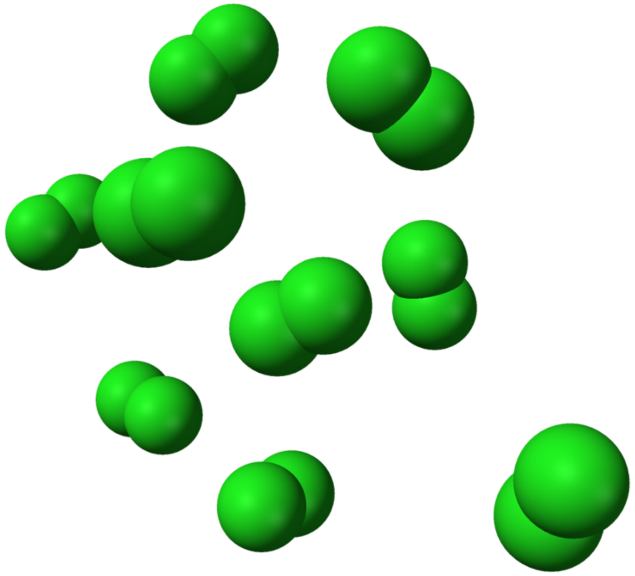


CH301 Unit 1

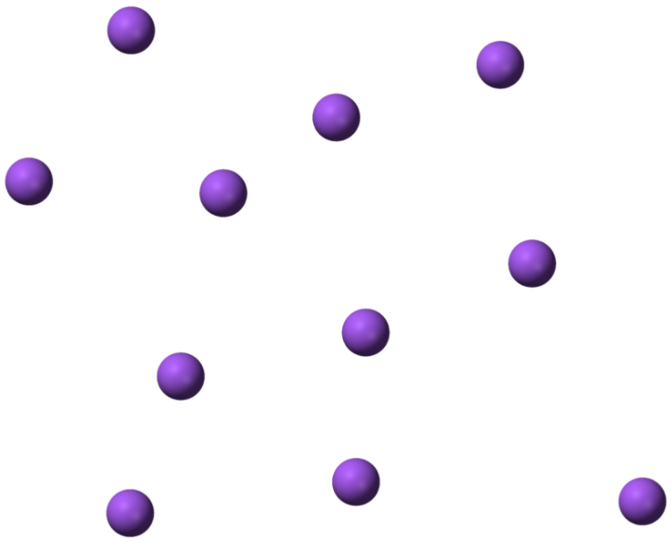
CHEMISTRY FUNDAMENTALS AND GAS LAWS

Goals for Our First Review

- Get acquainted
- Talk about what you're expected to know **now**
- Learn stoichiometry: common problem, gas problem
- Introduce gases: common relationships, ideal gas law

Pre-CH301 Knowledge

- You are expected to come into CH301 with a little bit of prior chemistry knowledge:
  - You will not be provided with prefixes (milli, kilo, micro, nano, etc.)
  - You should understand the relationship between molecular weight and weight; moles and atoms
  - You should be able to do stoichiometry as second nature by the first exam (or be okay with getting 8-12 points off to start)
  - Apply dimensional analysis to convert units
  - Understand the relationship between Celsius and Kelvin. **Kelvin = Celsius + 273.15**



Basic Terminology in Reaction Stoichiometry

- Mole: a mole is basically a packet of atoms (6.02×10^{23} atoms to be exact)
  - We use the term “mole” because it is easier to work with in a lab.
  - The mass of each element is presented as its **molar mass** on the periodic table (g/mol)
  - Based on the phase of matter, moles will look different (condensed phases vs. gas phase)
- Limiting reagent: the reactant that **runs out first**, thereby forcing the reaction to stop
- Excess: a reactant that is added in high quantities so that another reactant runs out first
  - You will have a certain amount of this “excess reagent” left over once the limiting reagent runs out
- NOTE: to determine the limiting reagent or the reactant(s) in excess, you must consider the ratio between **the amount present** and the **moles required** to run the reaction.
  - In other words, the limiting reagent is *not always* the reactant with the least number of moles present in the beginning (we will see an example of this later)

Common Stoichiometry Problem

Given the following unbalanced reaction:

$Fe(s) + O_2 (g) \rightarrow Fe_2O_3(s)$

If you have 5 moles of Fe and 10 moles of O_2, identify the limiting reagent and the total mass of your iron (III) oxide product.

