# Announcements for Monday, 25NOV2024

- Students requiring **ODS accommodations** for Exam 3 and the Final Exam
  - **Today** is the deadline to submit requests for final exams and all remaining exams for the Fall semester
- Week 12 Homework Assignments available on eLearning
  - Graded and Timed Quiz 11 – “Thermochemistry” due **tonight at 6:00 PM (EST)**
- **This Week: Changes in Designation of Class Days**
  - There **ARE** recitations this week
  - Tomorrow, 26NOV2024, is ***Thursday Classes***
  - Wednesday, 27NOV2024, is ***Friday Classes***
- Thanksgiving Break
  - Thursday, 28NOV2024 – Sunday, 01DEC2024
  - No classes for the entire university

**ANY GENERAL QUESTIONS?** Feel free to see me after class!

# Try These On Your Own

- A deep-sea diver exhales a 15.0-mL bubble of air at a depth where the pressure is 12.0 atm and the temperature is 8.0 °C. What is the volume of the bubble at the surface, where the atmospheric pressure is 770 torr and the temperature is 20.0 °C? **185 mL**

- A sample of gas at 100 °C and 1.05 atm occupies a volume of 825 mL. To what temperature must the gas be brought so that it occupies a volume of 1.50 L at 0.985 atm? **363 °C (636 K)**

- A 10.00-g sample of $CH_4$(g) initially at a pressure of 888 Torr and occupying a rigid container with a constant volume is heated from 62 °C to 458 °C. What mass of methane needs to be removed to maintain a constant pressure within the container? **5.42 g**

# Try This On Your Own

8.0 g of $CH_4$(g) is added to a rigid container at 0 °C and exerts a pressure of 650 torr. An amount of $O_3$(g) is added to the container, causing the pressure to increase to 2600 torr. What mass of $O_3$(g) was added? **72 g**

$$PV = nRT \xrightarrow[\text{variable P \& n}]{\text{constant V \& T}} \frac{P}{n} = \frac{RT}{V} = \text{constant} \Longrightarrow \frac{P_1}{n_1} = \frac{P_2}{n_2}$$

$$8.0 \text{ g CH}_4 \times \frac{1 \text{ mol CH}_4}{16.04 \text{ g}} = 0.50 \text{ mol gas} = n_1$$

$$650 \text{ torr} = P_1$$

$$2600 \text{ torr} = P_2$$

$$n_2 = \frac{P_2 n_1}{P_1} = \frac{(2600 \text{ torr})(0.50 \text{ mol})}{650 \text{ torr}} = 2.00 \text{ mol gas } \mathbf{Total} \text{ (i.e., initial gas + added gas)}$$

$$\text{moles of O}_3 \text{ added} = 2.00 \text{ mol Total} - 0.50 \text{ mol initial} = 1.5 \text{ mol O}_3 \text{ added}$$

$$1.5 \text{ mol O}_3 \times \frac{48.0 \text{ g}}{1 \text{ mol O}_3} = \mathbf{72 \text{ g O}_3 \text{ added}}$$

# Try These On Your Own

- A 10.0-L cylinder contains 55.0 g $CO_2(g)$ at a temperature of 325 °C. What is the pressure (in atm) within the cylinder? **6.13 atm**

