Chapter 12

States of Matter

Warm Up

- What are some properties of gases?

- How do gases differ from liquids and solids?

Today's Agenda

- QOTD: How can we account for the behavior of gases?

- Kinetic Molecular Theory and how it relates to behavior
- Graham's Law
- Dalton's Law

- Homework due Wednesday: Ch 12 34-50 evens

Gases

- It’s easy to distinguish certain metals
  - Physical appearance like color, shape

- Gases are tricky because you can’t see them or evaluate their appearance. Scientists wanted to figure out a way to study properties of gases and why they are so different from the other states of matter.

Kinetic – Molecular Theory

- Kinetic – to move
  - Objects in motion have kinetic energy

- Kinetic – molecular theory describes properties in terms of their motion.

- We can study gases based on how their particles move!

Gas Particles…

- Size – small and they are usually _far apart_ from one another. No forces holding them together!

- Motion – constantly randomly moving! Move in straight line until they collide.
- No energy is lost when gas particles collide - _elastic_ collision
  - SIMULATION! http://phet.colorado.edu/en/simulation/gas-properties

Kinetic Energy and Temperature

- Kinetic energy depends on mass and velocity!

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

in a gas all particles have the same mass but different velocity.

Temperature – measure of the average kinetic energy of the particles in a sample of matter

Behavior

- Now we know some basics about gas particles we can explain their behavior.

- Low density – d = m/v
  - Remember that gas particles are far apart and small, so less of them take up a large volume.
- Compression – all that space between particles makes it easy to squeeze and reduce volume. (foam ball or pillow)

Behavior

- Diffusion– gases can travel and mix together easily (no stirring like with liquids) until they are evenly mixed.
- Effusion – gases can escape through tiny openings.
  - Nail in a tire – air gradually escapes.
- Graham's law of effusion – larger the mass the slower a gas is to escape through an opening.

Graham's Law

- Lighter particles move faster than heavier particles.
- Remember KE = ½ mv^2

different gases have different masses, lighter particles have greater velocity.

$$\frac{\text{Velocity}_{\text{gasA}}}{\text{Velocity}_{\text{gasB}}} = \sqrt{\frac{\text{molar mass}_{\text{gasB}}}{\text{molar mass}_{\text{gasA}}}}$$

Graham's Law Practice

- Ammonia gas a molar mass of 17 g/mol; hydrogen chloride has a molar mass of 36.5 g/mol. What is the ratio of their diffusion rates?

- Use grahams law!

$$\frac{\text{Rate}_{NH_3}}{\text{Rate}_{HCl}} = \sqrt{\frac{36.5 \text{ g/mol}}{17 \text{ g/mol}}} = 1.47$$

Use Grahams Law

- Calculate the ratio of effusion rates for nitrogen gas and neon. (Remember what's special about nitrogen)!

- Calculate the ratio of diffusion rates for carbon monoxide and carbon dioxide.

Gas Pressure

- Pressure – force per unit area
  - P = F/A

- When gas particles collide, that _increases_ the _pressure_ inside a container. (The more particles, the more collisions, and the higher the pressure!!)

Atmospheric Pressure

- The more air particles, the more collisions, and the more pressure.

- Earth has _____ and causes more air particles to be closer to the earth's surface.

gravity

On mountains or up in airplanes, pressure is less because there are less air particles.

At sea level, atmospheric pressure is 1 kg/cm^2.

Warm Up

- In an experiment, nitrogen gas effuses at a rate of 50 mol/s and an unknown gas effuses at 25 mol/s. What is the molar mass of the unknown gas?