Common Stoichiometry Problem

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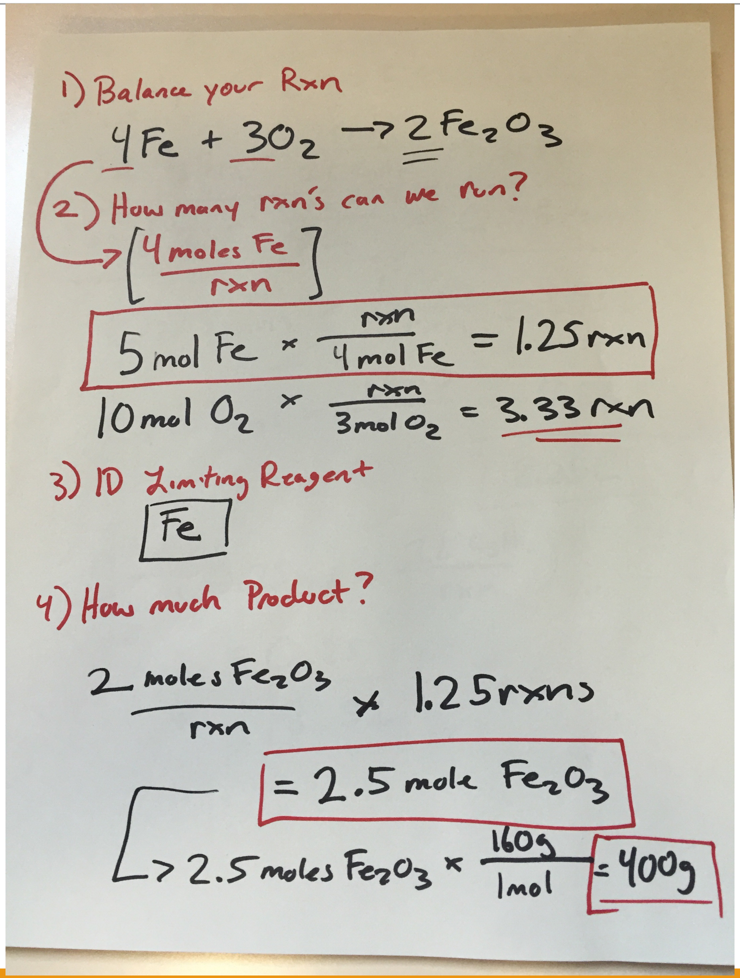
If you have 5 moles of Fe and 10 moles of O_2, identify the limiting reagent and mass of your iron (III) oxide product.

1. Balance the reaction: $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$
2. Solve for the number of reactions you can run with each reactant by comparing the coefficient and the moles you have.
   - You have 5 moles of iron and it takes 4 moles to run one “complete” reaction. Therefore, you can run 1.25 reactions.
   - You have 10 moles of oxygen and it takes 3 moles to rune on “complete” reaction. Therefore, you can run 3.33 reactions.
3. Identify the limiting reagent based on which reactant can run the *least number of reactions* based on the amount present.
   - It should be clear that you will run out of iron first. Therefore, iron is the limiting reagent and you have excess oxygen.
4. Using the number of reactions you can run with the limiting reagent, solve for how many moles of iron (III) oxide are present.
   - We decided we can only run 1.25 reactions. Therefore, we have multiply this times the 2 iron (III) oxide per reaction. This means we end up with 2.5 moles iron(III) oxide.
5. Using the number of moles of iron (III) oxide present, multiply by the molar mass to solve for the total mass of product.
   - The molar mass is 160g/mol. You will end up with 400 g iron oxide.

Common Stoichiometry Problem



Common Stoichiometry Problem

Given the following balanced reaction:

$C_5H_{12}(g) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O(g)$

If you have 1 L of pentane and 6 L of oxygen, what is the final volume of your system?

