# N27 – Gases

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**Target: I can describe and perform calculations for a hodgepodge of gas topics** (gas density, kinetic energy, effusion/ diffusion and gas stoichiometry).

# Gas Density

$$Density = \frac{mass}{volume} = \frac{\text{molar mass}}{\text{molar volume}}$$

**… so at STP…**

$$Density = \frac{\text{molar mass}}{22.4\ \text{L}}$$

# Density and the Ideal Gas Law

**Combining the formula for density with the Ideal Gas law, substituting and rearranging algebraically:**

$$D = \frac{MP}{RT}$$

$$M = \frac{DRT}{P}$$

**D =** Density

**M =** Molar Mass

**P =** Pressure

**R =** Gas Constant

**T =** Temperature in Kelvins

***"Molar Mass Kitty puts Dirt Over its Pee" - Ha!***

# Kinetic Energy of Gas Particles

**At the same conditions of temperature, all gases have the same average kinetic energy.**

$$KE = \frac{1}{2}mv^2$$

# The Meaning of Temperature

**Kelvin temperature is an index of the random motions of gas particles (higher *T* means greater motion.)**

$$(KE)_{avg} = \frac{3}{2}RT$$

# Root Mean Square Velocity

$$\mu_{rms} = \sqrt{\frac{3RT}{M}}$$

**R** = universal gas constant (the energy one, 8.314)

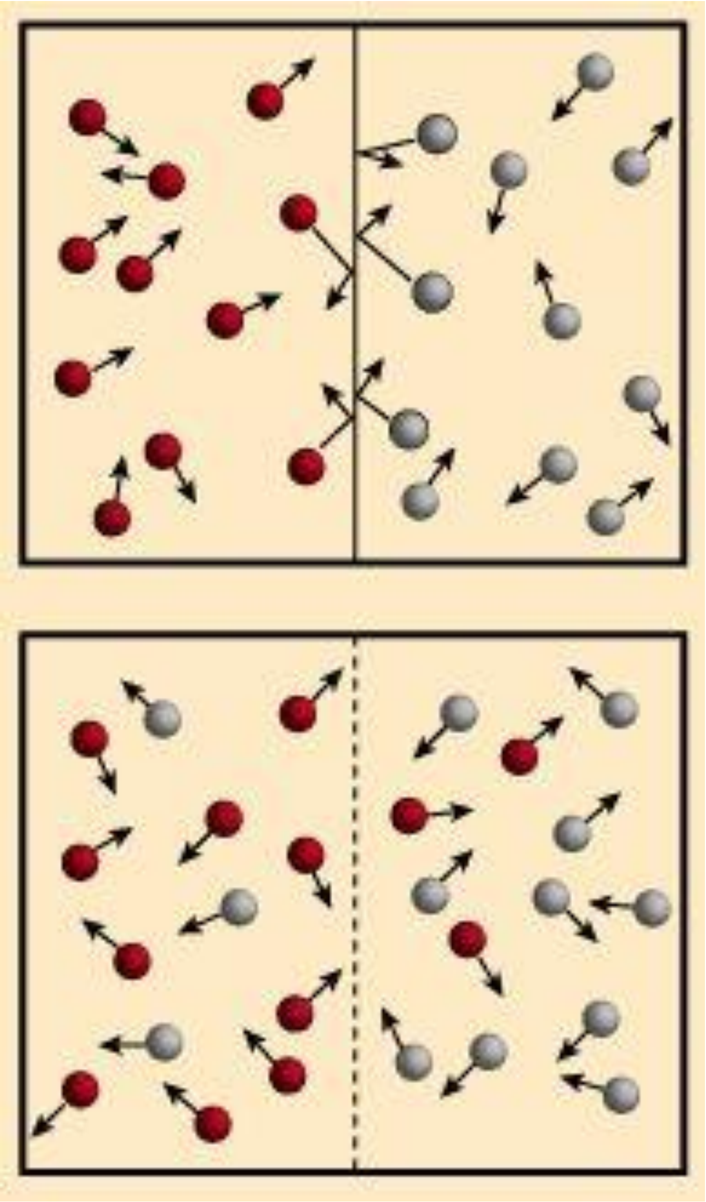
**T** = Kelvin Temperature

**M** = molar mass in <u>*KILOGRAMS*</u> (b/c of the Joule in "R")

# Diffusion

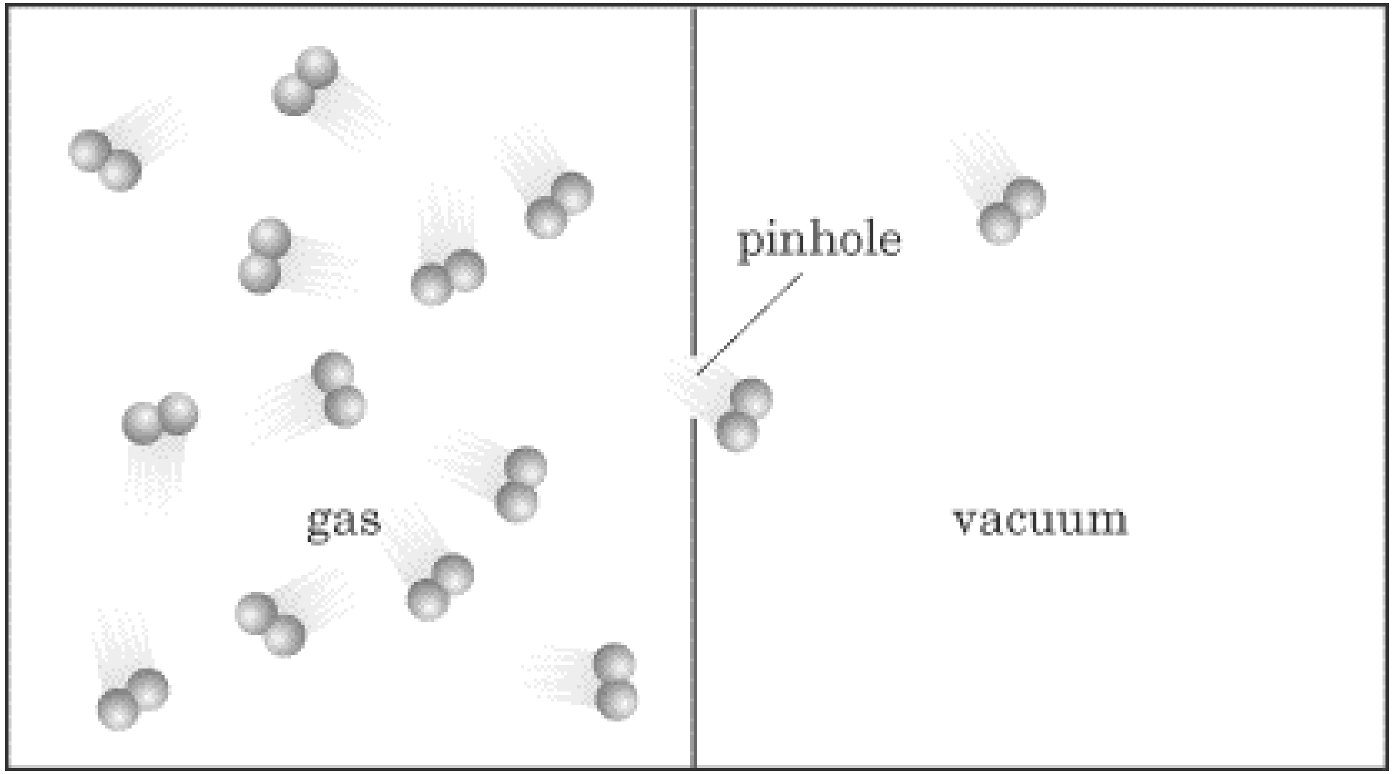
**Diffusion describes the mixing of gases.**

