SECTION 5 – GASES

5-1 -- Atmospheric Pressure
  • The Barometer
  • Two Factors Affecting Barometric Pressure

5-2 -- Units of Pressure
  • mm Hg, torr, atm, Pa, psi

5-2 -- Boyle’s Law

5-3 -- Charles’ Law

5-4 -- Avogadro’s Law

5-5 -- The Combined Gas Law and the Ideal Gas Law
  • Units of the Universal Gas Constant (R)

5-8 -- Gas Stoichiometry
  • Standard Temperature and Pressure (STP)
  • Molar Volume of a Gas at STP (22.4 L)

5-10 -- Rearranging the Ideal Gas Law
  • Molar Mass of a Gas
  • Density of a Gas

5-10 -- Dalton’s Law of Partial Pressures

5-12 -- Mole Fractions

5-14 -- The Kinetic Molecular Theory of Matter (KMT)
  • Four Postulates of KMT

5-15 -- The Meaning of Temperature
  • The Relationship between Temperature and Kinetic Energy

5-15 -- The Root Mean Square Velocity ($\mu_{\text{rms}}$)

5-16 -- Diffusion and Effusion of Gases
  • Diffusion Rates
  • Effusion
  • Graham’s Law of Effusion

5-18 -- Real Gases
  • What Does it Mean to “Behave Ideally”?
  • The Van Der Waals Equation
  • Corrected Pressure and Corrected Volume for Real Gases
Section 5 = Gases

- Although relatively few substances exist as gases under typical conditions, they're very important.

  ex: atmosphere

  \[ \rightarrow \text{supports life} \]
  \[ \rightarrow \text{waste receptacle for exhaust gases} \]
  \[ \rightarrow \text{shields us from harmful radiation} \]

- All gases exert \textit{pressure} on their surroundings. \[ \leftarrow \text{the force exerted by gas molecules as they strike the surfaces around them.} \]

- The gases most familiar to us are the ones that make up our atmosphere \((\text{N}_2, \text{O}_2, \text{Ar}, \text{CO}_2, \text{Ne}, \text{He}, \text{CH}_4, \ldots)\)

  \[ \rightarrow \text{together they exert \textit{atmospheric pressure} on us, and on the earth.} \]

- A device used to measure atmospheric pressure is a \underline{barometer} (invented by Italian physicist Torricelli)

\[ \downarrow \]

\[ \text{at sea-level, the atmosphere "pushes" the Hg 760mm up the barometer tube} \]

\[ \Rightarrow \text{Standard pressure} = 760\text{mm Hg} \]

* 2 factors that can change atmospheric pressure:

1. \underline{Altitude} - at higher elevations there is a smaller column (amount) of "air" above you, so the atmospheric pressure would be less (barometer reads \(< 760\text{mm Hg} \)

\[ \Rightarrow \text{opposite is also true: lower elevations} = \underline{\text{greater atmospheric pressure}} \]
ChemistryNotes.com

weather (humidity)

\[ \text{in the tropics, there's more H}_2\text{O molecules in the air. So, atmospheric pressure is greater.} \]
\[ \text{in dry regions and deserts, humidity is very low. Relatively few H}_2\text{O molecules in the air leads to lower atmospheric pressures.} \]

Units of Pressure

\[ 760 \text{ mm Hg} = 1 \text{ atm} = 760 \text{ torr} = 101,325 \text{ Pa} = 14.7 \text{ psi} \]

often used as conversion factors.

ex: Represent a pressure of 49 torr in atmospheres, mm Hg, and pascals.

\[ \frac{49 \text{ torr}}{1} \times \frac{1 \text{ atm}}{760 \text{ torr}} = 0.064 \text{ atm} \]
\[ \frac{49 \text{ torr}}{1} \times \frac{760 \text{ mm Hg}}{760 \text{ torr}} = 49 \text{ mm Hg} \]
\[ \frac{49 \text{ torr}}{1} \times \frac{101,325 \text{ Pa}}{760 \text{ torr}} = 6500 \text{ Pa} \]

3 Gas Laws en Route to the "Ideal Gas Law"

Boyle's Law \[ \Rightarrow \boxed{PV = k} \]

@ constant T

- balloon scenario = squeezing a balloon decreases its volume, so \[ PV = k \] (as \( P \uparrow, V \downarrow \)) \Rightarrow they are inversely proportional

if: \( P_1V_1 = k \) and \( P_2V_2 = k \) (situation\(_1\), and situation\(_2\))

then: \[ P_1V_1 = P_2V_2 \] @ constant T
Consider a 1.53 L sample of SO\(_2\)(g) at a pressure of 5.6 \times 10^3 \text{ Pa}. If the pressure is increased to 1.5 \times 10^4 \text{ Pa} at a constant temperature, what's the new volume of the gas?

