Importance of Gases

- Airbags fill with $\text{N}_2$ gas in an accident.
- Gas is generated by the decomposition of sodium azide, NaN$_3$.
  \[ 2 \text{NaN}_3 \rightarrow 2 \text{Na} + 3 \text{N}_2 \]

Hot Air Balloons — How Do They Work?

Three States of Matter

General Properties of Gases

- There is a lot of “free” space in a gas.
- Gases can be expanded infinitely.
- Gases occupy containers uniformly and completely.
- Gases diffuse and mix rapidly.

Properties of Gases

Gas properties can be modeled using math. Model depends on—

- $V =$ volume of the gas (L)
- $T =$ temperature (K)
- $n =$ amount (moles)
- $P =$ pressure (atmospheres)
Pressure

Pressure of air is measured with a BAROMETER (developed by Torricelli in 1643).

Pressure

Hg rises in tube until force of Hg (down) balances the force of atmosphere (pushing up).

P of Hg pushing down related to
• Hg density
• column height

Pressure

Column height measures P of atmosphere
• 1 standard atm = 760 mm Hg = 29.9 inches = about 34 feet of water

SI unit is PASCAL, Pa, where 1 atm = 101.325 kPa

IDEAL GAS LAW

P V = n R T

Brings together gas properties. Can be derived from experiment and theory.

Boyle’s Law

If n and T are constant, then PV = nRT = k

This means, for example, that P goes up as V goes down.


Boyle’s Law

A bicycle pump is a good example of Boyle’s law.
As the volume of the air trapped in the pump is reduced, its pressure goes up, and air is forced into the tire.
**Charles's Law**

If $n$ and $P$ are constant, then

$$V = \frac{(nR)}{P}T = kT$$

$V$ and $T$ are directly related.


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**Avogadro's Hypothesis**

Equal volumes of gases at the same $T$ and $P$ have the same number of molecules.

$$V = n \frac{(RT)}{P} = kn$$

$V$ and $n$ are directly related.

Twice as many molecules

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Balloons immersed in liquid $N_2$ (at -196 °C) will shrink as the air cools (and is liquefied).
**Using PV = nRT**

How much N\(_2\) is req'd to fill a small room with a volume of 960 cubic feet (27,000 L) to P = 745 mm Hg at 25 °C?

\[ R = 0.082057 \text{ L} \cdot \text{atm} / \text{K} \cdot \text{mol} \]

**Solution**

1. Get all data into proper units
   - \( V = 27,000 \text{ L} \)
   - \( T = 25 \text{ °C} + 273 = 298 \text{ K} \)
   - \( P = 745 \text{ mm Hg} \) (1 atm = 760 mm Hg)

2. \( R = 0.0821 \text{ L} \cdot \text{atm} / \text{K} \cdot \text{mol} \)

3. \( n = \frac{PV}{RT} \)

4. \( n = 0.98 \text{ atm} \times \frac{2.7 \times 10^4 \text{ L}}{0.0821 \text{ L} \cdot \text{atm} / \text{K} \cdot \text{mol} \times 298 \text{ K}} = 1.1 \times 10^3 \text{ mol (or about 30 kg of gas)} \)

**Gases and Stoichiometry**

\( 2 \text{H}_2\text{O}_2(\text{liq}) \rightarrow 2 \text{H}_2\text{O}(\text{g}) + \text{O}_2(\text{g}) \)

Decompose 1.1 g of H\(_2\)O\(_2\) in a flask with a volume of 2.50 L. What is the pressure of O\(_2\) at 25 °C? Of H\(_2\)O?

**Solution**

1. \( \text{Calculate moles of H}_2\text{O}_2 \text{ and then moles of O}_2 \text{ and H}_2\text{O}. \)
2. \( \text{Finally, calc. P from n, R, T, and V.} \)
Gases and Stoichiometry

\[ 2 \text{H}_2\text{O}_2(\text{liq}) \rightarrow 2 \text{H}_2\text{O}(g) + \text{O}_2(g) \]

What is \( P \) of \( \text{H}_2\text{O} \)? Could calculate as above. But recall Avogadro’s hypothesis.

\( V \propto n \) at same \( T \) and \( P \)

\( P \propto n \) at same \( T \) and \( V \)

There are 2 times as many moles of \( \text{H}_2\text{O} \) as moles of \( \text{O}_2 \). \( P \) is proportional to \( n \).

Therefore, \( P \) of \( \text{H}_2\text{O} \) is twice that of \( \text{O}_2 \).

\[ P \text{ of } \text{H}_2\text{O} = 0.32 \text{ atm} \]

Dalton’s Law of Partial Pressures

\[ 2 \text{H}_2\text{O}_2(\text{liq}) \rightarrow 2 \text{H}_2\text{O}(g) + \text{O}_2(g) \]

\[ 0.32 \text{ atm} \]

\[ 0.16 \text{ atm} \]

What is the total pressure in the flask?

\[ P_{\text{total in gas mixture}} = P_A + P_B + ... \]

Therefore,

\[ P_{\text{total}} = P(\text{H}_2\text{O}) + P(\text{O}_2) = 0.48 \text{ atm} \]

Dalton’s Law: total \( P \) is sum of PARTIAL pressures.

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Dalton’s Law

John Dalton

1766-1844

GAS DENSITY

Screen 12.6

\[ \text{PV} = n\text{RT} \]

\[ \frac{n}{V} = \frac{P}{RT} \]

\[ \frac{m}{M \cdot V} = \frac{P}{RT} \]

where \( M \) = molar mass

\[ d = \frac{m}{V} = \frac{PM}{RT} \]

\( d \) and \( M \) proportional

USING GAS DENSITY

The density of air at 15 °C and 1.00 atm is 1.23 g/L. What is the molar mass of air?

1. Calc. moles of air.

\[ V = 1.00 \text{ L} \quad P = 1.00 \text{ atm} \quad T = 288 \text{ K} \]

\[ n = \frac{PV}{RT} = 0.0423 \text{ mol} \]

2. Calc. molar mass

\[ \text{mass/mol} = \frac{1.23 \text{ g}}{0.0423 \text{ mol}} = 29.1 \text{ g/mol} \]