**The rate of diffusion is the rate of gas mixing.**

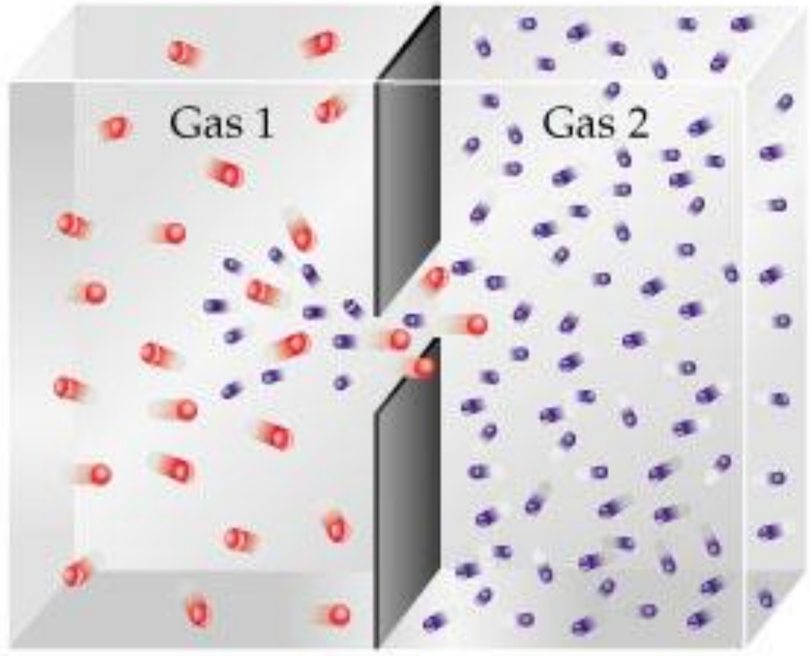


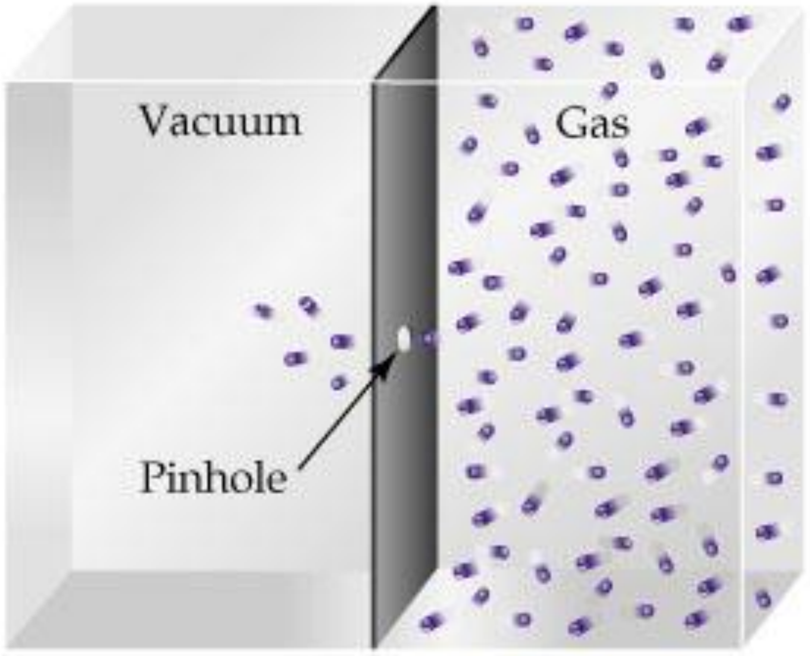
# Effusion

**Effusion describes the passage of gas into an evacuated chamber.**



# Diffusion versus Effusion




Diffusion

Effusion

# Graham's Law

## Rate of Effusion:

$$\frac{Rate\ of\ effusion\ for\ gas\ 1}{Rate\ of\ effusion\ for\ gas\ 2} = \frac{\sqrt{M_2}}{\sqrt{M_1}}$$

## Rate of Diffusion:

$$\frac{Distance\ traveled\ by\ gas\ 1}{Distance\ traveled\ by\ gas\ 2} = \frac{\sqrt{M_2}}{\sqrt{M_1}}$$

**M = molar mass**


Often given seconds it takes the gases to travel versus distance. No big deal! Use that data.

