

REAL GASES

- The empirical gas laws (including the ideal gas equation) do not always apply.
 - The gas laws don't apply in situations where the assumptions made by kinetic theory are not valid.
 - When would it be FALSE that the space between gas molecules is much larger than the molecules themselves?
 - at high pressure, molecules would be much closer together!
 - When would it be FALSE that attractive and repulsive forces would be negligible?
 - at high pressure, attractions and repulsions should be stronger!
 - at low temperature, attractions and repulsions have a more significant affect on the paths of molecules



- The gas laws are highly inaccurate near the point where a gas changes to liquid!
- In general, the lower the pressure and the higher the temperature, the more IDEAL a gas behaves.

van der Waals equation

- an attempt to modify $PV = nRT$ to account for several facts.
 - gas molecules actually have SIZE (they take up space)
 - attractive and repulsive forces

$$PV = nRT \quad] \text{ Ideal gas equation}$$

$$\left(P + \frac{n^2 a}{V^2} \right) (V - nb) = nRT \quad] \text{ van der Waals equation}$$

attempts to account for attractive / repulsive forces

attempts to account for molecular size

* "a" and "b" are experimentally determined parameters that are different for each gas. p 208

He: $a = 0,0346$, $b = 0,0238$ tiny, no special attractive forces

H₂O: $a = 5,537$, $b = 0,03049$ small, but strong attractions between molecules

CH₃CH₂OH: $a = 12,56$ $b = 0,08710$ larger, and strong attractions between molecules

2500 L of chlorine gas at 25.0 C and 1.00 atm are used to make hydrochloric acid. How many kilograms of hydrochloric acid could be produced if all the chlorine reacts?



- 1 - Convert 2500 L chlorine gas to moles. Use IDEAL GAS EQUATION.
- 2 - Convert moles chlorine gas to moles HCl. Use CHEMICAL EQUATION
- 3 - Convert moles HCl to mass. Use FORMULA WEIGHT.

$$\textcircled{1} \quad PV = nRT \quad \left| \quad \begin{array}{l} p = 1.00 \text{ atm} \quad R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \\ n = \frac{PV}{RT} \quad V = 2500 \text{ L} \quad T = 25.0^\circ = 298.2 \text{ K} \end{array} \right.$$

$$n_{\text{Cl}_2} = \frac{(1.00 \text{ atm})(2500 \text{ L})}{\left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}\right)(298.2 \text{ K})} = 102.1646983 \text{ mol Cl}_2$$

$$\textcircled{2} \text{ mol Cl}_2 = 2 \text{ mol HCl} \quad \textcircled{3} \quad \begin{array}{l} \text{HCl} - \text{H}: 1 \times 1.008 \\ \quad \quad \text{Cl}: 1 \times 35.45 \\ \hline 36.458 \text{ g HCl} = \text{mol HCl} \end{array}$$

$$102.1646983 \text{ mol Cl}_2 \times \frac{2 \text{ mol HCl}}{\text{mol Cl}_2} \times \frac{36.458 \text{ g HCl}}{\text{mol HCl}} = 7450 \text{ g HCl}$$

Since the problem asks for kilograms, let's convert.

$$7450 \text{ g HCl} \times \frac{\text{kg} = 10^3 \text{ g}}{10^3 \text{ g}} = \boxed{7.45 \text{ kg HCl}}$$



If 48.90 mL of 0.250 M HCl solution reacts with sodium carbonate to produce 50.0 mL of carbon dioxide gas at 290.2 K, what is the pressure of the carbon dioxide gas?

1 - Convert 48.90 mL of 0.250 M HCl to moles. Use MOLARITY.

2 - Convert moles HCl to moles carbon dioxide. Use CHEMICAL EQUATION.

3 - Convert moles carbon dioxide to pressure. Use IDEAL GAS EQUATION.

$$\textcircled{1} 0.250 \text{ mol HCl} = \text{L} \quad \text{mL} = 10^{-3} \text{ L} \quad \textcircled{2} 2 \text{ mol HCl} = \text{mol CO}_2$$

$$48.90 \text{ mL} \times \frac{10^{-3} \text{ L}}{\text{mL}} \times \frac{0.250 \text{ mol HCl}}{\text{L}} \times \frac{\text{mol CO}_2}{2 \text{ mol HCl}} = 0.006125 \text{ mol CO}_2$$

