Gas Laws

Gas Pressure in General
  Dalton’s Law
  Charles’s Law
  Boyle’s Law
  Gay-Lussac’s Law
  Combined Gas Laws
  Graham’s Law
  Ideal Gas Law
Ideal Gas Law

PV = nRT
Ideal Gas Law

**Ideal Gas Law**

PV = nRT

The pressure of a gas times its volume equals the number of moles of the gas times a constant (R) times the temperature of the gas.

The ideal gas law is the final and most useful expression of the gas laws because it ties the amount of a gas (moles) to its pressure, volume and temperature.

The ideal gas law is a critical tool used in chemical and engineering calculations involving gases.
R - The Gas Constant

\[ PV = nRT \]

The factor “R” in the ideal gas law equation is known as the “gas constant”.

\[ R = \frac{PV}{nT} \]

The pressure times the volume of a gas divided by the number of moles and temperature of the gas is always equal to a constant number.
The Value of $R$

$PV = nRT$

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

The numerical value of the constant depends on which units the pressure volume and temperature are in.

There are numerous values for $R$ that correspond to different groups of units of measurement.
The Value of $R$

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

If: $P$ is in kPa, $V$ is in Liters, $T$ is in K, $n$ is in moles

$R = 8.314 \text{ L} \cdot \text{kPa} \text{ mol} \cdot \text{K}$

If: $P$ is in atm, $V$ is in Liters, $T$ is in K, $n$ is in moles

$R = 0.0821 \text{ L} \cdot \text{atm} \text{ mol} \cdot \text{K}$

If: $P$ is in mmHg, $V$ is in Liters, $T$ is in K, $n$ is in moles

$R = 62.4 \text{ L} \cdot \text{mmHg} \text{ mol} \cdot \text{K}$
### The Value of R

<table>
<thead>
<tr>
<th>Value of R</th>
<th>Units</th>
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<tbody>
<tr>
<td>R = 8.314 L·kPa</td>
<td>mol·K</td>
</tr>
<tr>
<td>R = 0.0821 L·atm</td>
<td>mol·K</td>
</tr>
<tr>
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<td>mol·K</td>
</tr>
</tbody>
</table>

- When using the ideal gas equation you must choose the value of R that fits the other units you are using.
- Note that the only difference in these three R values is the unit for pressure.
- There are many other values of R for other combinations of measurement units.

For English engineering units the value of R is: 10.73 psi·ft\(^3\) lbmol·°R
Using the Ideal Gas Law

A cylinder of helium has a volume of 10 liters. The pressure in the cylinder is 8 atm and the temperature is 20°C. What is the quantity (moles) of helium in the cylinder?

\[ PV = nRT \]
\[ n = \frac{PV}{RT} \]

\[ P = 8 \text{ atm} \quad V = 10 \text{ L} \quad T = 20 + 273 = 293 \text{ K} \]

Pressure is in atm, volume is in liters, temp is in K

For R we need to use \[ R = 0.0821 \text{ L} \cdot \text{atm} \text{ mol}^{-1} \cdot \text{K}^{-1} \]
Using the Ideal Gas Law

\[ PV = nRT \]

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

\[ P = 8 \text{ atm} \quad V = 10 \text{ L} \quad T = 293 \text{ K} \quad R = 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \]

\[ n = \frac{PV}{RT} = \frac{(8 \text{ atm})(10 \text{ L})}{0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} (293 \text{ K})} = 3.33 \text{ moles} \]

How many grams of helium is this?

\[ 3.33 \text{ moles He} \quad 4.00 \text{ g He} \quad = 13.32 \text{ g Helium} \]

\[ 1 \text{ mole He} \]
Using the Ideal Gas Law

- The volume of this room is about 600,000 liters. If the room was full of nitrogen at 1 atm and 20°C, how many grams of nitrogen are in the room?

\[ PV = nRT \]

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

\[ P = 1 \text{ atm} \quad V = 600000 \text{ L} \quad T = 20 + 273 = 293 \text{ K} \]

Pressure is in atm, volume is in liters, temp is in K

For R we need to use \[ R = 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \]
Using the Ideal Gas Law

$PV = nRT$

$n = \frac{PV}{RT}$

$P = 1 \text{ atm}$  $V = 600000 \text{ L}$  $T = 293 \text{ K}$  $R = 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}$

$n = \frac{PV}{RT} = \frac{(1 \text{ atm})(600000 \text{ L})}{0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}(293 \text{ K})} = 24943 \text{ moles}$

$24943 \text{ moles } N_2$  $28.00 \text{ g } N_2$  $1 \text{ mole } N_2$

$= 698404 \text{ g nitrogen}$  $1538 \text{ lbs.}$
Dinitrogen monoxide (N\textsubscript{2}O), laughing gas, is used by dentists as an anesthetic. If 2.86 mol of gas occupies a 20.0 liter tank at 23 °C, what is the pressure (mmHg) in the tank in the dentist office?

\[ PV = nRT \]

\[ P = \frac{nRT}{V} \]

Notice we pick the correct value for R

\[ P = \frac{(2.86 \text{ mol}) \left[ 62.4 \frac{\text{L} \cdot \text{mmHg}}{\text{mol} \cdot \text{K}} \right] (296 \text{ K})}{20 \text{ L}} = 2641 \text{ mmHg} \]
Ideal Gas Law Practice

A balloon contains 1 gram of Helium. What is the volume of the balloon if the pressure is 103 kPa and the temperature is 30°C?

\[ PV = nRT \]

\[ V = \frac{nRT}{P} \]

\[ n = \frac{1 \text{ gram He}}{4.0 \text{ g/mol}} = 0.25 \text{ mol He} \]

\[ T = 30 + 273 = 303 \text{ K} \]

\[ V = \frac{(0.25 \text{ mol}) \left[ 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \right] (303 \text{ K})}{103 \text{ kPa}} = 6.11 \text{ liters} \]
Where Did 22.4 L/mol Come From?

- What is the volume of 1 mole of a gas at STP?

\[ PV = nRT \]

\[ V = \frac{nRT}{P} \]

\( P = 1 \text{ atm} \quad n = 1 \text{ mol} \quad T = 273 \text{ K} \quad R = 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \)

\[ V = \frac{nRT}{P} = \frac{(1 \text{ mol}) \left( 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \right)(273 \text{ K})}{1 \text{ atm}} = 22.4 \text{ L} \]