If they tell you gas 1 travels 4 times faster, that is this part of the equation:

$$\frac{Rate\ gas\ 1}{Rate\ gas\ 2}$$

Careful to notice it isn't gas 1 on the top of both parts of the equation!

# Practice

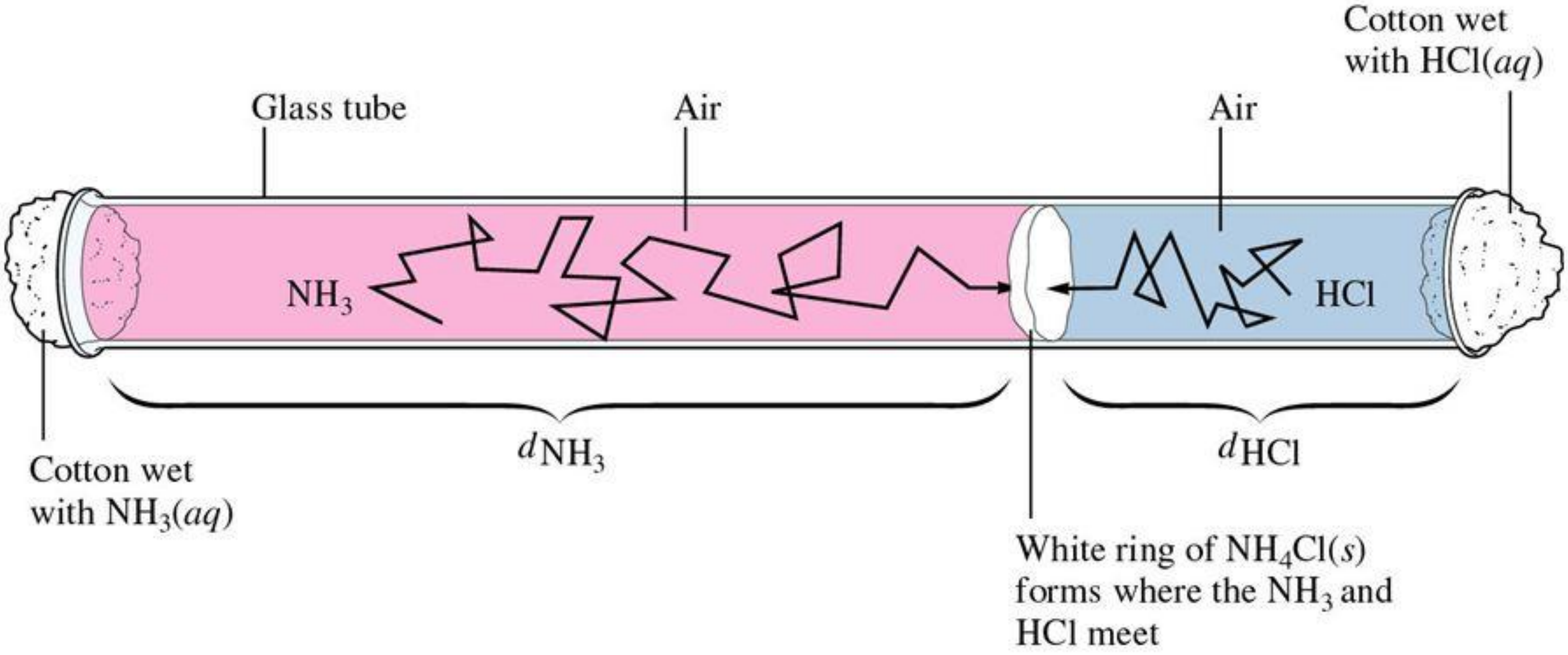
**Under the same conditions of temperature and pressure, does hydrogen iodide or ammonia effuse faster? Calculate the relative rates at which they effuse.**

