N27 – Gases

Gas Density and More

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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!

<u>Kinetic Energy of Gas Particles</u>

At the same conditions of temperature, all gases have the same <u>average</u> 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)

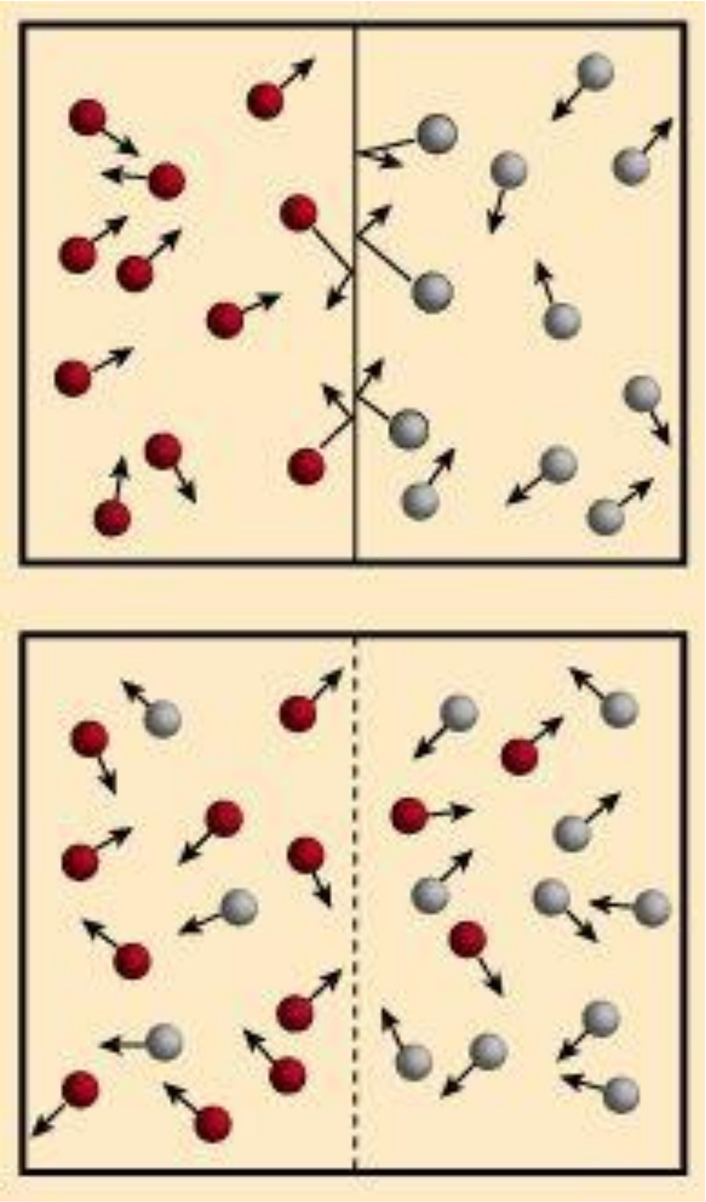
T = Kelvin Temperature

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

Diffusion

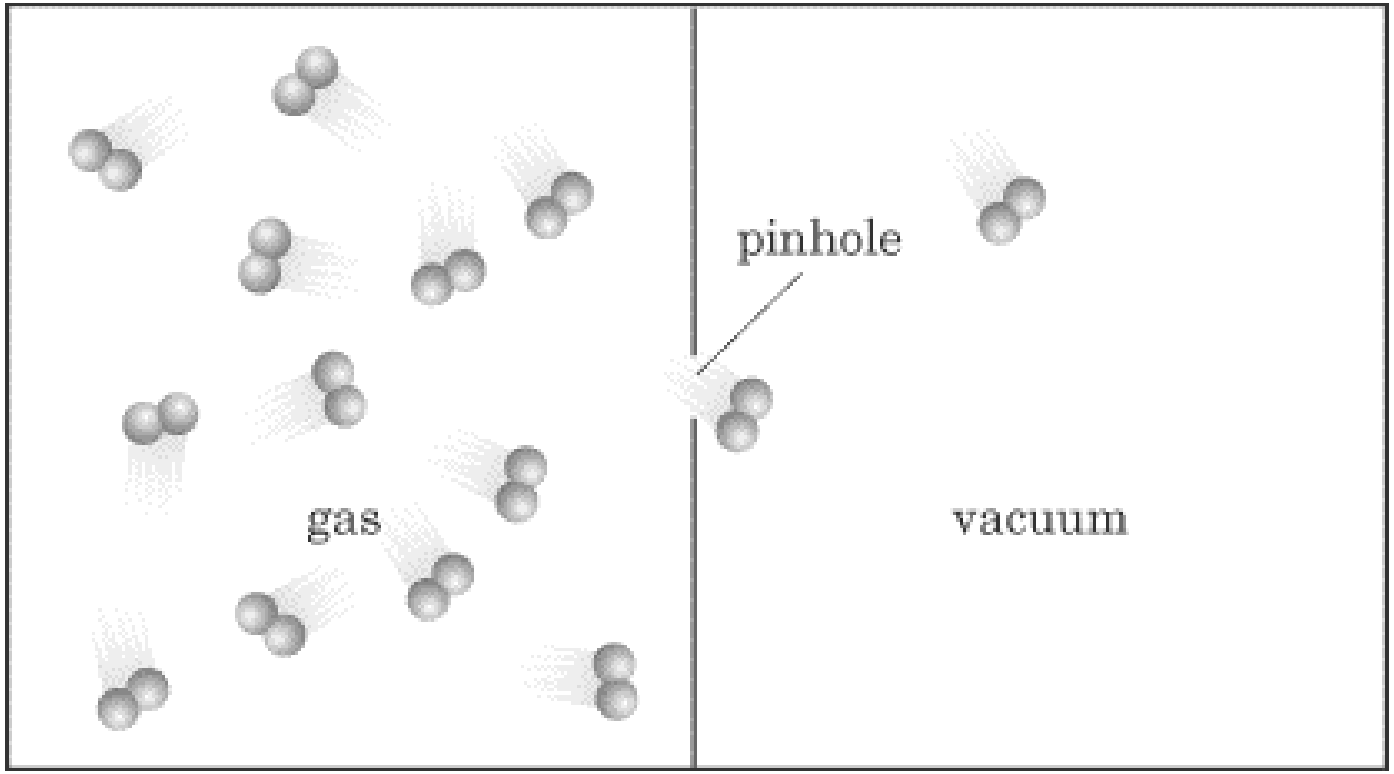
Diffusion describes the mixing of gases.

The rate of diffusion is the rate of gas mixing.