\[ P_1V_1 = P_2V_2 \]

\[ (5.6 \times 10^3 \text{ Pa})(1.53 \text{ L}) = (1.5 \times 10^4 \text{ Pa})(V_2) \]

\[ V_2 = 0.57 \text{ L} \]

**Charles' Law** ⇒ \[ \frac{V}{T} = k \]

@ constant \( P \)

- **balloon scenario** = as you increase the temperature of the gas in a balloon, you also increase the gas' volume. (think of limp hot air balloon -- what happens when heat (fire) is turned on? ⇒ balloon expands.

so, \[ \frac{V_1}{T_1} = k \] (as \( T \uparrow, V \uparrow \)) ⇒ they are **directly proportional**

if: \[ \frac{V_1}{T_1} = k \text{ and } \frac{V_2}{T_2} = k \] (situation\(_1\), and situation\(_2\))

then: \[ \frac{V_1}{T_1} = \frac{V_2}{T_2} \]

⇒ constant \( P \)

**Ex:** A sample of gas at 15°C and 1 atm has a volume of 2.58 L. What volume will this gas occupy at 38°C and 1 atm?

\[ \text{L} \Rightarrow 15 + 273 = 288 \text{ K} = T_1 \Rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2} \]

\[ \frac{2.58 \text{ L}}{288 \text{ K}} = \frac{V_2}{311 \text{ K}} \]

"cross multiply and divide"...

\[ V_2 = 2.79 \text{ L} \]
Avogadro’s Law: for a gas at constant temperature and pressure, the volume is directly proportional to the number of moles of the gas.

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

@ constant T, P

- the greater the amount of something in moles (n), the more space it’s going to take up (V).

As n↑, V↑ ⇒ they are directly proportional.

If: \( \frac{V_1}{n_1} = k \) and \( \frac{V_2}{n_2} = k \) (situation 1 and situation 2)

Then: \( \frac{V_1}{n_1} = \frac{V_2}{n_2} \) (constant T, P)

Example: Suppose you have 12.2 L of O₂ gas, containing 0.50 mol at a pressure of 1 atm and temperature of 25°C. If all of this O₂ were converted to ozone, O₃, at the same temperature and pressure, what would be the volume of the ozone?

Asked for volume of O₃. Assuming this is V₂, we need to calculate n₂ for O₃ (not O₂) before applying Avogadro’s Law. So,

\[ 3 \text{O}_2 \rightarrow 2 \text{O}_3 \]

\[ \frac{0.50 \text{ mol O}_2}{1} \times \frac{2 \text{ mol O}_3}{3 \text{ mol O}_2} = 0.33 \text{ mol O}_3 \ (n_2) \]

\[ \frac{V_1}{n_1} = \frac{V_2}{n_2} \Rightarrow \frac{12.2 \text{ L}}{0.50 \text{ mol}} = \frac{V_2}{0.33 \text{ mol}} \]

\[ V_2 = 8.1 \text{ L O}_3 \]
*Now, putting all 3 laws together to get the combined gas law and the ideal gas law:

**Boyle's Law (constant T)**
\[ P_1V_1 = P_2V_2 \text{ or } PV = k \]

**Charles' Law (constant P)**
\[ \frac{V_1}{T_1} = \frac{V_2}{T_2} \text{ or } \frac{V}{T} = k \]

**Avogadro's Law (constant P, T)**
\[ \frac{V_1}{n_1} = \frac{V_2}{n_2} \text{ or } \frac{V}{n} = k \]

**Combined Gas Law**
\[ \frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2} \text{ or } \frac{PV}{nT} = k \]

\[ k = \text{the universal gas constant} \]
\[ k = \frac{0.0821 \text{ L} \cdot \text{atm}}{\text{K} \cdot \text{mol}} \]

**Ideal Gas Law**
\[ PV = nRT \]

\[ \text{pressure (atm)} \quad \text{volume (L)} \quad \text{temp. (K)} \quad \text{moles (mol)} \]

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

*units of "R" force us to have P, V, n, T in specific units!!*

**Example:** A sample of Hz gas occupies a volume of 8.56 L at a temperature of 0°C and a pressure of 1.5 atm. How many moles of hydrogen are present?