$$\frac{Rate\ of\ effusion\ for\ gas\ 1}{Rate\ of\ effusion\ for\ gas\ 2} = \frac{\sqrt{M_2}}{\sqrt{M_1}}$$

$$\frac{Rate\ of\ NH_3}{Rate\ of\ HI} = \frac{\sqrt{HI}}{\sqrt{NH_3}} = \frac{\sqrt{127}}{\sqrt{17}} = 2.74$$

# Sometimes Some Strange Scenarios

**Identify that the story is about how far gases travel – Graham's Law problem!**



# Real Gases

**Must correct ideal gas behavior when at high pressure (smaller volume) and low temperature (attractive forces become important).**

$$\left(P_{observed} + a\left(\frac{n}{V}\right)^2\right) \text{x} \left(V - nb\right) = nRT$$

**corrected pressure**

**Compared to $P_{ideal}$**

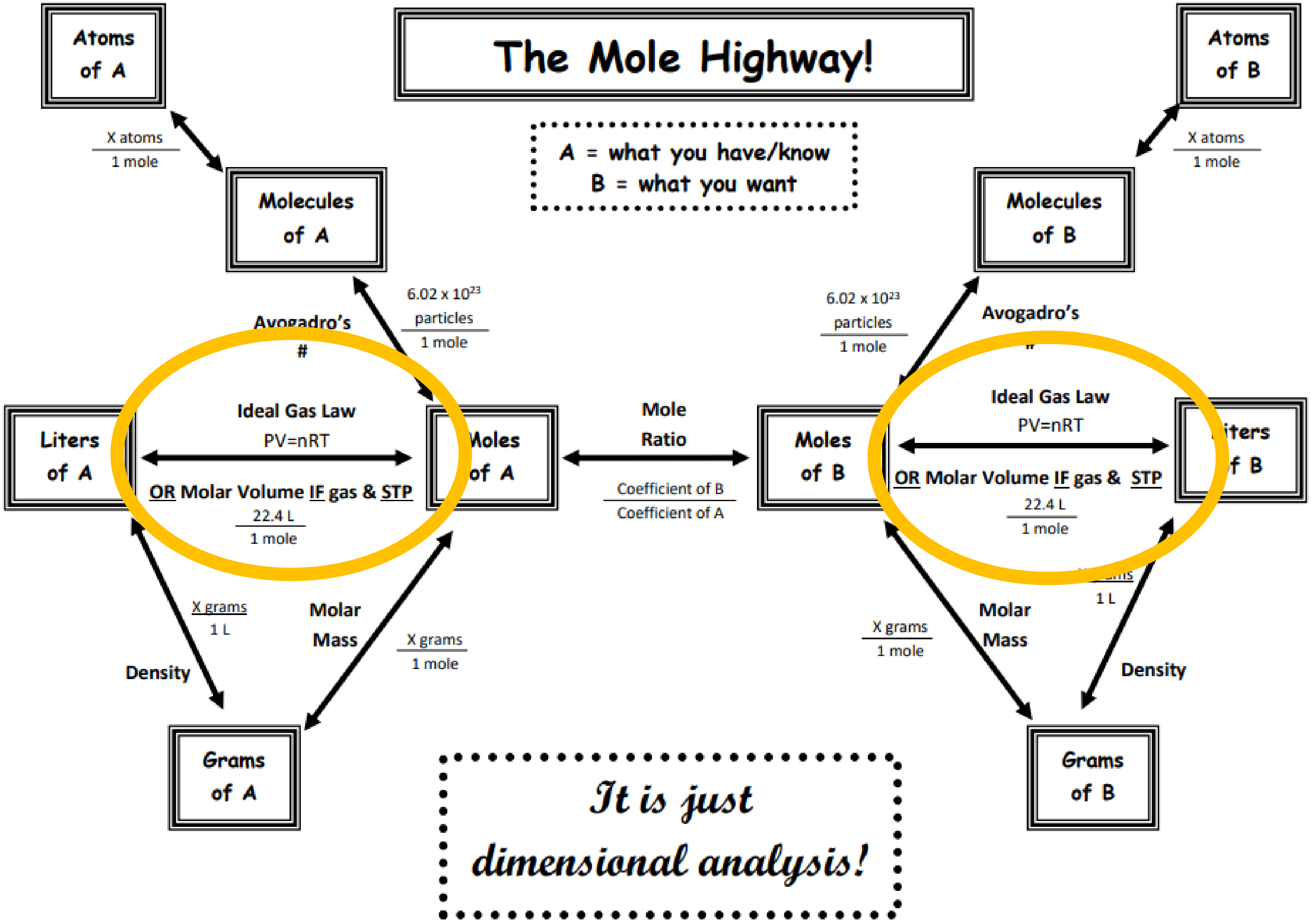
*Attractive forces in a real gas = less collisions*

