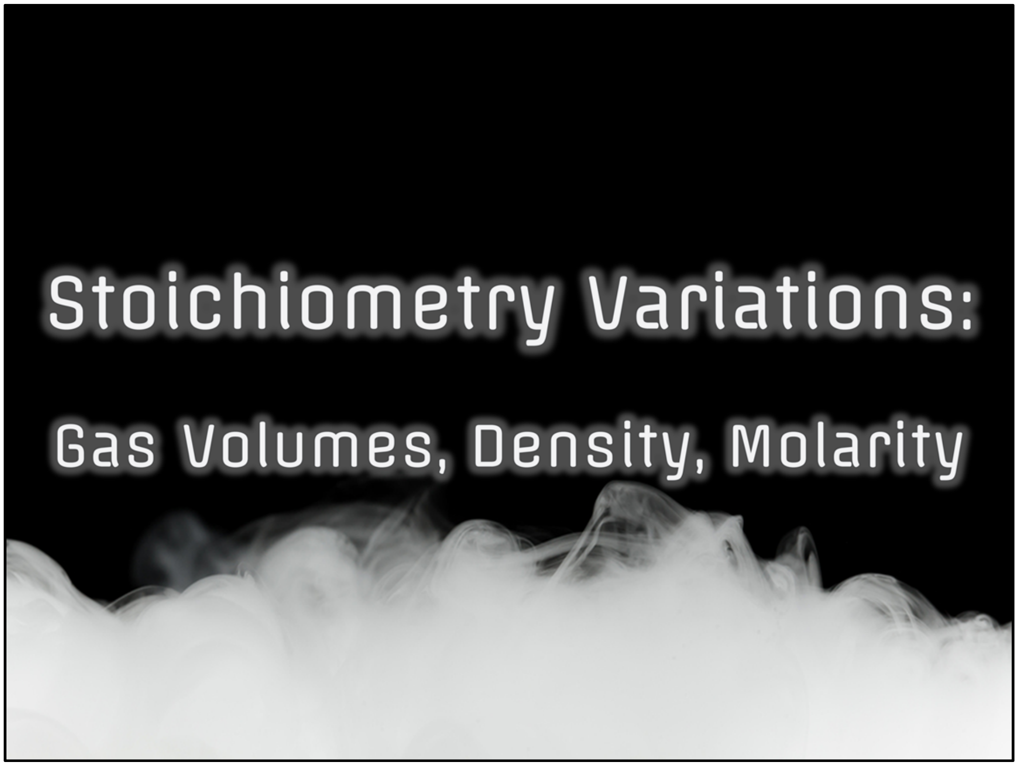
Module 7: Stoichiometry
Stoichiometry Variations: Gas Volumes, Density, and Molarity



