*Intro to Gases and The Early Gas Laws

By Shawn P. Shields, Ph. D.

*Introduction to Gases

* Gases are a phase of matter without a fixed volume nor a fixed shape.

* Gases are described in terms of four macroscopic observables:

  * Pressure

  * Temperature

  * Volume

  * Moles of gas

*Introduction to Gases

* The early gas laws described these macroscopic observables or characteristics relative to each other.
  * Boyle's law describes the relationship between **pressure and volume** of a gas at a fixed temperature and amount of gas.
  * Charles's law describes the relationship between **temperature and volume** of a gas at a constant pressure and amount of gas.
  * Avogadro's law says **one mole of any gas at STP** (**S**tandard **T**emperature and **P**ressure; 0°C and 1 atm) will take up a volume of **22.4 L**.

*Pressure Units

*These are the pressure units that we will focus on in this course:

1 atm = 760 torr = 760 mmHg = 1.01325×10^5 Pa

*You should especially practice with these:

1 atm = 760 torr = 760 mmHg

Practice: Pressure Unit Conversions

- Convert 0.378 atm to torr.

- Convert 6.4×10^{-2} torr to atmospheres.

- Convert 106.9 Pa to torr.

*Practice: Pressure Unit Conversions (Solutions)

*Convert 0.378 atm to torr.

Use the relationship 760 torr = 1 atm

We need to cancel out atm, so put that unit on the bottom in the conversion factor

$$0.378\ \text{atm}\left(\frac{760\ \text{torr}}{1\ \text{atm}}\right) = 287\ \text{torr}$$

*Practice: Pressure Unit Conversions (Solutions)

*Convert 6.4×10^{-2} torr to atmospheres.

We need to use the relationship 760 torr = 1 atm again

But this time we need to cancel out torr, so put that unit on the bottom in the conversion factor

$$6.4 \times 10^{-2}\ \text{torr}\left(\frac{1\ \text{atm}}{760\ \text{torr}}\right) = 8.4 \times 10^{-5}\ \text{atm}$$

*Practice: Pressure Unit Conversions (Solutions)

*Convert 106.9 Pa to torr.

Use the equality 760 torr = 1.01325×10^5 Pa

This time we need to cancel out Pascals, so put that unit on the bottom in the conversion factor with torr in the numerator

$$106.9\ \text{Pa}\left(\frac{760\ \text{torr}}{1.01325\times10^5\ \text{Pa}}\right) = 0.8018\ \text{torr}$$

*The Early Gas Laws

* Boyle's Law

* Charles Law

* Avogadro's Law

*Boyle's Law

Boyle's law states that

- the pressure of a gas is *inversely* related to its volume when the temperature and the amount of gas are held constant (or unchanged)

- So, when the volume decreases, the pressure increases, and vice-versa

$$P_1V_1 = P_2V_2$$

*Mini Quiz

* A gas has a pressure of 560 torr when it is held in a 3.5 L cylinder. Calculate the pressure of the gas (in torr) when the volume of the cylinder is increased to 6.3 L.

*Mini Quiz Solution (ptI)

* A gas has a pressure of 560 torr when it is held in a 3.5 L cylinder. Calculate the pressure of the gas (in torr) when the volume of the cylinder is increased to 6.3 L.
* Use Boyle's law:

$$P_1V_1 = P_2V_2$$

Step 1: Identify what you are given and what you are calculating:

* P_1 = 560 torr P_2 = ?
* V_1 = 3.5 L V_2 = 6.3 L

*Mini Quiz Solution (pt II)

Step 2: Solve for the unknown quantity (in this case P_f):

*$P_1 = 560$ torr $P_2 = ?$

*$V_1 = 3.5$ L $V_2 = 6.3$ L

$$P_1V_1 = P_2V_2$$

$$(560 \text{ torr})(3.5 \text{ L}) = P_f(6.3 \text{ L})$$

$$P_2 = 311 \text{ torr}$$

*Charles's Law

In Charles's law,

- the Kelvin (K) temperature of a gas is directly related to the volume
- The pressure and amount of gas are constant
- when the temperature of a gas increases, its volume increases

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

*Mini Quiz

*A gas has a temperature of 15.0 °C when it is held in a 2.36 L cylinder. Calculate the new temperature of the gas (in °C) when the volume is expanded to 8.32 L.

*Mini Quiz Solution (ptI)

*A gas has a temperature of 15.0 °C when it is held in a 2.36 L cylinder. Calculate the new temperature of the gas (in °C) when the volume is expanded to 8.32 L.

- Use Charles' law:

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

Step 1: Identify what you are given and what you are calculating:

*T_1 = 15.0 °C T_2 = ?

*V_1 = 2.36 L V_2 = 8.32 L

*Mini Quiz Solution (pt II)

Step 2: Convert given temperatures from °C to K:

*T_1 = 15.0 °C + 273 = 288 K

*NOTE: Temperatures in gas laws are ALWAYS in Kelvin (K)!

*Mini Quiz Solution (pt III)

Step 3: Solve for the unknown quantity (in this case T_2 and convert to °C):

*T_1 = 288K T_2 = ?

*V_1 = 2.36 L V_2 = 8.32 L

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

$$\frac{2.36\ L}{288\ K} = \frac{8.32\ L}{T_2}$$

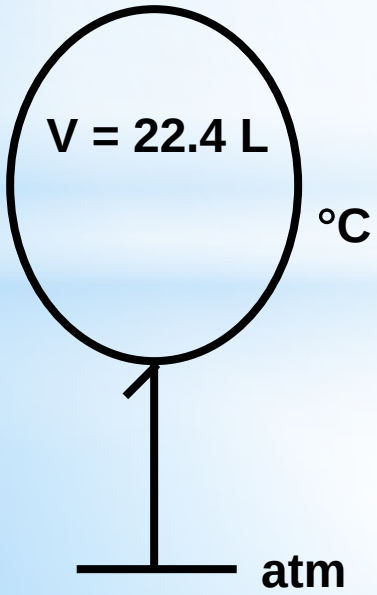
$$T_2 = 8.32\ L \left(\frac{288\ K}{2.36\ L} \right)$$

$$T_2 = 1015\ K = 742\ °C$$

*Avogadro's Law

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

*When the gas is under standard conditions, 1 mole of any ideal gas has a volume of 22.4 L.



*standard conditions: pressure is 1 atm and the temperature is 0°C.