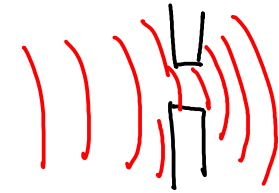
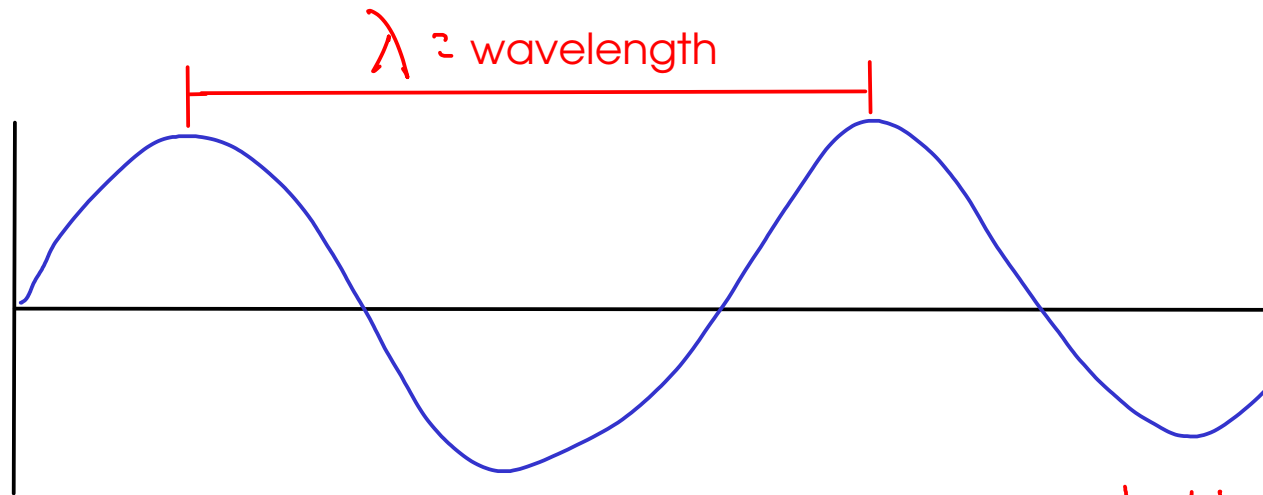
(1) (2)

$$\textcircled{3} \begin{array}{l} PV = nRT \\ P = \frac{nRT}{V} \end{array} \quad \begin{array}{l} n = 0.006125 \text{ mol CO}_2 \\ R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \\ T = 290.2 \text{ K} \end{array} \quad V = 50.0 \text{ mL} \times \frac{10^{-3} \text{ L}}{\text{mL}} = 0.0500 \text{ L}$$

$$P = \frac{(0.006125 \text{ mol CO}_2)(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}})(290.2 \text{ K})}{(0.0500 \text{ L})} = 2.91 \text{ atm CO}_2$$

2.91 atm CO₂
at 290.2 K,
50.0 mL

LIGHT



Diffraction

$$\text{frequency} = \text{wavelengths} / \text{time} = \nu \quad \text{s}^{-1} : \text{Hertz}, \text{ Hz}$$

- Light has properties of WAVES such as DIFFRACTION (it bends around small obstructions).
- Einstein noted that viewing light as a particle that carried an energy proportional to the FREQUENCY could explain the PHOTOELECTRIC EFFECT!

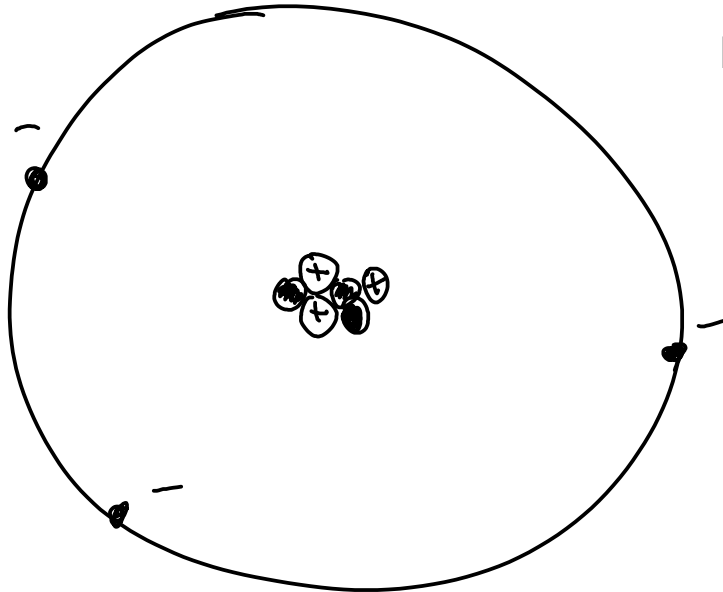
$$E_{\text{photon}} = h \nu$$

Planck's constant: $6.63 \times 10^{-34} \text{ J}\cdot\text{s}$

photon = particle or packet of light

(The photoelectric effect is the emission of electrons from a metal caused by exposure to light. Einstein discovered that if the light were not of the correct FREQUENCY, increasing the INTENSITY of the light would not cause electron emission. He concluded that individual photons must have enough energy to excite an electron - i.e. they must have the appropriate frequency.)

The photoelectric effect and Einstein's ideas about the energy content of light led us to discover a new model for the atom! How? Let's start with the nuclear model:



Nuclear model:

- Protons and neutrons in a dense NUCLEUS at center of atom
- Electrons in a diffuse (mostly empty) ELECTRON CLOUD surrounding NUCLEUS.

... so what's wrong with the nuclear model? Among other things, it doesn't explain ...