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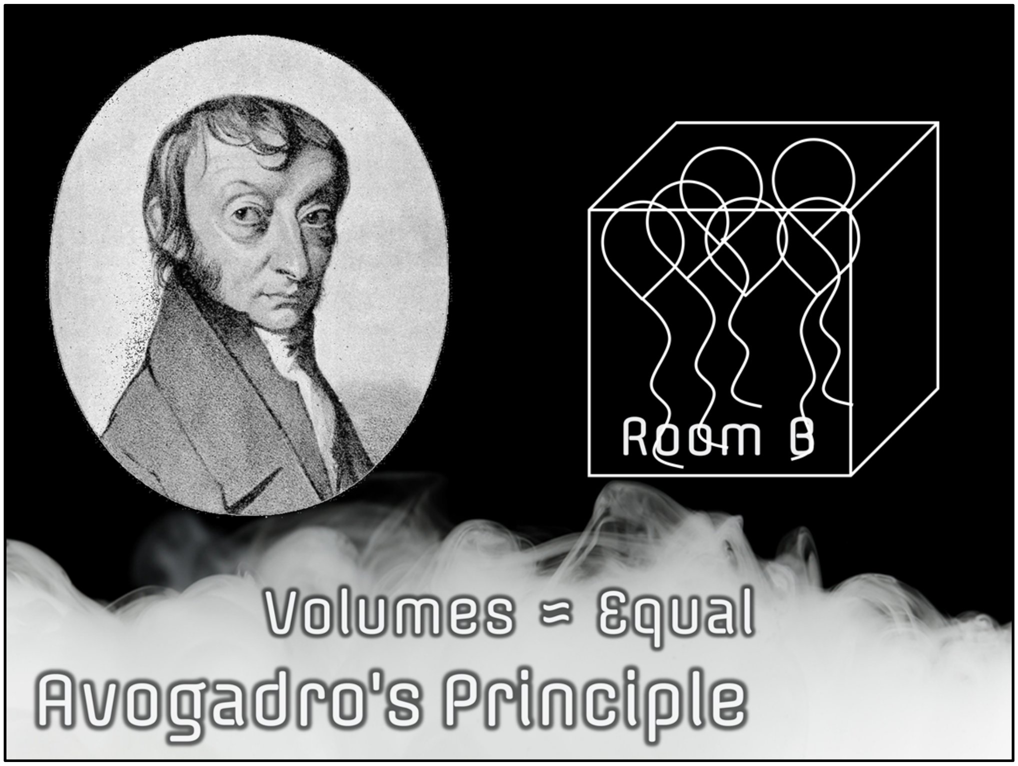
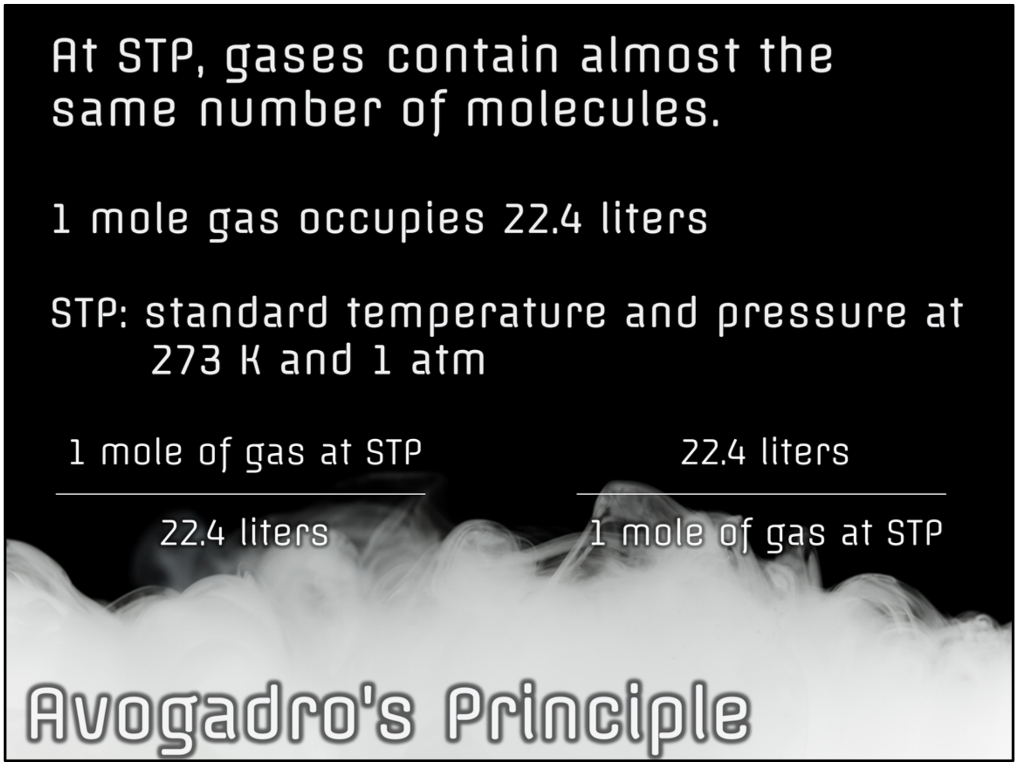


Imagine two identical rooms that are exactly the same, with one exception. Room B has ten small helium-filled balloons that have floated to the top. If you measure the volumes of Rooms A and B, being sure to subtract the volume of the small balloons from the volume of Room B, you will find the volumes are essentially the same, with the volume of Room A only being slightly larger than the volume of Room B.