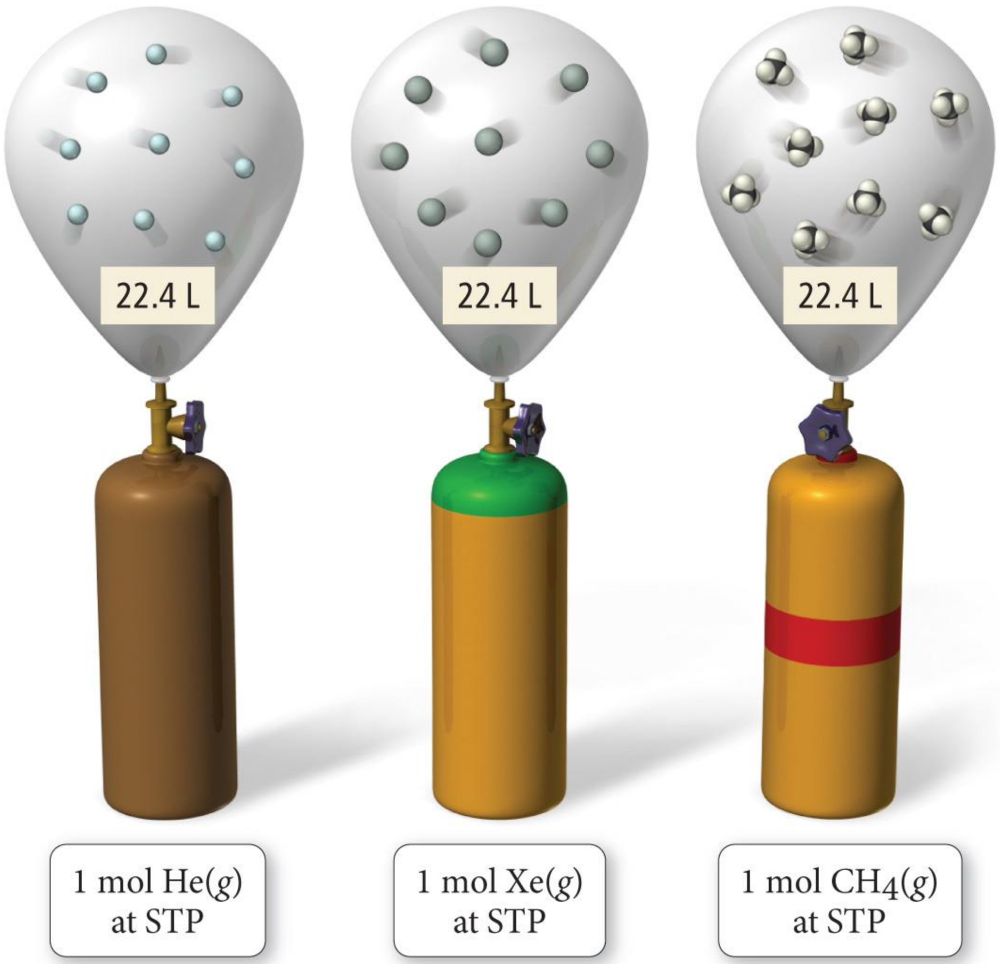
- What mass of $NH_3(g)$ will exert the same pressure as 12 mg of $H_2S(g)$ in the same container under the same conditions? **6.0 mg**

- How many gas particles are in a bedroom measuring 3.65 m × 3.05 m × 2.40 m at room temperature (25 °C) and standard atmospheric pressure (1.0 atm)? **$6.6 \times 10^{26}$ particles**

# Going Beyond PV = nRT

other gas properties can be calculated from the ideal gas law by making mathematical substitutions and rearrangements

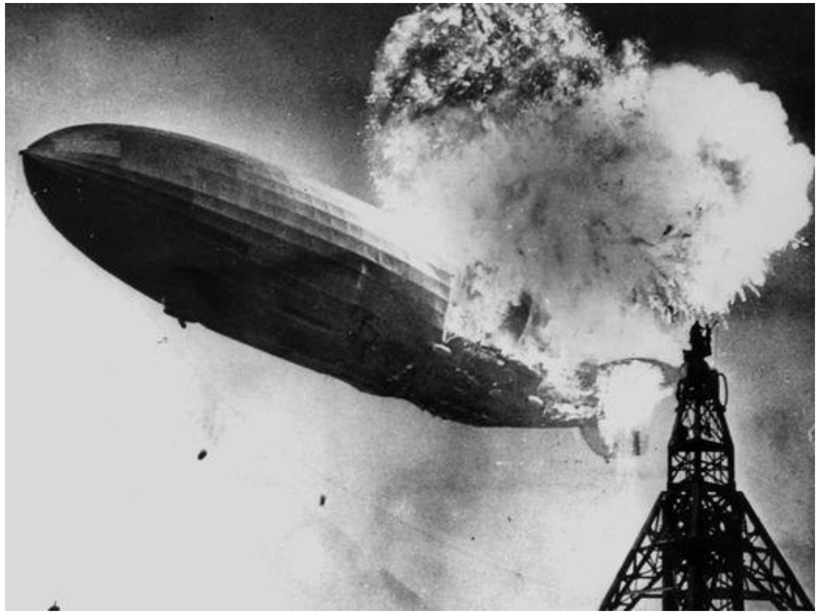
1. **Molar Volume =** the volume occupied by 1 mole of gas at specific temperature and pressure
   - Standard Temperature and Pressure (STP) = 0 °C (273.15 K) and 1.0 atm
   - for an ideal gas **at STP**, the molar volume is…
   - this is one way we can tell that a gas is behaving ideally
   - molar volume is ***independent*** of gas identity



