Chapter 5
Gases -2
Gas Laws

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Gas Laws

- Gas laws – empirical relationships among gas parameters.
  - Volume (V)
  - Pressure (P)
  - Temperature (T)
  - Amount of a gas (n)

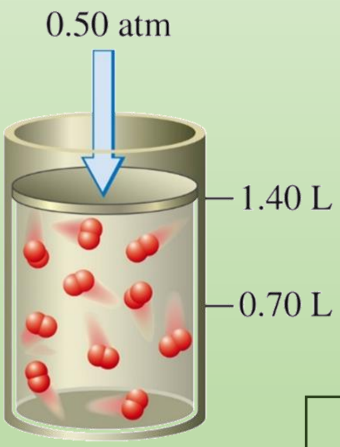
- By holding two of these physical properties constant, it becomes possible to show a simple relationship between the other two properties.

Boyle's Law

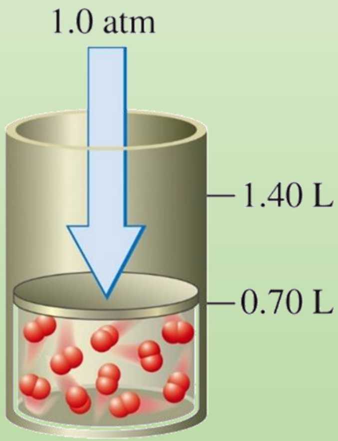
- The volume of a sample of gas is inversely proportional to pressure at constant temperature. (one increases if the other decreases and *vice versa*)

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

When a 1.00-g sample of O_2 gas at 0^{o}C is placed in a container at a pressure of 0.50 atm, it occupies a volume of 1.40 L.



When the pressure on the O_2 is doubled to 1.0 atm, the volume is reduced to 0.70 L, half the original volume.

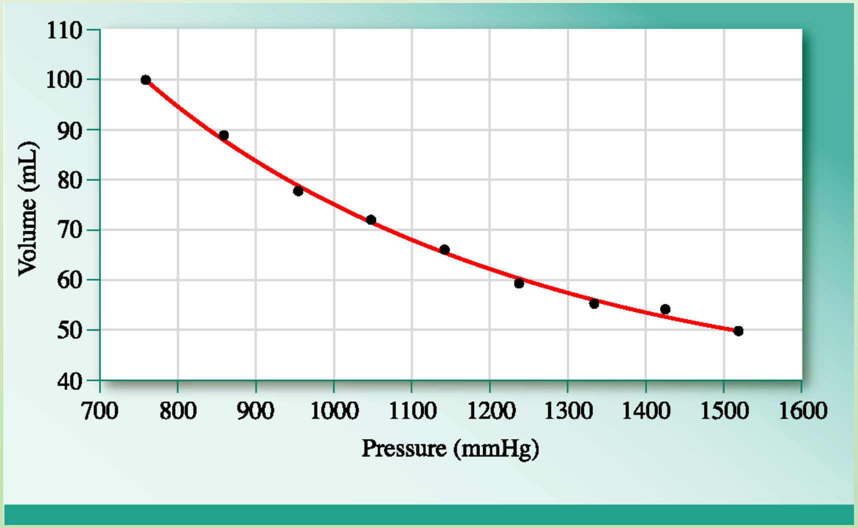


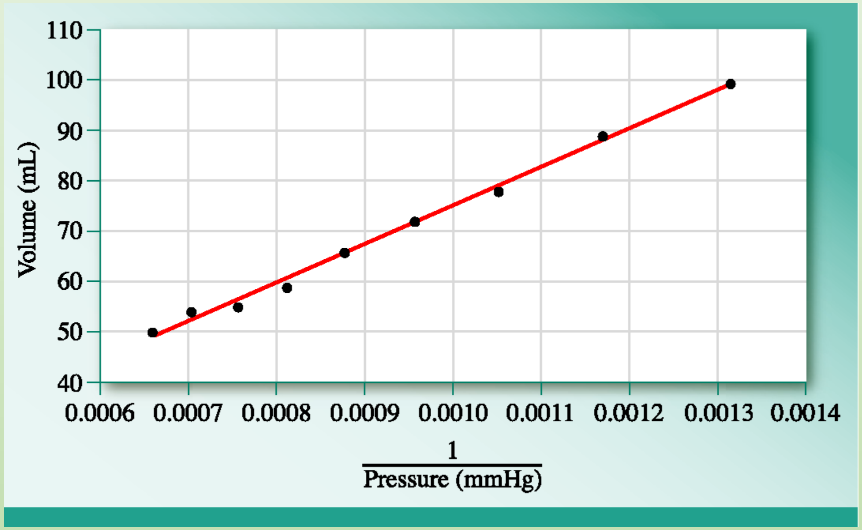
$$PV = constant$$

$$P_1V_1=P_2V_2$$

Boyle's Law Contd….