This is because the volume of those little tiny spheres hanging from the ceiling are extremely negligible compared to the volume of the entire room. Amedeo Avogadro had this all figured out when he studied the properties of gases in the year 1811. In a gas, the particles are very far apart and each particle is extremely small compared to the vast volume between particles. Essentially, the volume of each particle does not change the volume of the entire amount of gas.



This is known as **Avogadro's Principle**, which states that at standard temperature and pressure, or STP, gases contain *almost* the same number of molecules. In other words, the volume of one mole of all gases is approximately the same if they are at standard temperature and pressure. At standard temperature and pressure, one mole of any gas occupies 22.4 L.

STP is the abbreviation for standard temperature and pressure, and it is found at 273 Kelvin and 1 atmosphere. There are two conversion factors which express standard temperature and pressure and volume in liters. The first conversion factor says 1 mole of gas at standard temperature and pressure is equivalent to 22.4 L. The second conversion factor is similar, except it is the reciprocal of the first. The second conversion factor is written as 22.4 L over 1 mole of gas at standard temperature. Both conversion factors are used in mole-to-mole conversion problems.

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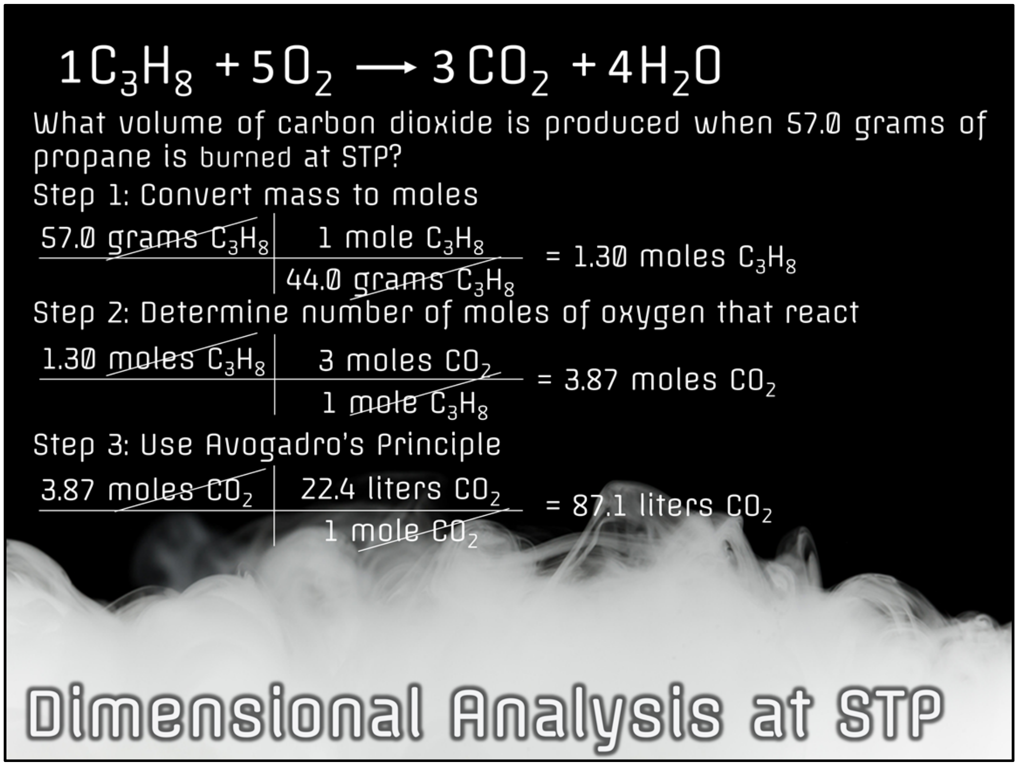

Consider the reaction of propane gas and oxygen. Propane gas, or C_3H_8, reacts with oxygen gas, or O_2, to produce gaseous carbon dioxide, or CO_2, and water vapor, H_2O. Start off by writing a balanced equation of the reaction. There needs to be the same amount of moles of each element on both sides of the reaction. The balanced equation will have 1 mole of C_3H_8, 5 moles of O_2, which produces 3 moles of CO_2 and 4 moles of H_2O. The coefficient of 1 in front of C_3H_8 does not need to be written. Using this balanced equation, determine what volume of carbon dioxide is produced when 57.0 grams of propane is burned at STP. To solve this, use dimensional analysis.