Note: don't worry about converting liters into moles. The steps are the same with liters as long as you are working with gases

Common Stoichiometry Problem

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$C_5H_{12}(g) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O(g)$

If you have 1 L of pentane and 6 L of oxygen, what is the final volume of your system?

Answer: 8.5L; 8.25L from carbon dioxide and water, 0.25L from excess pentane

Common Stoichiometry Problem

$$1\,C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$$

$$1L\ C_5H_{12} \times \frac{rxn}{1L\ C_5H_{12}} = 1\ rxn$$

$$6L\ O_2 \times \frac{rxn}{8L\ O_2} = 0.75\ rxn$$

$$0.75\ rxns \times \frac{5L\ CO_2}{rxn} = 3.75L\ CO_2$$

+

$$0.75\ rxns \times \frac{6H_2O}{rxn} = 4.5L\ H_2O$$

$$8.25L$$

$$1 - \left(0.75\ rxn \times \frac{1L\ C_5H_{12}}{rxn}\right)$$

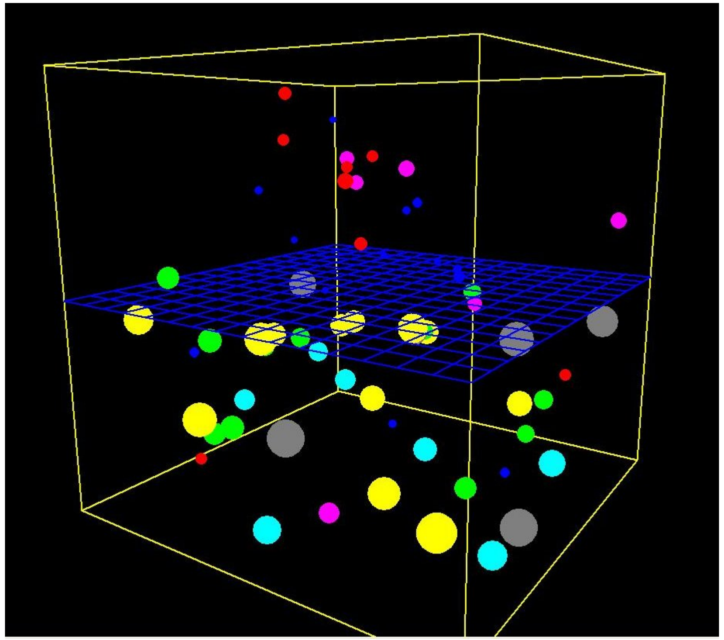
$$= 0.25$$

excess C_5H_{12}

$$8.5L$$

Introduction to Gases

- As an introduction to gases, we pretend that all gases are "ideal gases."
- This comes with a few assumptions:
  - A gas consists of a bunch of molecules that obey Newtonian physics
  - Gas molecules are tiny spheres and they all have the same volume – however, this volume is so small we consider it negligible.
  - No forces act upon these gas molecules except for instantaneous, perfectly elastic collisions – in particular, gas molecules do not attract each other



Modeling Gases

- We describe ideal gases using **state functions**
  - State functions: a quantity or description that explains the current state of a chemical system
- The state functions we use to describe gases are:

1. Pressure (P): In physics, pressure is **Force per unit Area**; in gases, we consider pressure to be the number of **collisions** between the gas and the walls of the container (units are in tor, bar, atm)
2. Volume (V): gases will occupy the complete volume of the container. The volume is always the total volume of the container (units in L)
3. Temperature (T): temperature is an important variable in describing energy. You will ~~almost~~ always use **Kelvin**
4. Number of moles (n): the quantity of gas present; usually constant unless you are pumping in more gas or vacuuming it out.

Modeling Gases

- We describe ideal gases using **state functions**
  - State functions: a quantity or description that explains the current state of a chemical system
  - Another way to describe them is that they explain the final and initial, but not the process in between
- The state functions we use to describe gases are:
  1. Pressure (P): number of **collisions** between the gas and the walls of the container
  2. Volume (V): the volume of the **container**
  3. Temperature (T): **Kelvin**
  4. Number of moles (n): the **quantity** of gas present
- For now, we can use a few very important relationships to model gases.