# Going Beyond PV = nRT

## 2. **Gas Density (d) =** mass of gas per unit volume

- $\mathrm{d} = \dfrac{\mathrm{P}\mathcal{M}}{\mathrm{RT}}$
- for gases, density is usually given in g/L
- gases with molar masses less than that of air ($\sim$ 28.8 g/mol) tend to rise in air
  - balloons filled with He or $H_2$ float



# Try This

The density of sulfur vapor at 445 °C and 755 mmHg is 4.33 g/L. What is the molecular formula of sulfur vapor? **$S_8$ (256 g/mol)**

$$P = 755\ \mathrm{mmHg} \times \frac{1\ \mathrm{atm}}{760\ \mathrm{mmHg}} = 0.9934\ \mathrm{atm} \qquad T = 445 + 273 = 718\ \mathrm{K}$$

$$d = \frac{P\mathcal{M}}{RT} \longrightarrow \mathcal{M}\ \text{of}\ S_x = \frac{dRT}{P} = \frac{(4.33\ \mathrm{g/L})\,(0.08206\ \mathrm{L \cdot atm/mol \cdot K})(718\ \mathrm{K})}{0.9934\ \mathrm{atm}}$$

$$\mathcal{M}\ \text{of}\ S_x = 256\ \ \mathrm{g/mol}$$

$$x = \frac{256\ \mathrm{g/mol}}{32\ \mathrm{g/mol}} = 8$$

# Try These On Your Own

- The oil produced from eucalyptus leaves contains the volatile organic compound eucalyptol. At 190. °C, a sample of eucalyptol vapor had a density of 0.400 g/L and a pressure of 60.0 torr. Calculate the molar mass of eucalyptol.

- 50.0 g of an unknown gas occupies a volume of 7.686 L at STP. Identify the unknown gas from the following: He, Ne, Ar, Xe, HI, or $SF_6$?

- Consider a balloon filled with helium at 27 °C at atmospheric pressure. To what temperature should the helium be brought to cause an increase in density by a factor of 1.5?

# Properties of Gas Mixtures

- gas samples are usually impure and contain other gaseous impurities
- dry air is a mixture of gases
- working with gas mixtures requires that we work with each component individually
  - gases within a mixture behave independently of one another
  - the pressure exerted by a particular component in a gas mixture would be the same as if the component was by itself

**TABLE 10.2 Composition of Dry Air**

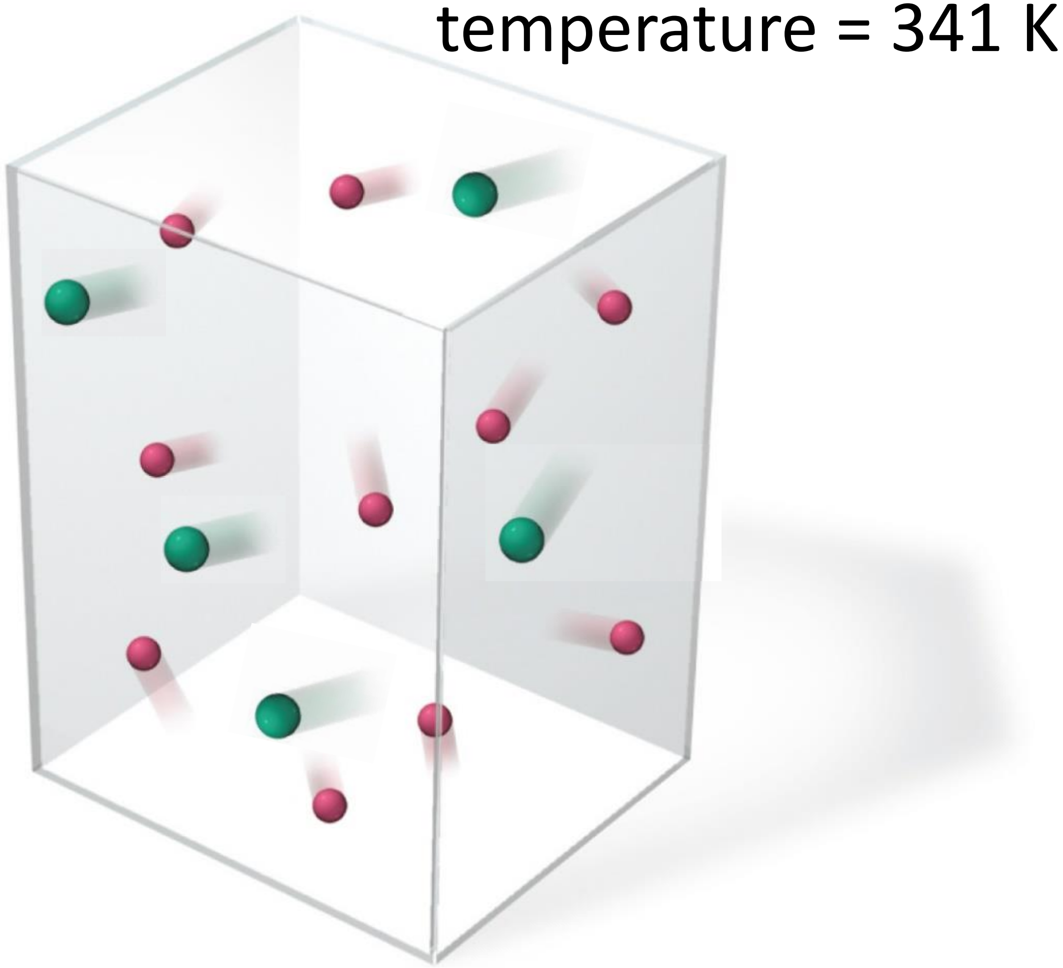
| Gas | Percent by Volume (%) |
|---|---|
| Nitrogen ($N_2$) | 78 |
| Oxygen ($O_2$) | 21 |
| Argon (Ar) | 0.9 |
| Carbon dioxide ($CO_2$) | 0.04 |