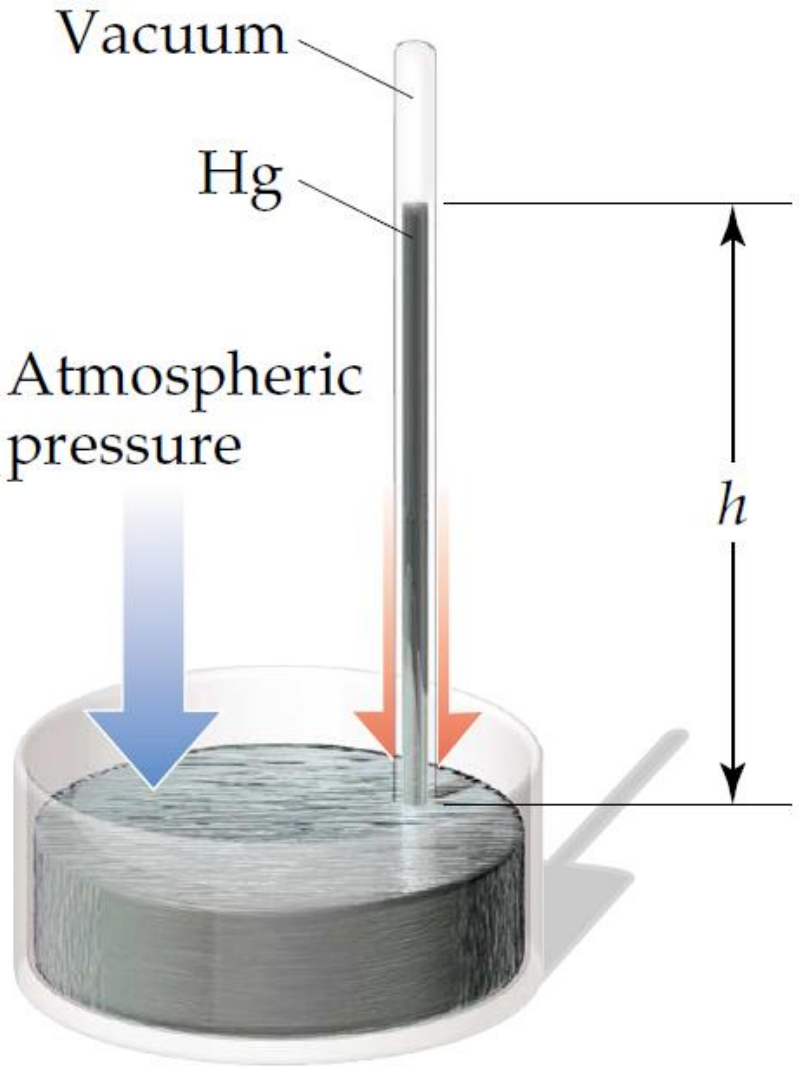
Today's Agenda

- QOTD: How can you use total pressure to find the partial pressure of a gas in a mixture?

- Units of pressure
- Dalton's Law of Partial Pressure
- Intermolecular Forces

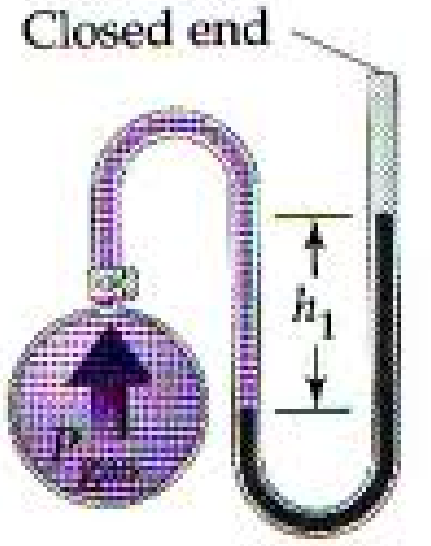
- Quiz next Tuesday – Ch 12.1, 12.2, 12.4

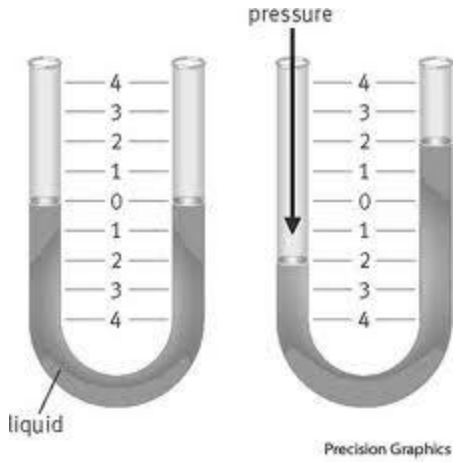
The Barometer



- Torricelli designed the first barometer to measure atmospheric pressure.
- Gravity forces down on Hg, but air pressure forces Hg up the tube.
- Changes and air temperature and humidity cause variations. Why?

Manometer





- Measures gas pressure in a closed container. The pressure of a gas is measured by how far up the tube the liquid is forced to go!

Since we're talking about pressure…

- Remember this…

I told you not to worry about these yet….

Well now it's time to talk about units of pressure! YAY!

Mass (g) ⇄ **Mole** ⇄ **Volume (L)**

x MM g/mol

÷ MM g/mol

x 22.4 L/mol

÷ 22.4 L/mol

of a gas at STP
T = 273K. 0 °C
P = 1 atm,
760 mmHg
101 KPa

x 6.022 x 10^{23} count/mol

÷ 6.022 x 10^{23} count/mol

Count

(particles, molecules, atoms, formula units(F.U.))