Modeling Gases: Common Laws

Charles Law

- The volume and temperature of a gas are directly proportional
- As temperature increases, volume increases
- $V/T = k$
- $V_1/T_1 = V_2/T_2$

Boyle's Law

- The pressure and volume of a gas are inversely proportional
- As volume decreases, pressure increases
- $PV = k$
- $P_1V_1 = P_2V_2$

Avogadro's Law

- The volume and number of moles of a gas are directly proportional
- $V/n = k$
- $V_1/n_1 = V_2/n_2$

Gay-Lussac Law relates Pressure and Temperature in the same way as Charles Law (no one cares about it for some reason)

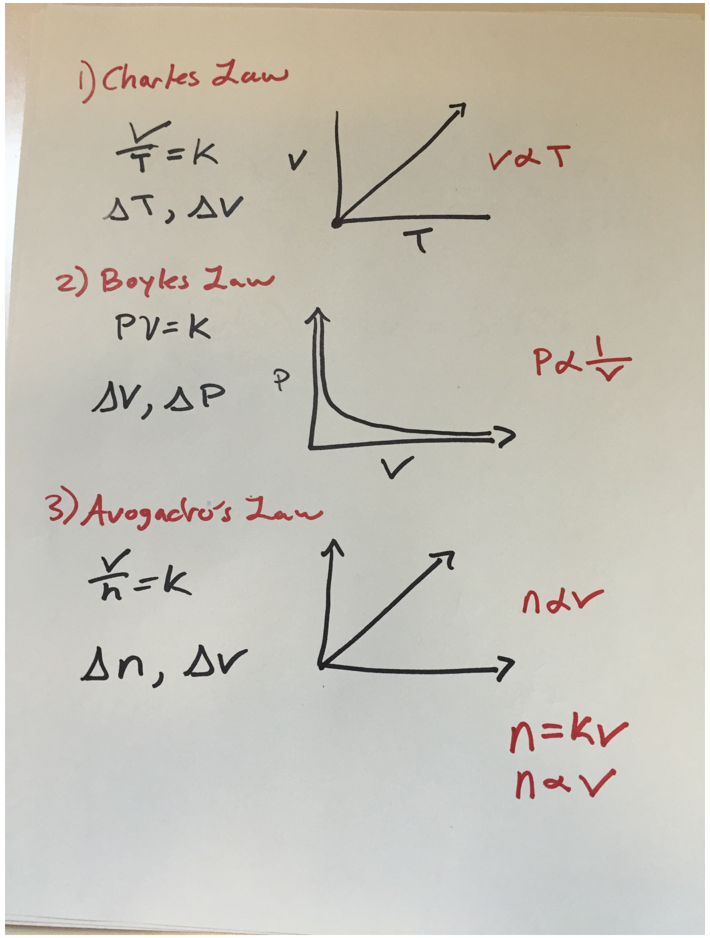
Quick Questions

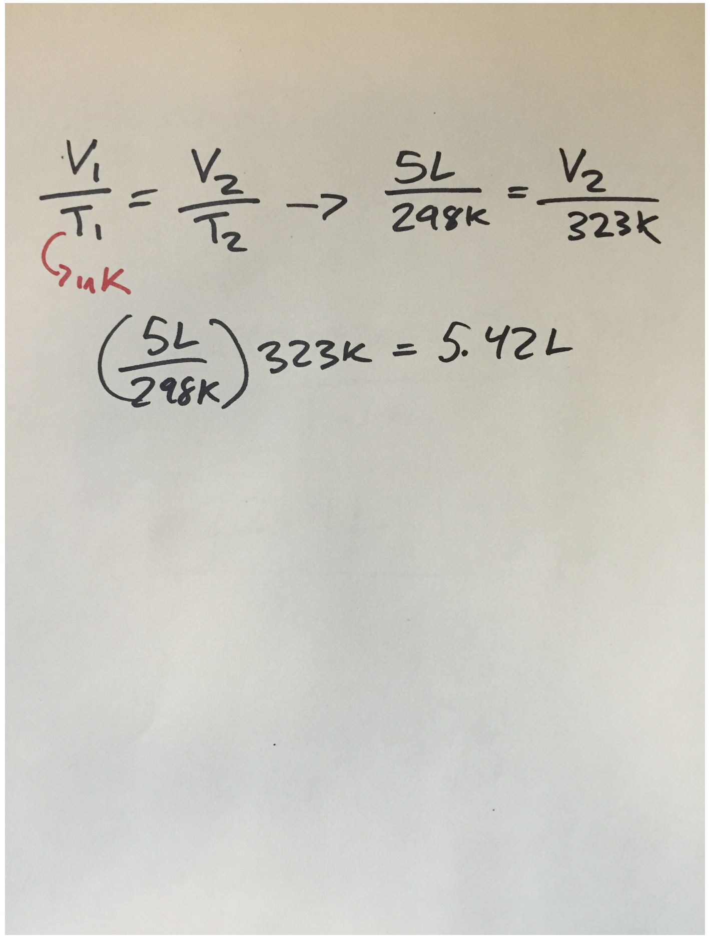
If you have a gas in a closed container with a volume of 10L and a pressure of 0.5atm. What volume container is necessary to create a system with a pressure of 1atm with the same amount of gas?

Suppose your new container adjusts in size to maintain a constant pressure. What is the volume of your new container when you heat it from 25 degrees Celsius to 50 degrees Celsius?

Hint: for the second question, ask yourself first if it as simple as doubling?

Quick Questions





Quick Questions

If you have a gas in a closed container with a volume of 10L and a pressure of 0.5atm. What volume container is necessary to create a system with a pressure of 1atm with the same amount of gas? 5L

Suppose your new container adjusts in size to maintain a constant pressure. What is the volume of your new container when you heat it from 25 degrees Celsius to 50 degrees Celsius? 5.42L

Hint: for the second question, ask yourself first if it as simple as doubling?

Modeling Gases: The Ideal Gas Law

- The relationship between these state functions is presented in the following equation:

$$PV = nRT$$

- How we use it: we will use this formula when we change one state function and keep all other state functions except one constant.