# Pressure of Gas Mixtures

consider the following scenario

- container at constant volume and temperature
- a mixture of two gases
  - 5 moles gas A 
  - 10 moles gas B 

**container**
volume = 70. L
temperature = 341 K



What is the ***total*** pressure within the container?

What is the ***pressure of each component*** in the mixture?

How is partial pressure of each component related to the amount (in moles) of each component?

# Total Pressure of the Gas Mixture

**PV = nRT**

$$P_{total} = \frac{n_{total}RT}{V}$$

$$= \frac{(15\ \text{mol})(0.08206\frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}})(341\ \text{K})}{70.\ \text{L}}$$

$$P_{total} = 6.0\ \text{atm}$$

$P_{total}$ depends *only* on the total amount of gas particles and NOT on their individual identities

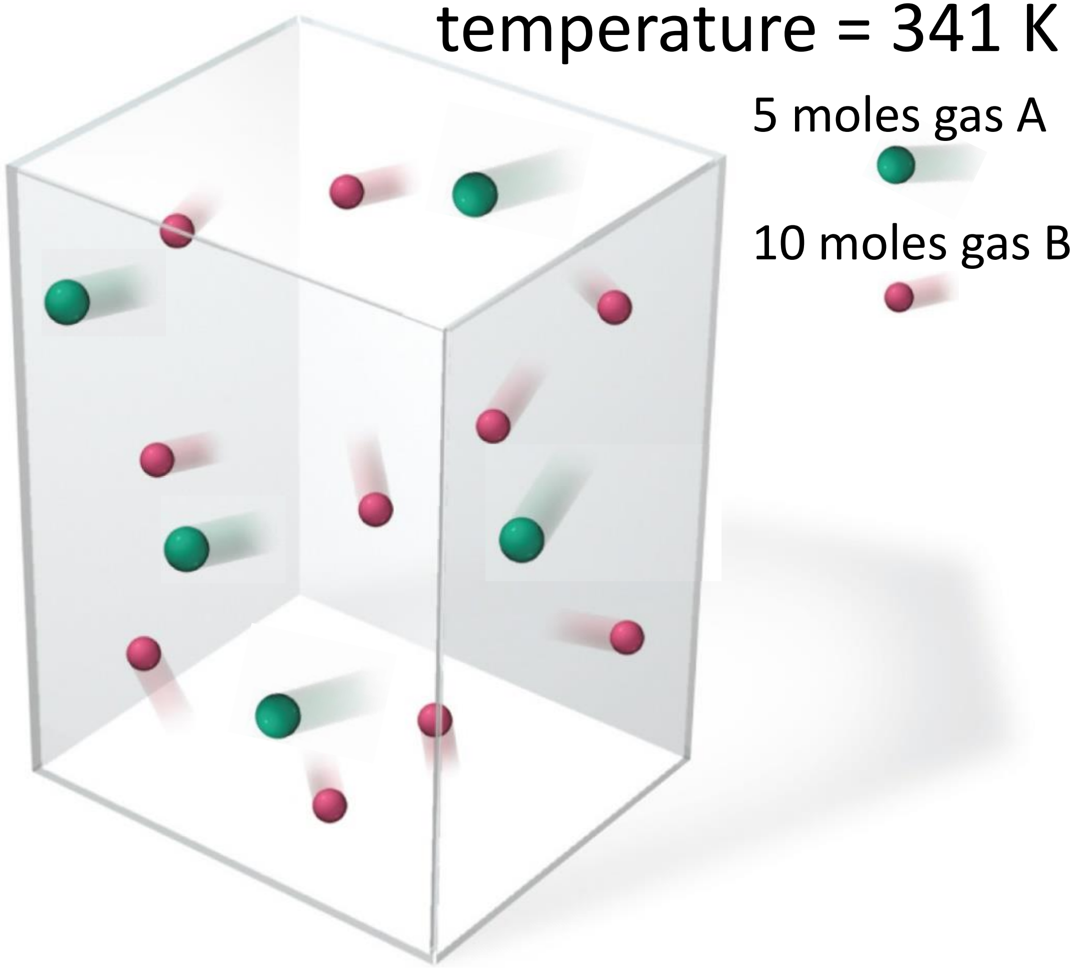
**<u>container</u>**

volume = 70. L

temperature = 341 K

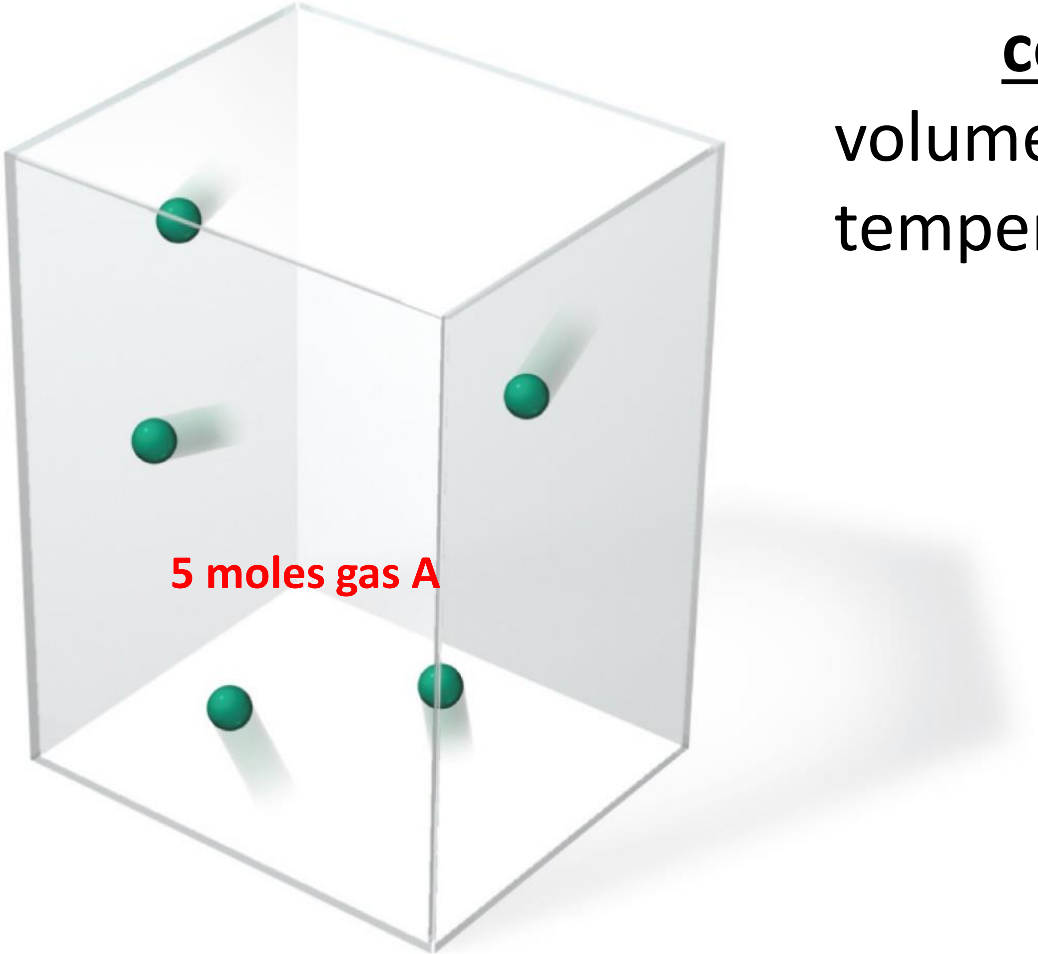
5 moles gas A

10 moles gas B



# Partial Pressures of Each Component

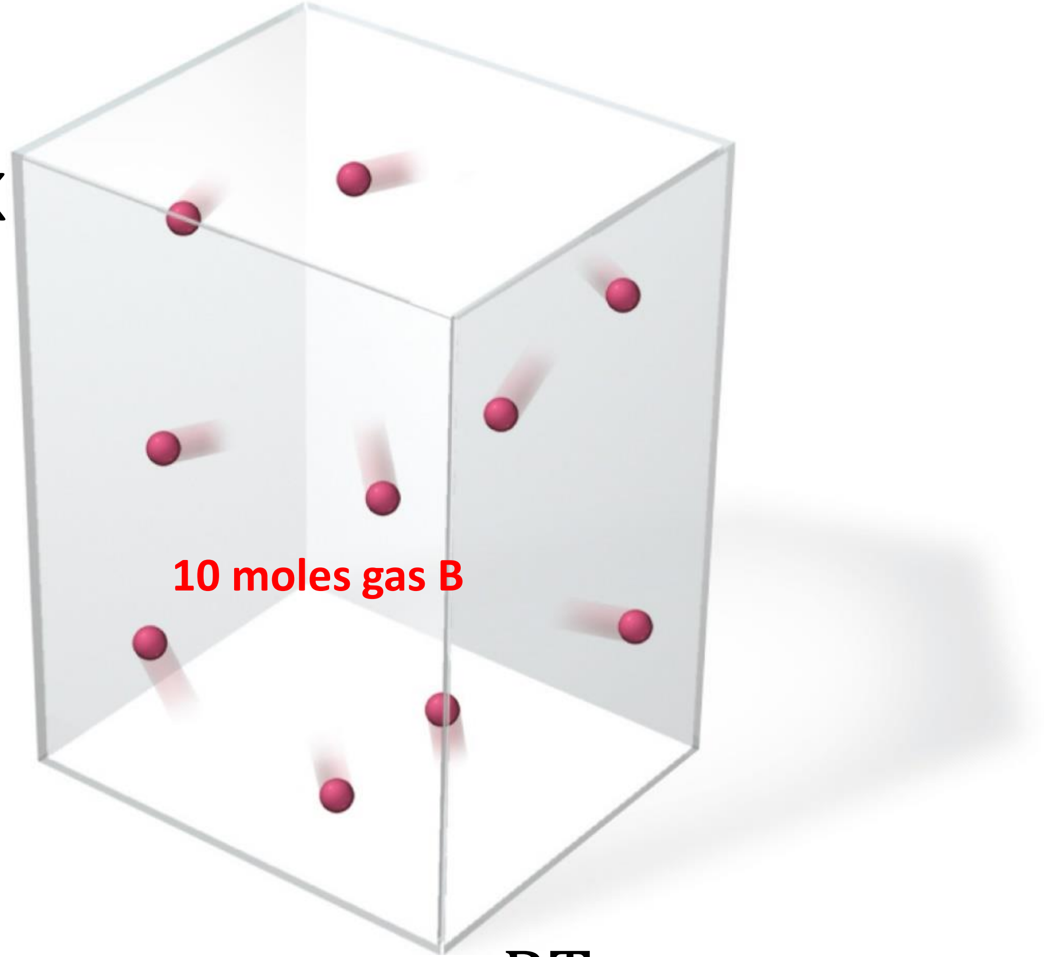
- we can treat each component separately