**corrected volume**

**Compared to $V_{ideal}$**

*Real gases take up some volume since they are not "point particles"*

# Gas Stoichiometry

# Gas Stoichiometry Tips/Reminders

If reactants and products are at the same conditions of temperature and pressure, then mole ratios of *gases* are also **volume ratios.**

$$3\ H_2(g) \quad + \quad N_2(g) \quad \rightarrow \quad 2NH_3(g)$$

$$3 \text{ moles } H_2 \quad + \quad 1 \text{ mole } N_2 \quad \rightarrow \quad 2 \text{ moles } NH_3$$

***So how many liters of each?***

$$3 \text{ liters } H_2 \quad + \quad 1 \text{ liter } N_2 \quad \rightarrow \quad 2 \text{ liters } NH_3$$

# Gas Stoichiometry Tips/Reminders

How many liters of ammonia can be produced when 12 liters of hydrogen react with an excess of nitrogen?

$$3\,H_2(g) + N_2(g) \rightarrow 2NH_3(g)$$

$$\frac{12\ \text{L}\ H_2}{} \times \frac{2\ \text{L}\ NH_3}{3\ \text{L}\ H_2} = 8.0\ \text{L}\ NH_3$$

# Gas Stoichiometry Tips/Reminders

How many liters of oxygen gas, at STP, can be collected from the complete decomposition of 50.0 grams of potassium chlorate?

$$2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$$

| | | | |
|---|---|---|---|
| 50.0 g $KClO_3$ | 1 mol $KClO_3$ | 3 mol $O_2$ | 22.4 L $O_2$ |
| | 122.55 g $KClO_3$ | 2 mol $KClO_3$ | 1 mol $O_2$ |

= 13.7 L $O_2$

# Gas Stoichiometry Tips/Reminders

How many liters of $O_2$, at 37.0°C and 0.930 atm, can be collected from the decomposition of 50.0 g of $KClO_3$?

**2 $KClO_3$(s) → 2 KCl(s) + 3 $O_2$(g)**

| 50.0 ~~g KClO~~$_3$ | 1 ~~mol KClO~~$_3$ | 3 mol $O_2$ | = "n" mol $O_2$ |
|---|---|---|---|
| | 122.55 ~~g KClO~~$_3$ | 2 ~~mol KClO~~$_3$ | 0.612 mol $O_2$ |

$$V = \frac{nRT}{P} = \frac{(0.612 mol)\left(0.0821\frac{L\,atm}{K\,mol}\right)(310 K)}{0.930\ atm} = 16.7\ \text{L}$$

**YouTube Link to Presentation:**

https://youtu.be/bE5TiE4bDsQ