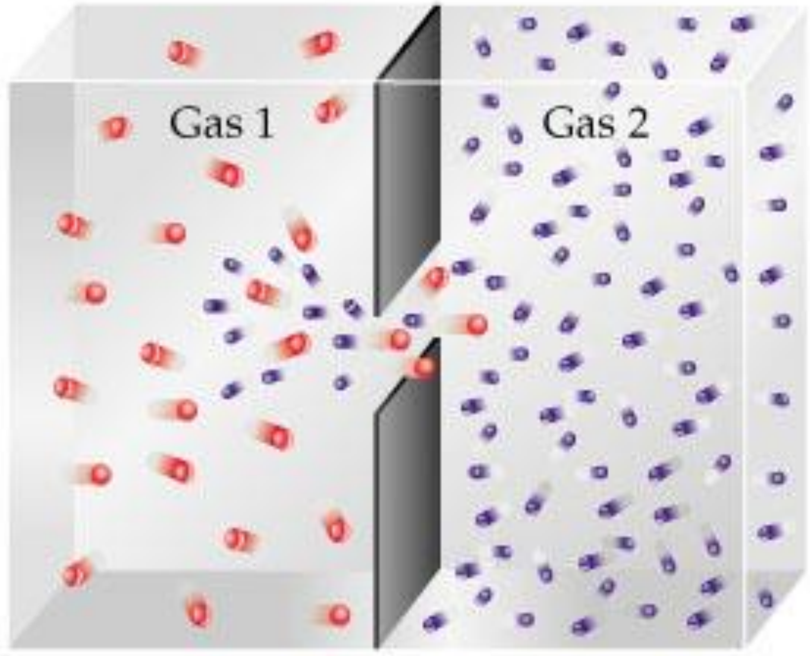


Effusion

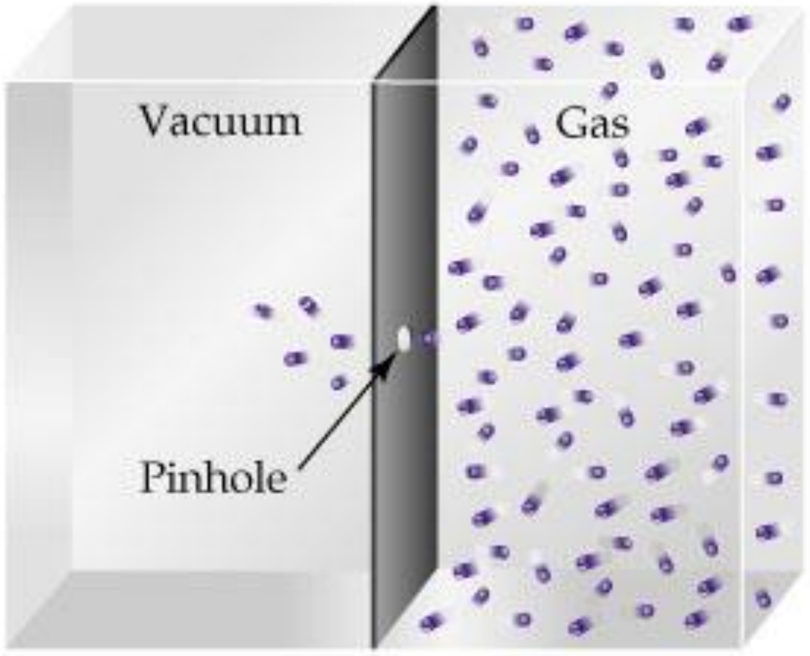
Effusion describes the passage of gas into an evacuated chamber.



Diffusion versus Effusion



Diffusion



Effusion

Graham's Law

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

Rate of Effusion:

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

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

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