For step one, convert the mass of propane to moles of propane. The 57.0 grams of C_3H_8 is multiplied by the conversion factor of 1 mole of C_3H_8 over 44.0 grams of C_3H_8. The unit of grams of C_3H_8 will cancel out, and the result is 1.30 moles of C_3H_8.

In step two, use the molar coefficients to determine the number of moles of oxygen that react with the moles of propane. Multiply 1.30 moles of C_3H_8 by the conversion factor of 3 moles of CO_2 over 1 mole of C_3H_8. The unit mole for C_3H_8 will cancel out, and the answer is 3.87 moles of CO_2. Even though 1.30 times 3 equals 3.90, the answer to step two is 3.87 since the answer to step one was rounded up to 1.30.

For step three, multiply the product from step two by Avogadro's principle, which is the conversion factor of 22.4 liters of CO_2 over 1 mole of CO_2. All of these steps can be put together into one set of conversion factors. You are given the mass of propane, the equation is balanced, and you want to find out the amount of liters of CO_2 that will be produced in this reaction.

Module 7: Stoichiometry
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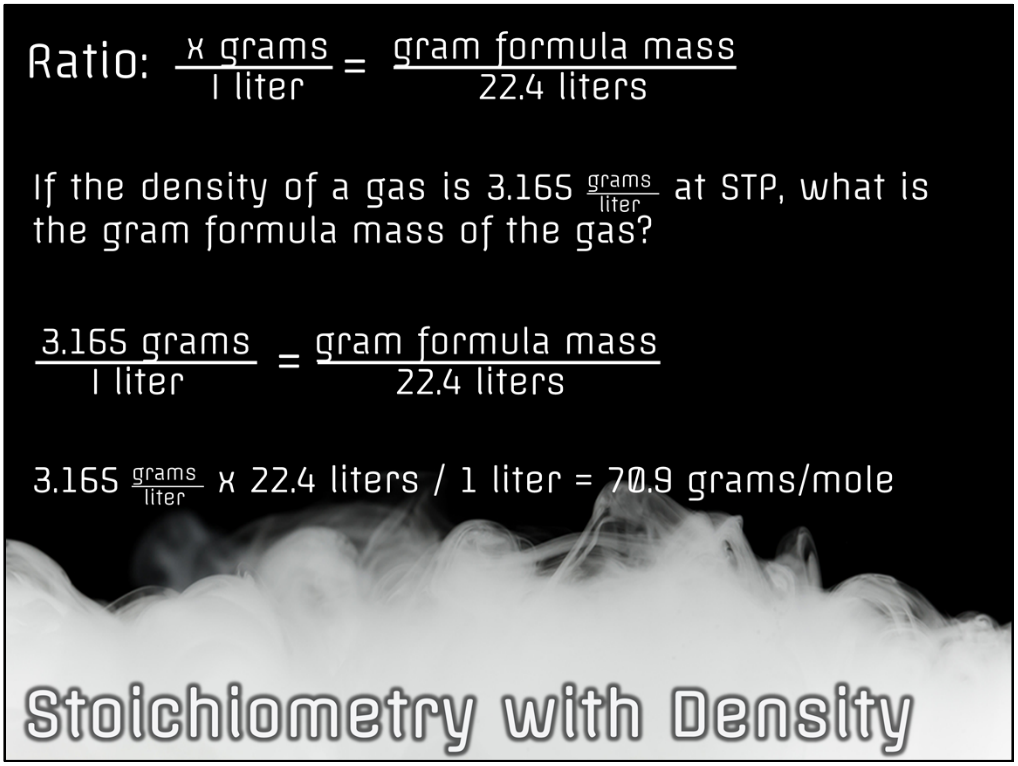

Another type of stoichiometry problem using Avogadro's principle involves converting gas density to mass. To complete this calculation you will need to use a ratio. The ratio states the following: *x* grams per liter equals the gram formula mass over 22.4 L. Are you still wondering how to solve these types of conversions? Take a moment to view an example problem. The example states: If the density of a gas is 3.165 grams per liter at STP, what is the gram formula mass of the gas?