Units of Pressure

- Pascals (Pa) **SI unit** (named after Blaise Pascal)

1Pa = 1 N/m^2 (remember P = F/A)

- psi (pressure per square inch) – engineers
- mmHg (millimeters of mercury) torr, and bar – barometers and manometers
- atm (atmospheres) - air pressure

Conversions for Pressure Units

1 atm = 101.3 kPa = 760 mmHg = 760 torr

1 atm = 14.7 psi = 1.01 bar

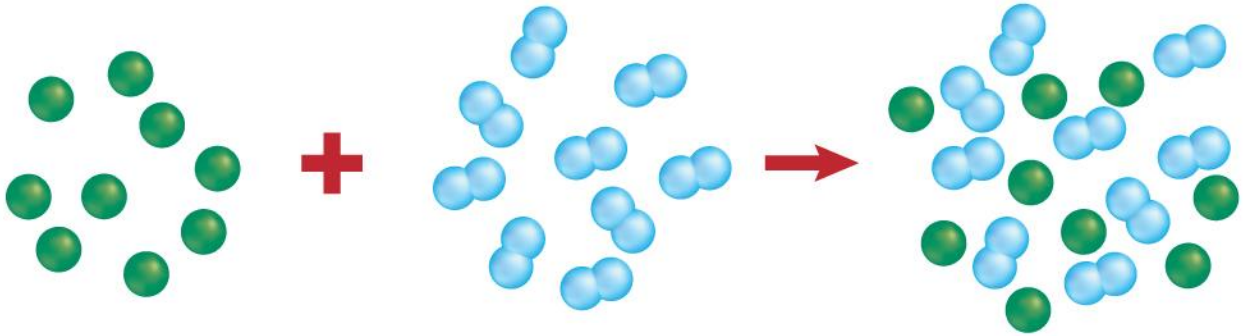
all of these units can be converted to one another using 1 atm.

Usually chemists talk about atm, mmHg/torr, and sometimes kPa…

Dalton's Law of Partial Pressures

Each gas has it's own pressure associated with it depending on moles, volume, and temp (not type) but any mixture (air) as a whole has a combined pressure of all the gases!

$$P_{total} = P_1 + P_2 + P_3 + \ldots P_n$$



Dalton's Law Problem

- A mixture of O_2, carbon dioxide, and N_2 has a total pressure of 0.97 atm. What is the partial pressure of O_2 if the partial pressure of CO_2 is 0.70 atm and the partial pressure of N_2 is 0.12 atm.

- We are given the total pressure (P_t) , and two partial pressures (P_{CO2}, and P_{N2}). We need to find the remaining partial pressure of O_2.

Daltons Law Problem

$$P_{total} = P_{N2} + P_{CO2} + P_{O2}$$

Rearrange to solve for P_{O2}

$$P_{O2} = P_{total} - P_{N2} - P_{CO2}$$

Plug in values

$$P_{O2} = 0.97 \text{ atm} - 0.70 \text{ atm} - 0.12 \text{ atm}$$

$$P_{O2} = 0.15 \text{ atm}$$

Your Turn

- What is the partial pressure of hydrogen gas in a mixture of hydrogen and helium if the total pressure is 600 mm Hg and the partial pressure of helium is 439 mm Hg?

- Find the total pressure for a mixture that contains four gases with partial pressures of 5 kPa, 4.56 kPa, 3.02 kPa, 1.20 kPa.

Measuring Gases over Water

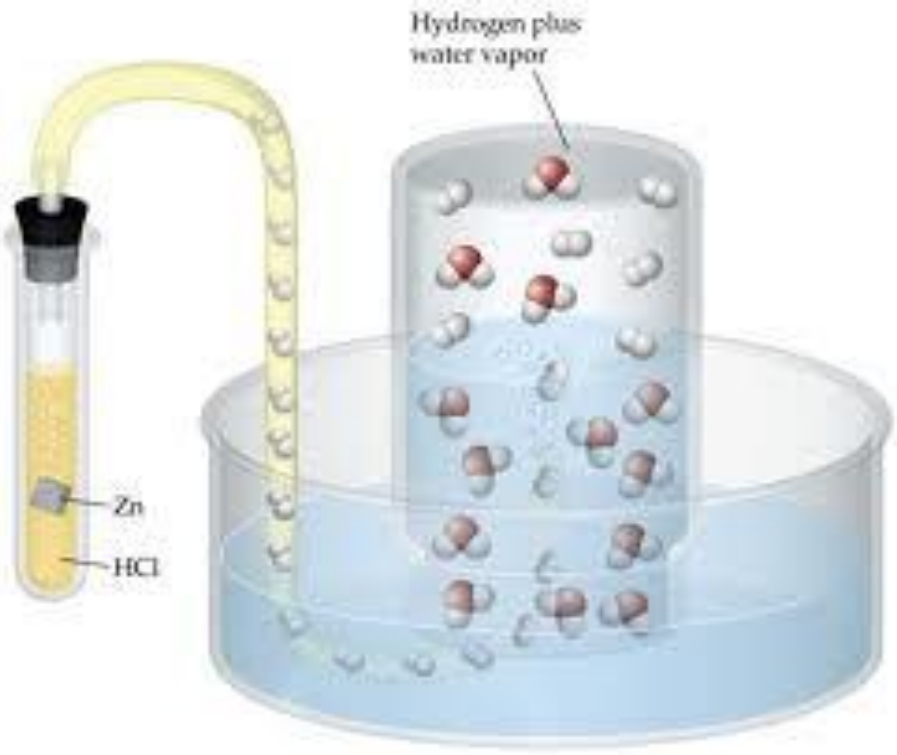
The product of a reaction is a gas.