**<u>container</u>**

volume = 70. L

temperature = 341 K




$$P_{\text{gas A}} = \frac{n_{\text{gas A}} RT}{V} = 2.0 \text{ atm}$$

$$P_{\text{gas B}} = \frac{n_{\text{gas B}} RT}{V} = 4.0 \text{ atm}$$

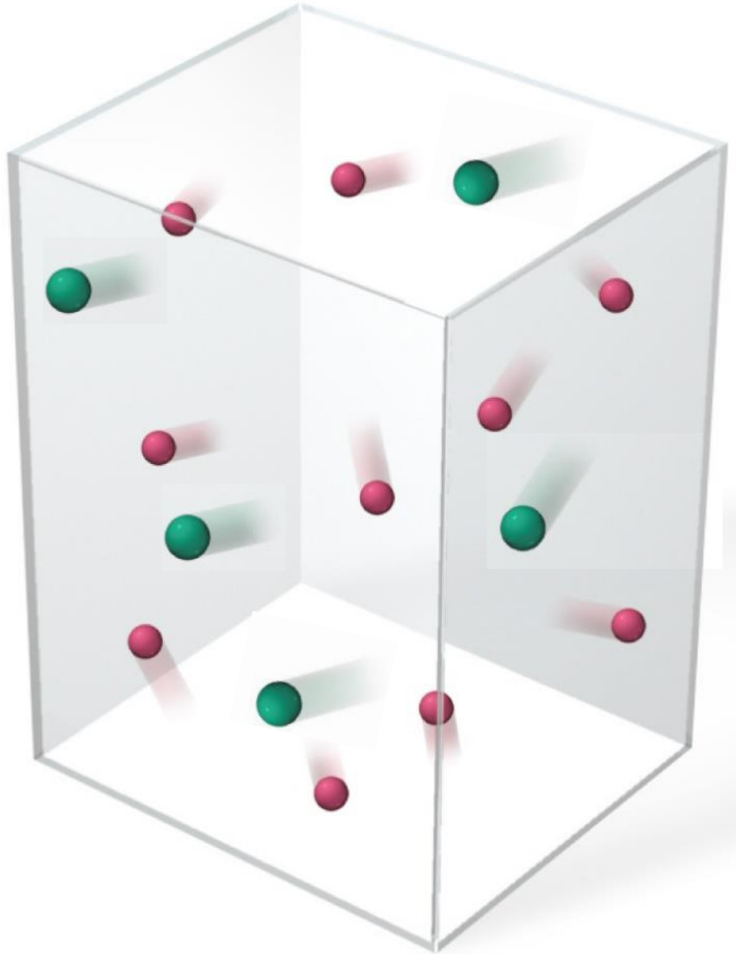
# Partial Pressure vs. Amount

the partial pressure of a component only depends on its relative amount within the mixture

**mole fraction (χ)** = gives the relative amount of each component within a mixture

$$\chi_{gas\,A} = \frac{n_A}{n_{total}} \qquad \chi_{gas\,B} = \frac{n_B}{n_{total}}$$

$$P_{gas\,A} = \chi_{gas\,A}\,P_{total} \qquad P_{gas\,B} = \chi_{gas\,B}\,P_{total}$$