Rate of Diffusion:

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

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

M = molar mass

Practice

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

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

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

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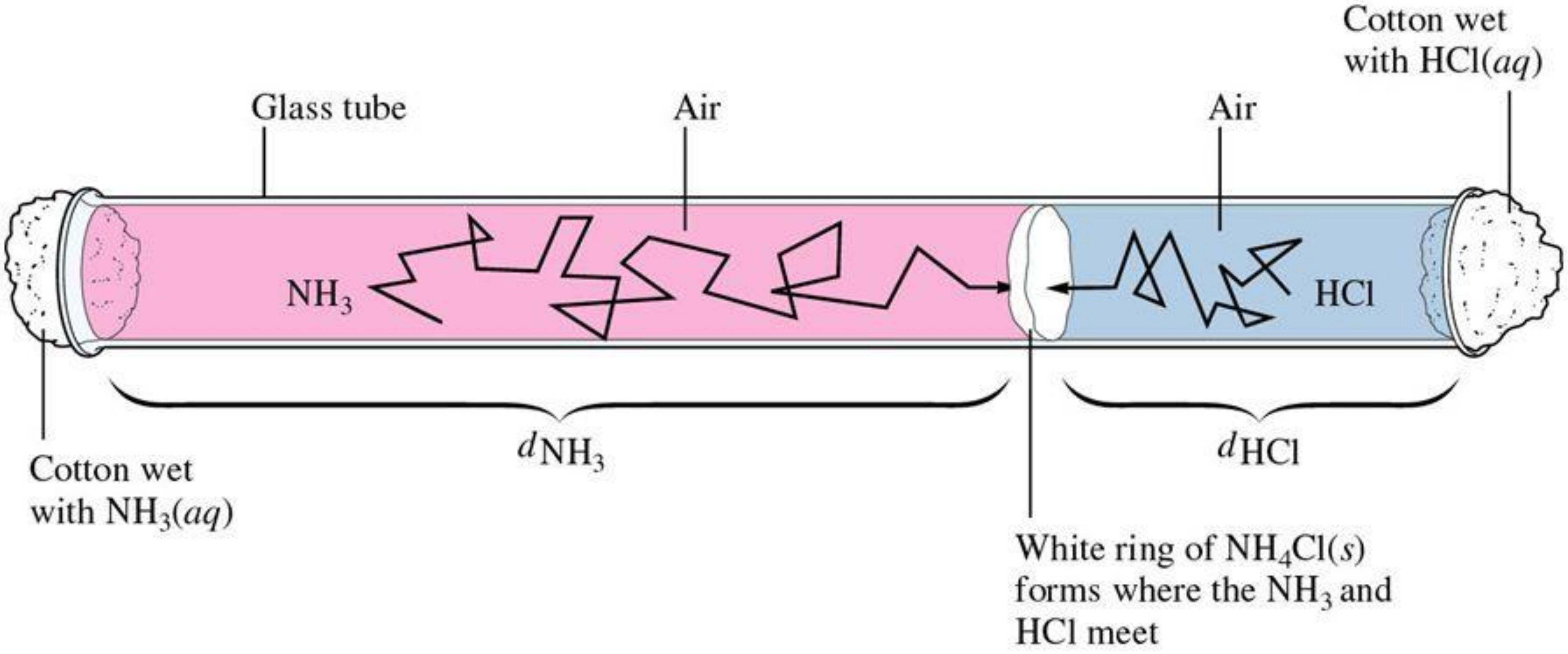
NH_3 effuses 2.74 times faster than HI

