ma$$

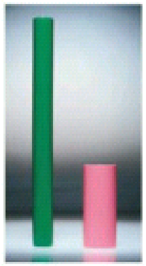
Measured in Newton (N) where 1 N is the force required to produce an acceleration of 1 m/s^2 in a 1 kg block.

$$1\ N = 1\ kg \cdot m/s^2$$

$$P = \frac{F}{A}$$

Measured in Pascal (Pa) $1\ Pa = 1\ N/m^2 = 1\,\frac{kg}{m \cdot s^2}$

Force vs. Pressure



- Both cylinders have the same mass and therefore exert the same force on the surface.
- Which cylinder exerts a greater pressure?

left : smaller A

Pressure of a Gas

$$P = \frac{F}{A}$$

- Which Force?

molecules of gas hitting the walls

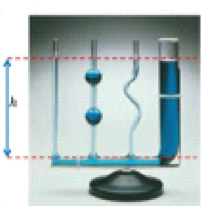
- Which Area?

Area of vessel walls containing gas

.........so how do we measure this?

Liquid Pressure

ρ = density

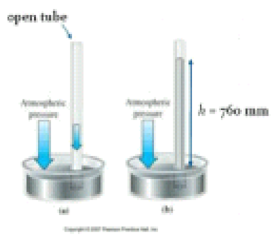


$$P = \frac{F}{A} = \frac{mg}{A} = \frac{\rho V g}{A} = \frac{\rho A h g}{A} = \rho h g$$

Pressure exerted by a liquid is proportional to the density of the liquid and the height of liquid in the column.

All have same pressure

Using Liquid Pressure to Determine Gas Pressure



1 atm = 760 mmHg
= 760 Torr
= ? Pa

$P = \rho h g$

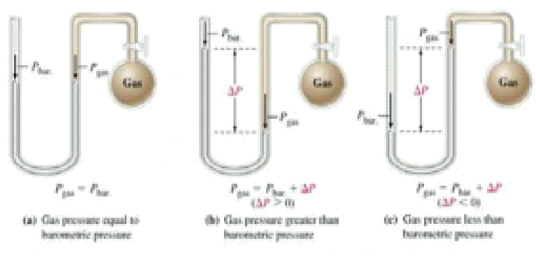
$\rho = 13.5951\ g/cm^3$

$g = 9.80655\ m/s^2$

$P = 1.01325 \times 10^5\ Pa$

Why mercury and not water? (Ex. 6.1 p196)

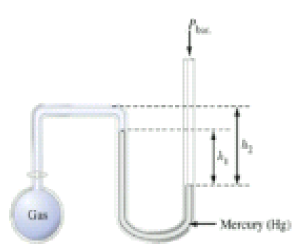
Measuring Pressure with an Open-end Manometer



$\Delta P_{mmHg} = \Delta h_{Hg}$

Example 1: Ch6 #5 (p231)

5. What is the pressure (in mmHg) of the gas inside the apparatus below if $P_{bar.}$ = 740 mmHg, h_1 = 30 mm and h_2 = 50 mm?



740 − 30 = 710 mmHg

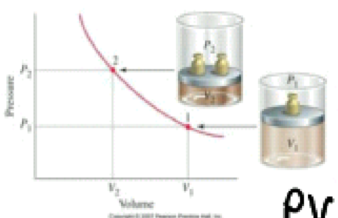
Gas Laws

- Gas laws are mathematical equations relating volume of a gas to the number of moles, temperature and pressure.

$$V = f(n, T, P)$$

- Simple gas laws were established by holding 2 of the three variables constant and measuring the relationship between *V* and each individual variable.

1. Constant *n* and *T* (Boyle)



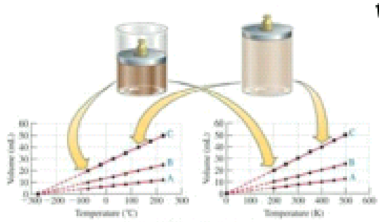
$P \propto \frac{1}{V}$

or

$PV = a$

$P_1V_1 = P_2V_2$

2. Constant *n* and *P* (Charles)



$V \propto T$

$V = bT$

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Temperature must be in K!

T(K) = T(°C) + 273.15

3. Constant *T* and *P* (Avogadro)

- The volume of a gas is proportional to the amount of gas.

$$V \propto n$$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} = C$$

- At STP: 0 °C (273.15 K) and 1 atm

$$1 \text{ mol gas} = 22.414 \text{ l}$$

Putting it all together…

1. Boyle's Law $V \propto \frac{1}{P}$
2. Charle's Law $V \propto T$
3. Avodgadro's Law $V \propto n$

$$V \propto \frac{nT}{P}$$

$$pV \propto nT$$

The Ideal Gas Law

$$pV = nRT$$

where R is the gas constant.

TABLE 6.3 Five Common Values of R
0.082057 atm L mol^{-1} K^{-1}
0.083145 bar L K^{-1} mol^{-1}
8.3145 kPa L K^{-1} mol^{-1}
8.3145 Pa m^3 mol^{-1} K^{-1}
8.3145 J mol^{-1} K^{-1}

$$R = \frac{pV}{nT}$$

$$R = \frac{1 \text{atm} \times 22.4 \text{L}}{1 \text{mol} \times 273.15 \text{K}} = 0.082 \frac{\text{atm} \cdot \text{L}}{\text{mol} \cdot \text{K}}$$

$pV = nRT$ may also be expressed as $pV_m = RT$ where

$V_m = \frac{V}{n}$ (the molar volume)

The Ideal Gas Law

Any gas whose behavior conforms to the ideal gas equation is called an ideal or perfect gas.

Ideal gas assumes that:

- there are no intermolecular forces between gas molecules.
- gas molecules have no molecular volume.

Fairly good approximation for many gases at higher temperature and lower pressure.

Applying the Ideal Gas Law!

Example 2:

You inflate your bicycle tire with dry air to a pressure of 35 psi in the summer, when the temperature is 30 °C.

Assuming the volume of the tire is constant and no air has leaked out, what would the pressure be in winter when the temperature drops to –20 °C?

$30\,°C + 273.15 = 303.15\,K$

$-20\,°C + 273.15 = 253.15\,K$

$PV = nRT$

$\frac{P}{T} = \frac{nR}{V} = a$

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$\frac{35}{303.15} = \frac{P_2}{253.15}$

$P_2 = 29.2$ psi

Suggested Readings

6.1 Properties of Gases: Gas Pressure
6.2 The Simple Gas Laws
6.3 Combining Gas Laws: The Ideal Gas Equation and the General Gas Equation
6.4 Applications of the Ideal Gas Equation
6.5 Gases in Chemical Reactions