Graphical representation





Solved Problem:

A volume of oxygen gas occupies 38.7 mL at 751 mmHg and 21°C. What is the volume if the pressure changes to 359 mmHg while the temperature remains constant?

V_i = 38.7 mL
P_i = 751 mmHg
T_i = 21° C

V_f = ?
P_f = 359 mmHg
T_f = 21° C

$$V_\mathrm{f} = \frac{P_\mathrm{i} V_\mathrm{i}}{P_\mathrm{f}}$$

$$V_\mathrm{f} = \frac{(38.7\ \mathrm{mL})(751\ \mathrm{mmHg})}{(359\ \mathrm{mmHg})}$$

= 81.0 mL
(3 significant figures)

Charles's Law

- The volume of a sample of gas at constant pressure is directly proportional to the absolute temperature (K).

$$V \propto T$$

At room Temp

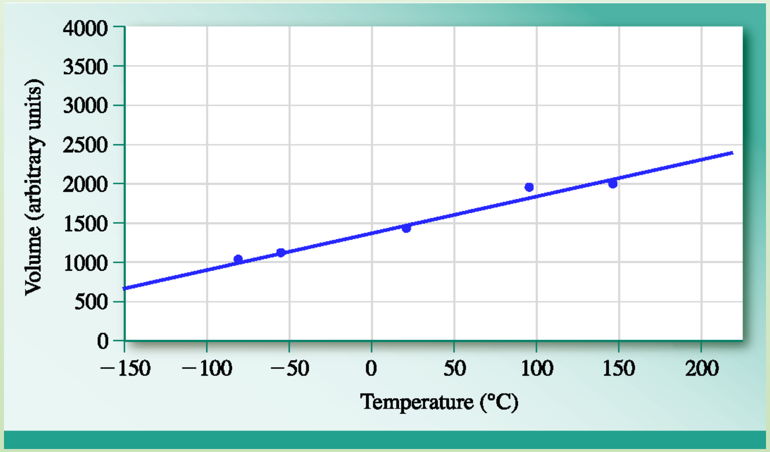
At – 72°C

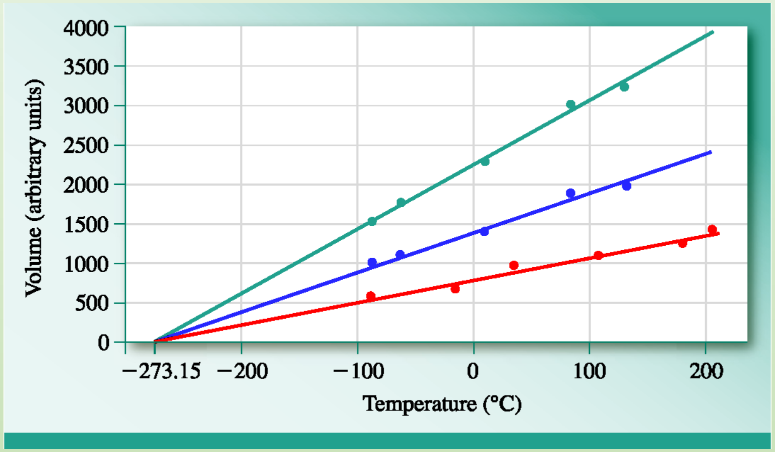
$$\frac{V}{T} = \text{constant}$$

$$\frac{V_i}{T_i} = \frac{V_f}{T_f}$$

Charles's Law contd….

Graphical Representation





The temperature -273.15°C is called **absolute zero.** It is the temperature at which the volume of a gas is hypothetically zero.

This is the basis of the absolute temperature scale, the Kelvin scale (K).

Solved Problem:
You prepared carbon dioxide by adding HCl(*aq*) to marble chips, $CaCO_3$. According to your calculations, you should obtain 79.4 mL of CO_2 at 0°C and 760 mmHg. How many milliliters of gas would you obtain at 27°C?