If you know that 1 mole of any gas at STP occupies 22.4 liters, you can set up a ratio. Substitute in 3.165 grams for *x* in the ratio to get 3.165 grams per 1 liter equals gram formula mass per 22.4 L. This equation works because the gram formula mass is 1 mole. Next, solve the ratio using algebra by multiplying 3.165 grams times 22.4 L. Finally, divide by 1 liter to get the gram formula mass of 70.9 grams per mole.

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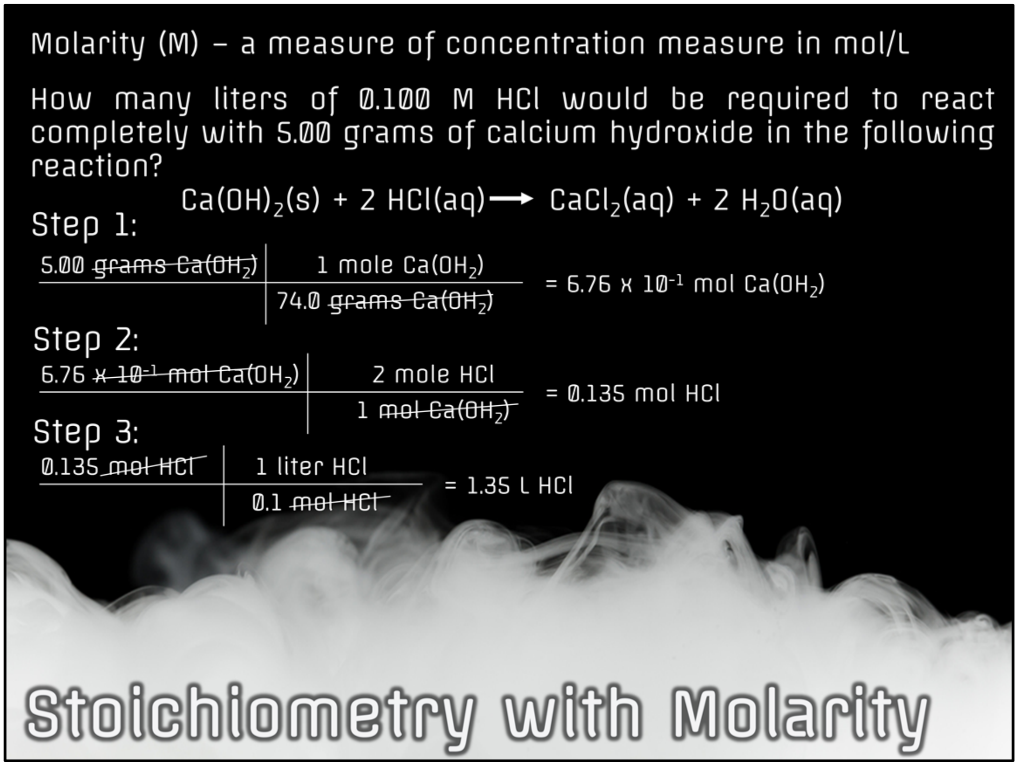

Molarity, abbreviated as M, is the concentration of a solution and is measured in moles per liter. Molarity, like density, can be used as a conversion factor. Consider the following problem: How many liters 0.100 molarity of HCl would be required to react completely with 5.00 grams of $Ca(OH)_2$? Please view the reaction for this equation.

For step one, convert the mass of $Ca(OH)_2$ to moles of $Ca(OH)_2$. To do so, start with the given amount of $Ca(OH)_2$, which is 5.00 grams. The conversion factor is 1 mole of $Ca(OH)_2$ over the gram formula mass of $Ca(OH)_2$, which is 74.0 grams. Using dimensional analysis, the answer to step one is 6.76 times 10^{-1} mole of $Ca(OH)_2$.

For step two, multiply the mole amount times the conversion factor of two moles of HCl per 1 mole of $Ca(OH)_2$, which is from the balanced equation, to get 0.135 moles HCl. In step three, multiply 0.135 moles of HCl by 1 liter HCl per 0.1 HCl, which is molarity expressed as a conversion factor. The volume of hydrochloric acid that is produced is 1.35 L.

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