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.

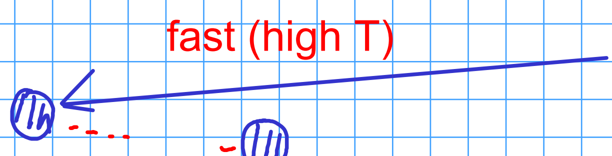
    - When would it be FALSE that the space between gas molecules is much larger than the molecules themselves?

      - 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

$$PV = nRT$$ Ideal gas equation

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

nb: attempts to account for molecular size

$\frac{n^2 a}{V^2}$: attempts to account for attractive / repulsive forces

* "a" and "b" are experimentally determined parameters that are different for each gas. p211

He: a = 0.0346, b = 0.0238 tiny, no special attractive forces

H_2O: a = 5.537, b = 0.03049 small, but strong attractions between moleculres

CH_3CH_2OH: 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?

$$H_2 + Cl_2 \rightarrow 2\,HCl$$

1: Start with chlorine gas. We know volume, pressure, and temperature of the gas - SO we know how many MOLES we have. Use ideal gas equation.

2: Change from moles of chlorine to moles of HCl. Use chemical equation.

3: Change from moles of HCl to kilograms of HCl. Use formula weight.

$$PV = nRT \qquad n = \frac{PV}{RT}$$

$P = 1.00$ atm $\quad V = 2\bar{5}00$ L

$T = 25.0\,^{\circ}C = 298.2$ K

$R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$

(1)
$$n = \frac{(1.00\ atm)(2\bar{5}00\ L)}{\left(0.08206 \frac{L \cdot atm}{mol \cdot K}\right)(298.2\ K)} = 102.165\ mol\ Cl_2$$

$$102.165\ mol\ Cl_2 \times \frac{2\ mol\ HCl}{1\ mol\ Cl_2} \times \frac{36.461\ g\ HCl}{1\ mol\ HCl} \times \frac{kg}{10^3\ g} = \boxed{7.45\ kg\ HCl}$$

(2) (3)

Calculate the mass of 22650 L* of oxygen gas at 25.0 °C and 1.18 atm pressure.

$\uparrow O_2$

*Volume of a 10'x10'x8' room

$32.00\ g\ O_2 = 1\ mol\ O_2$

Use the ideal gas equation to find out how many moles of oxygen gas are in the room. THEN, change that number of moles to mass using the formula weight of oxygen gas.

$$n = \frac{PV}{RT}$$

$P = 1.18\ atm$

$V = 22650\ L$

$R = 0.08206\ \frac{L\text{-}atm}{mol\text{-}K}$

$T = 25.0°C = 298.2\ K$

$$n = \frac{(1.18\ atm)(22650\ L)}{\left(0.08206\ \frac{L\text{-}atm}{mol\text{-}K}\right)(298.2\ K)} = 1092\ mol\ O_2$$

$$1092\ mol\ O_2 \times \frac{32.00\ g\ O_2}{1\ mol\ O_2} = 3\bar{5}000\ g\ O_2$$

(35 kg, 77 lb)

$$2\,HCl + Na_2CO_3 \rightarrow CO_2 + H_2O + 2\,NaCl$$

If 48.90 mL of hydrochloric acid solution react with sodium carbonate to produce 125.0 mL of carbon dioxide gas at 0.950 atm and 290.2 K. What is the molar concentration of the acid?

1) Find moles of carbon dioxide gas produced. Use the ideal gas equation.
2) Convert moles of carbon dioxide to moles of hydrochloric acid. Use chemical equation.
3) Find the molarity of acid by dividing moles and volume (in liters)

$$n_{CO_2} = \frac{PV}{RT}$$

$P = 0.950\ atm$

$V = 125.0\ mL = 0.1250\ L$

$R = .08206\ \frac{L\cdot atm}{mol\cdot K}$

$T = 290.2\ K$

① $$n_{CO_2} = \frac{(0.950\ atm)(0.1250\ L)}{\left(.08206\ \frac{L\cdot atm}{mol\cdot K}\right)(290.2\ K)} = 0.0049866\ mol\ CO_2$$

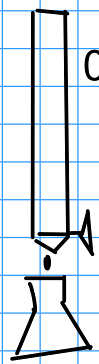
② $$0.0049866\ mol\ CO_2 \times \frac{2\ mol\ HCl}{1\ mol\ CO_2} = 0.0099732\ mol\ HCl$$

③ $$M_{HCl} = \frac{0.0099732\ mol\ HCl}{48.90\ mL \times \frac{10^{-3}\ L}{mL}} = \boxed{0.204\ M\ HCl}$$

This converts the 48.90 mL to L ... Molarity = mol/L

If 35.70 mL of 0.1504 M sulfuric acid is needed to completely react away 10.00 mL of sodium hydroxide solution, what is the concentration of the sodium hydroxide solution?

$$H_2SO_4 + 2\,NaOH \rightarrow Na_2SO_4 + 2\,H_2O$$



0.1504 M sulfuric acid

(35.70 mL used)

10.00 mL of unknown NaOH

1) Find the moles of sulfuric acid used from the volume given. Use the MOLARITY of the sulfuric acid.

2) Convert the moles of sulfuric acid to moles of NaOH

3) Calculate the MOLARITY of the NaOH by dividing moles of NaOH by the volume of NaOH used (in L)

$$35.70\ mL\ H_2SO_4 \times \frac{10^{-3}\ L}{mL} \times \underbrace{\frac{0.1504\ mol\ H_2SO_4}{L}}_{①} \times \underbrace{\frac{2\ mol\ NaOH}{1\ mol\ H_2SO_4}}_{②} = 0.01074\ mol\ NaOH$$

③ $$\frac{0.01074\ mol\ NaOH}{10.00\ mL \times \frac{10^{-3}\ L}{mL}} = \boxed{1.074\ \underline{M}\ NaOH}$$