V_i = 79.4 mL
P_i = 760 mmHg
T_i = 0° C = 273 K

V_f = ?
P_f = 760 mmHg
T_f = 27° C = 300. K

$$V_f = \frac{T_f V_i}{T_i}$$

$$V_f = \frac{(300.\ \text{K})(79.4\ \text{mL})}{(273\ \text{K})}$$

= 87.3 mL
(3 significant figures)

Avogadro's Law

The volume of a gas sample is directly proportional to the number of moles in the sample at constant pressure and temperature.

$$V \ \alpha \ n$$

$$\frac{V}{n} = constant$$

$$\boxed{\frac{V_i}{n_i} = \frac{V_f}{n_f}}$$

$$3H_2(g) \quad + \quad N_2(g) \quad \longrightarrow \quad 2NH_3(g)$$

3 molecules	+	1 molecule	→	2 molecules
3 moles	+	1 mole	→	2 moles
3 volumes	+	1 volume	→	2 volumes

Dalton's Law of Partial Pressure

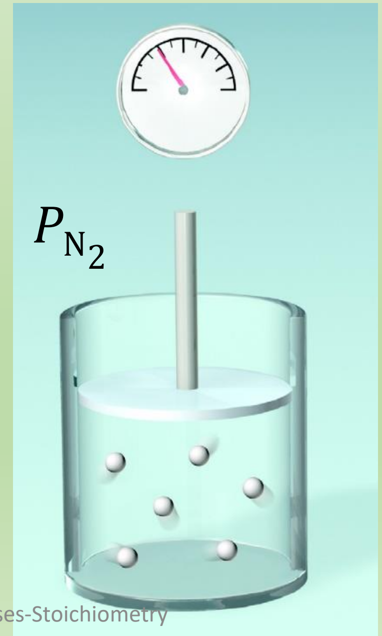
- Dalton found that in a mixture of unreactive gases, each gas acts as if it were the only gas in the mixture as far as pressure is concerned.
- The sum of the partial pressures of all the different gases in a mixture is equal to the total pressure of the mixture:

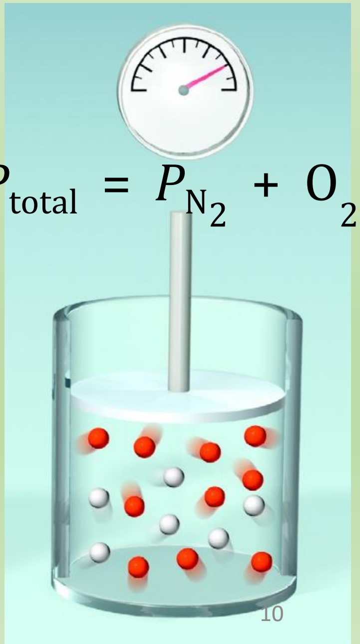
$$P = P_A + P_B + P_C + \ldots$$

Partial Pressure

The pressure exerted by

a particular gas in a mixture





Solved Problem:

A 100.0-mL sample of air exhaled from the lungs is analyzed and found to contain 0.0830 g N_2, 0.0194 g O_2, 0.00640 g CO_2, and 0.00441 g water vapor at 35°C. What is the partial pressure of each component and the total pressure of the sample?

$$P_{N_2} = \frac{\left(0.0830\ \text{g N}_2 \frac{1\ \text{mol N}_2}{28.01\ \text{g N}_2}\right)\left(0.08206 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}}\right)(308\ \text{K})}{(100.0\ \text{mL})\left(\frac{1\ \text{L}}{10^{-3}\ \text{mL}}\right)} = 0.749\ \text{atm}$$

$$P_{O_2} = \frac{\left(0.0194\ \text{g O}_2 \frac{1\ \text{mol O}_2}{32.00\ \text{g O}_2}\right)\left(0.08206 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}}\right)(308\ \text{K})}{(100.0\ \text{mL})\left(\frac{1\ \text{L}}{10^{-3}\ \text{mL}}\right)} = 0.153\ \text{atm}$$

$$P_{CO_2} = \frac{\left(0.00640\ \text{g CO}_2 \frac{1\ \text{mol CO}_2}{44.01\ \text{g CO}_2}\right)\left(0.08206 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}}\right)(308\ \text{K})}{(100.0\ \text{mL})\left(\frac{1\ \text{L}}{10^{-3}\ \text{mL}}\right)} = 0.0368\ \text{atm}$$

$$P_{H_2O} = \frac{\left(0.00441\ \text{g H}_2\text{O} \frac{1\ \text{mol H}_2\text{O}}{18.01\ \text{g H}_2\text{O}}\right)\left(0.08206 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}}\right)(308\ \text{K})}{(100.0\ \text{mL})\left(\frac{1\ \text{L}}{10^{-3}\ \text{mL}}\right)} = 0.0619\ \text{atm}$$

$$P = P_{N_2} + P_{O_2} + P_{CO_2} + P_{H_2O} = 1.00\ \text{atm}$$

Key Points

- The gas laws
  - Boyle's law
  - Charles' law
  - Avogadro's law
  - Dalton's law