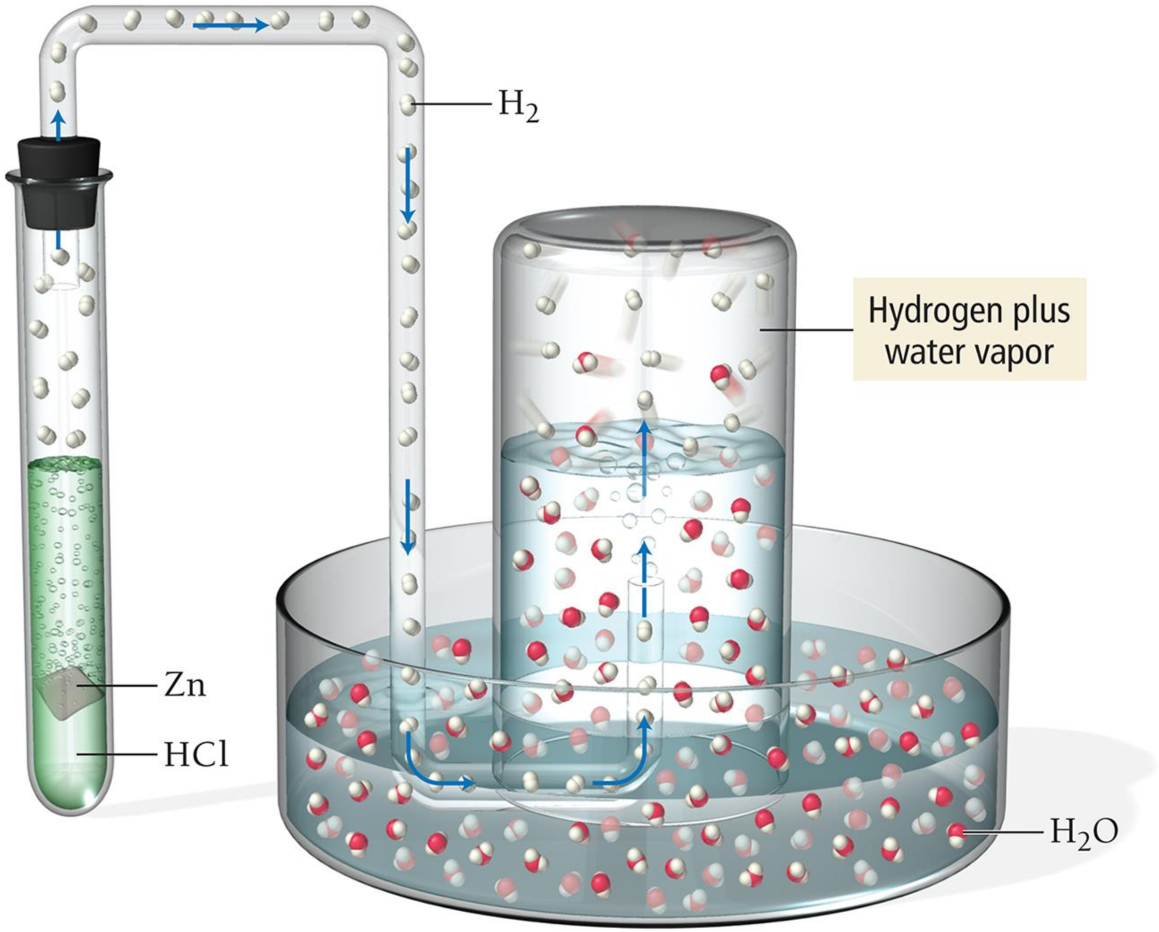
$P_{gas\,A} + P_{gas\,B} = P_{total}$

2.0 atm + 4.0 atm = 6.0 atm

**Dalton's Law of Partial Pressures**

# Collecting Gases over Water

- a common laboratory technique used for gaseous products
- gases generated from a reaction are collected over water
  - $Zn(s) + 2\ HCl(aq) \longrightarrow H_2(g) + ZnCl_2(aq)$
- the total pressure ($P_{total}$) over the water is due to a ***mixture of gases***
  - $P_{gas}$ = pressure of the generated gas
  - $P_{water}$ = the partial pressure of water at a given temperature (i.e., the vapor pressure of water)






$$P_{total} = P_{gas} + P_{water}$$

# Vapor Pressure of Water

**vapor pressure =** pressure exerted on the surface of a liquid by its vapor

- vapor pressure increases with increasing temperature
  - higher temperature = more evaporation of liquid = higher vapor pressure
- when vapor pressure equals atmospheric pressure, the liquid boils

**TABLE 10.3 Vapor Pressure of Water versus Temperature**

| Temperature (°C) | Pressure (mmHg) | Temperature (°C) | Pressure (mmHg) |
|---|---|---|---|
| 0 | 4.58 | 55 | 118.2 |
| 5 | 6.54 | 60 | 149.6 |
| 10 | 9.21 | 65 | 187.5 |
| 15 | 12.79 | 70 | 233.7 |
| 20 | 17.55 | 75 | 289.1 |
| 25 | 23.78 | 80 | 355.1 |
| 30 | 31.86 | 85 | 433.6 |
| 35 | 42.23 | 90 | 525.8 |
| 40 | 55.40 | 95 | 633.9 |
| 45 | 71.97 | 100 | 760.0 |
| 50 | 92.6 | | |

# Try This On Your Own

A mixture of $CO_2$(g) and $O_2$(g) that is 60.0% carbon dioxide by mass exerts a pressure of 894 torr at 25 °C.  What percentage of the total pressure is due to the partial pressure of the oxygen gas?

# Try These On Your Own

- A container holds equal masses of He, $CO_2$, and Ar. The pressure within the container at 156 °C is 18.4 atm. What is the partial pressure of Ar?

- In the reaction of Zn with excess HCl(aq), 0.010 mol $H_2(g)$ was collected over water at 25 °C and a total pressure of 802.8 mmHg. What volume of hydrogen gas was collected? The vapor pressure of water at 25 °C is 23.78 mmHg.

- At 2730 °C, hydrogen molecules dissociate into hydrogen atoms according to the equation $H_2(g) \rightarrow 2\ H(g)$. 10.0 g $H_2(g)$ is placed into a 100.0-L container, sealed and heated to 2730 °C so that the hydrogen molecules begin to dissociate. What is the partial pressure of hydrogen molecules and the total pressure within the container once 25% of $H_2$ has dissociated?