- Examples:
  - If you **double** pressure and keep the same number of moles and temperature, the volume will **half**.
  - If you **double** the temperature and maintain the same number of moles and pressure, the volume will **double**.
- What about R? R will never change value **unless you change the units** because it is a constant. Constants in the natural sciences are used to relate state functions with different units. ***Make sure you use the *correct* R value***
  - Note: R is NOT a state function

Quick Concluding Question

STP is short for "Standard temperature and pressure." For gases this is defined as 0 degrees Celsius and 1atm pressure. Knowing this, what is the volume of 1 mole gas at STP?

R = 0.08206 L atm/mol K

R = 8.314 J/mol K

Note: This is a value worth memorizing for exams

Quick Concluding Question

$$PV = nRT$$

$$1\,\text{atm}\,(V) = 1\,\text{mol}\left(0.08206\,\frac{\text{L atm}}{\text{mol K}}\right)273\,\text{K}$$

$$\downarrow$$

$$L = \frac{1\,\text{mol}\left(0.08206\,\frac{\text{L atm}}{\text{mol K}}\right)273\,\text{K}}{1\,\text{atm}}$$

$$= 22.4\,\text{L}$$

Summary:

- Ideal gases are pretty easy if you use the ideal gas law properly.
  - Students who get these problems wrong usually do one of two things:
    - Their R value is wrong
    - They do not convert from Celsius to Kelvin
- Stoichiometry is important for gases, so learn it
  - Remember to differentiate between questions asking for the quantity of product and the quantity of total species in the final system
- Coming up:
  - Mixtures of gases: partial pressure and concentrations
  - Looking at different descriptions of gases: velocity, kinetic energy, density
    - Differentiating number density and mass density
  - Deviating from ideal gases: understanding that gas molecules have volume and there are very small but non-negligible interactions between them
  - Exam!