\[ PV = nRT \]
\[ n = \frac{PV}{RT} = \frac{(1.5 \text{ atm})(8.56 \text{ L})}{(0.0821 \text{ L} \cdot \text{atm})/(273 \text{ K})} \]
\[ n = 0.57 \text{ mol } \text{Hz} \]
Calculate the volume of 0.845 mol of nitrogen gas at a pressure of 699.2 torr and a temperature of 315 K.

\[ PV = nRT \]

\[ V = \frac{nRT}{P} = \frac{(0.845 \text{ mol}) \cdot (0.0821 \frac{L \cdot \text{atm}}{K \cdot \text{mol}}) \cdot (315 \text{ K})}{0.9200 \text{ atm}} = 23.8 \text{ L} \]

Tip: PV = nRT problems don't typically have a "situation 1" and "situation 2" occurring. There's usually just one situation. Before/After type problems usually require Boyle's Law, Charles Law, Avogadros Law, or Combined Gas Law.

A sample of methane gas with a volume of 38 mL at 5°C is heated to 86°C at constant pressure. Calculate its new volume.

\[ V_1 = 38 \text{ mL} \]
\[ T_1 = 5°C + 273 = 278 \text{ K} \]
\[ V_2 = ? \]
\[ T_2 = 86°C + 273 = 359 \text{ K} \]

\[ \frac{V_1}{T_1} = \frac{V_2}{T_2} \]

\[ \frac{38 \text{ mL}}{278 \text{ K}} = \frac{V_2}{359 \text{ K}} \]

\[ V_2 = 49 \text{ mL CH}_4 \]

Q: How come it wasn't necessary to convert \( V_1 \) and \( V_2 \) into liters (L)?

\[ \text{"R" (in PV = nRT) is } = 0.0821 \frac{L \cdot \text{atm}}{K \cdot \text{mol}} \]

but "R" is not being used here!!
**Example:** Diborane gas \((B_2H_6)\) has a pressure of \(345\text{torr}\) at a temperature of \(-15^\circ\text{C}\) and a volume of \(3.48\text{L}\). If conditions change such that the temperature is \(36^\circ\text{C}\) and the pressure is \(468\text{torr}\), what will be the volume of the sample?

\[
\begin{align*}
\text{Use combined gas law:} & \quad \frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2} \\
\left(\frac{345\text{torr}}{258\text{K}}\right)\left(3.48\text{L}\right) &= \left(\frac{468\text{torr}}{309\text{K}}\right)\left(V_2\right) \\
V_2 &= 3.07\text{L} \quad \text{B}_2\text{H}_6
\end{align*}
\]

**Ex:** A gaseous sample contains \(0.35\text{mol}\) Argon at a temperature of \(13^\circ\text{C}\) and a pressure of \(568\text{torr}\). If it's heated to \(56^\circ\text{C}\) and a pressure \(897\text{torr}\), calculate the change in volume that occurs.

\[
\begin{align*}
\text{We need to find the change in volume} & \quad (\Delta V) = V_2 - V_1 \\
\text{First, need to use} \quad pV = nRT \text{ twice} \\
\text{\(n_1 = n_2\) remains unchanged} & \quad n = 0.35\text{mol} \\
T_1 &= 13^\circ\text{C} + 273 = 286\text{K} \\
p_1 &= 568\text{torr} \\
T_2 &= 56^\circ\text{C} + 273 = 329\text{K} \\
p_2 &= 897\text{torr} \\
V_1 &= ? \\
V_2 &= ?
\end{align*}
\]

\[
\begin{align*}
\text{\(P_1V_1 = nRT_1\)} & \quad \text{\(V_1 = \frac{nRT_1}{P_1} = \frac{(0.35\text{mol})(0.0821\frac{\text{L} \cdot \text{atm}}{\text{K} \cdot \text{mol}})(286\text{K})}{(0.747\text{atm})} \Rightarrow V_1 = 11\text{L}\) } \\
\text{\(568\text{torr} \times \frac{1\text{atm}}{760\text{torr}} = \)} & \quad \text{change in volume} = -3.0\text{L} \\
\text{\(P_2V_2 = nRT_2\)} & \quad \text{\(V_2 = \frac{nRT_2}{P_2} = \frac{(0.35\text{mol})(0.0821\frac{\text{L} \cdot \text{atm}}{\text{K} \cdot \text{mol}})(329\text{K})}{(1.18\text{atm})} \Rightarrow V_2 = 8.0\text{L}\) }
\end{align*}
\]
SECTION 5 – GASES

Were the FREE Section 5 Notes Useful?

Want the FULL VERSION of the Section 5 Notes?

*Download Them Instantly at:*

[ChemistryNotes.com]