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}

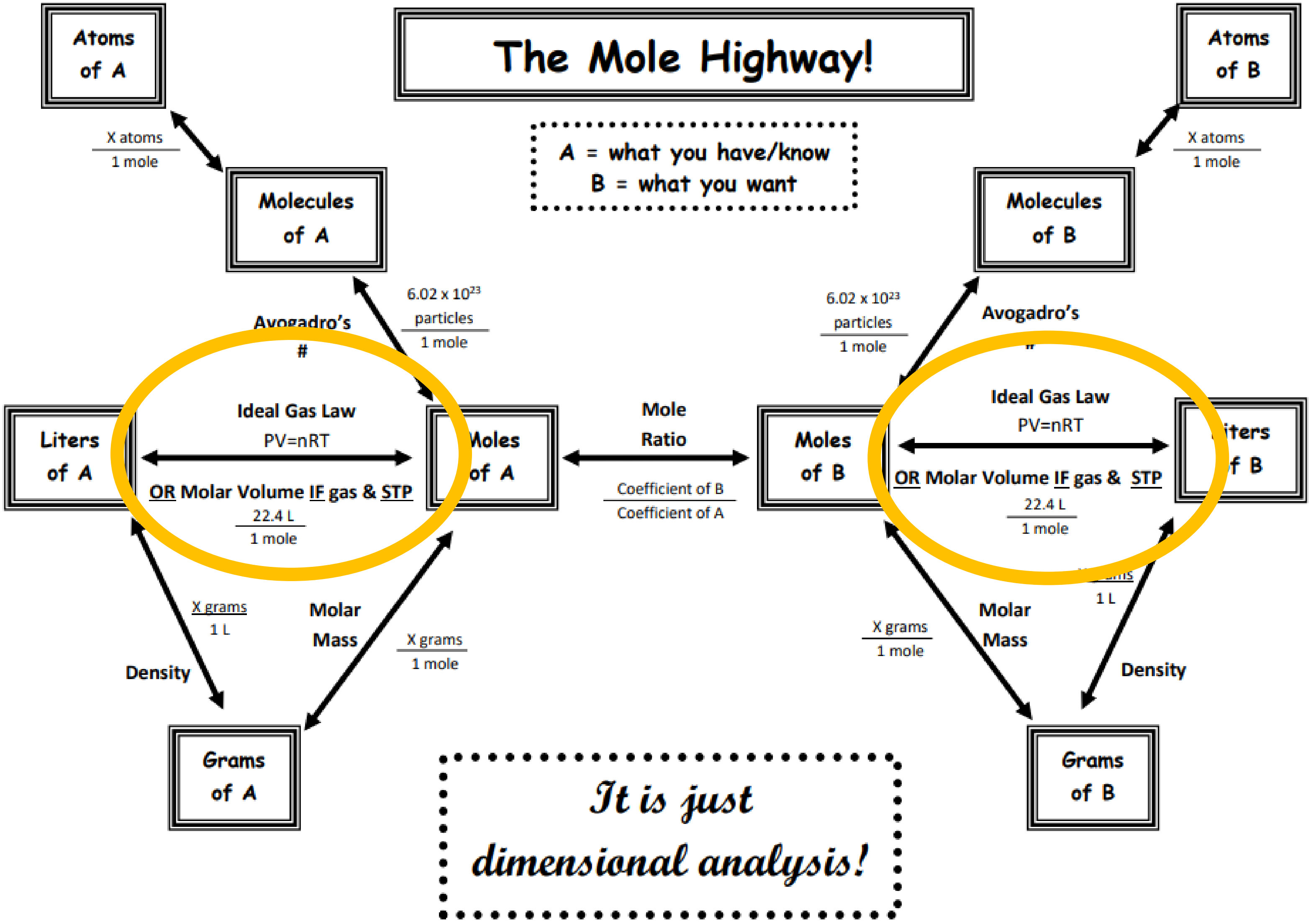
Attractive forces in a real gas = less collisions

corrected volume

Compared to V_{ideal}

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

Gas Stoichiometry



<u>Gas Stoichiometry Tips/Reminders</u>

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

$3\ H_2(g)$ + $N_2(g)$ → $2NH_3(g)$

3 moles H_2 + 1 mole N_2 → 2 moles NH_3

So how many liters of each?

3 liters H_2 + 1 liter N_2 → 2 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?

$$\underline{3}\ H_2(g) + N_2(g) \rightarrow \underline{2}NH_3(g)$$

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

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 $KClO_3$?

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

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

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

YouTube Link to Presentation:

https://youtu.be/bE5TiE4bDsQ