This gas is collected in a beaker by displacing water.

The gas collected will be a mixture of water vapor ($H_2O_{(g)}$) and H_2 gas.

You can use Dalton's law to find the partial pressure of H_2!

$Zn + 2\ HCl \rightarrow ZnCl_2 + H_2$



Challenge Problems

- 36g of water vapor takes 250s to effuse out of a container. How many grams of O_2 will effuse out of the same container in 400s? (HINT: convert grams to moles and find rate in mol/s)

- Air is a mixture of gases. It is roughly 78% N_2, 21 % O_2, and 1% Ar. If the atmospheric pressure is 780 mmHg, what are the partial pressures of each gas?

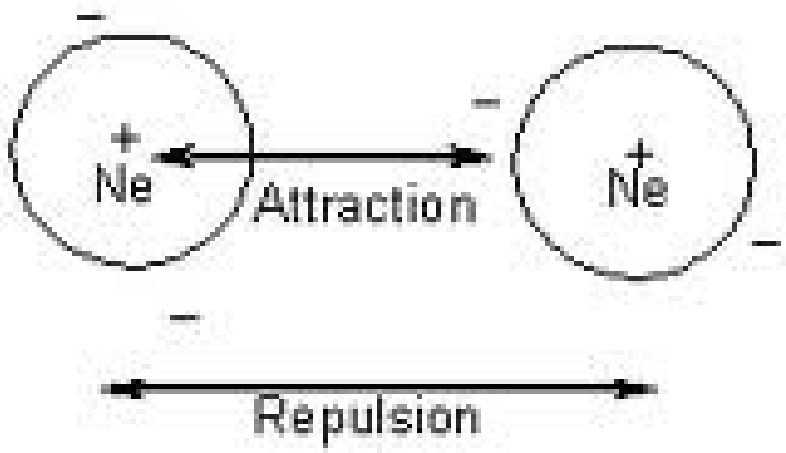
Section 12.2 – Forces of Attraction

- Intermolecular forces – attraction within and between particles. Forces that hold molecules of liquids and solids together.
  - Do gases have such forces??

- Molecules know one another is around because of interactions that are specific to their structure!

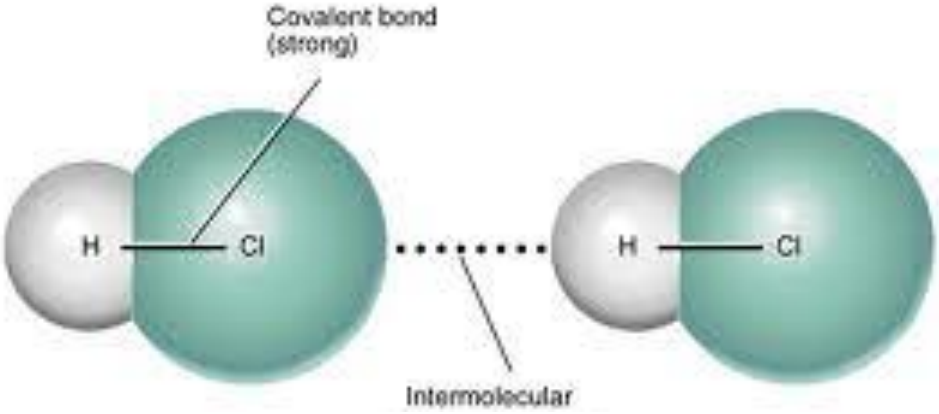
Types of Forces

- (London) dispersion forces – exist for ALL molecules. Weak forces that form between non-polar atoms.
- The + nucleus of one atom is attracted to the – electron cloud of another atom.



Types of Forces

- Dipole-Dipole – attraction between oppositely charged regions of POLAR molecules.



Types of Forces

- Hydrogen Bonding – strongest of all the IMF's. Attraction between molecules containing a hydrogen atom bonded to O, N, or F.
- These types of bonds are what keep the proteins in your body together!!