145 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.

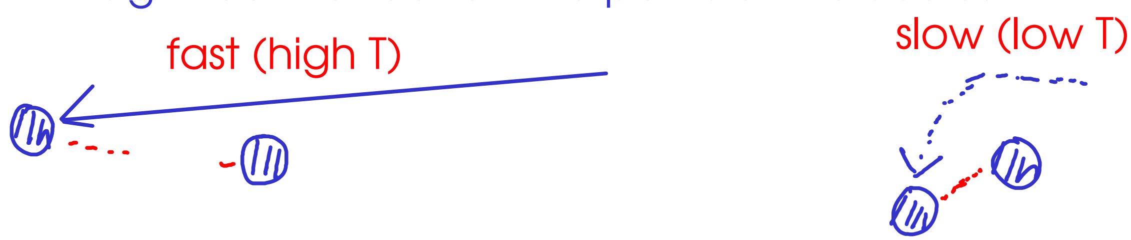
    - When would it be FALSE that the space between gas molecules is much larger than the molecules themselves?

      - 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.

146 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. p 208

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

147 $25\bar{0}0$ 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 - Convert volume of chlorine gas to moles using ideal gas equation.
2 - Convert moles chlorine gas to moles HCl using chemical equation.
3 - Convert moles HCl to mass using formula weight.

① $PV = nRT$ | $P = 1.00$ atm | $R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$ | $T = 25.0\,^{\circ}C = 298.2$ K

$n = \frac{PV}{RT}$ | $V = 25\bar{0}0$ L

$$n_{Cl_2} = \frac{(1.00\text{ atm})(25\bar{0}0\text{ L})}{\left(0.08206 \frac{L \cdot atm}{mol \cdot K}\right)(298.2\text{ K})} = 102.1646983 \text{ mol } Cl_2$$

mol Cl_2 = 2 mol HCl

H: 1 × 1.008
Cl: 1 × 35.45
36.458 g HCl = mol HCl

Kg = 10^3 g

$$102.1646983 \text{ mol } Cl_2 \times \frac{2 \text{ mol HCl}}{\text{mol } Cl_2} \times \frac{36.458 \text{ g HCl}}{\text{mol HCl}} \times \frac{\text{Kg}}{10^3 \text{ g}} = \boxed{7.45 \text{ kg HCl}}$$

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

↑ O_2

*Volume of a 10'x10'x8' room

1 - Convert 22650 L of oxygen gas to moles using ideal gas equation.
2 - Convert moles oxygen gas to mass using formula weight.

① $PV = nRT$

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

$P = 1.18\ atm$

$V = 22650\ L$

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

$T = 25.0° = 298.2\ K$

$$n_{O_2} = \frac{(1.18\ atm)(22650\ L)}{\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(298.2\ K)} = 1092.222357\ mol\ O_2$$

$32.00\ g\ O_2 = mol\ O_2$

$$1092.222357\ mol\ O_2 \times \frac{32.00\ g\ O_2}{mol\ O_2} = 35\bar{0}00\ g\ O_2$$

35.0 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?

We need to calculate $\underline{M}_{HCl} = \dfrac{\text{mol HCl}}{\text{L HCl solution}}$ ← 48.90 mL = 0.04890 L

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1 - Convert 125.0 mL of carbon dioxide gas to moles using ideal gas equation.
2 - Convert moles carbon dioxide gas to moles HCl using chemical equation.
3 - Calculate molarity of HCl by dividing mol HCl / 0.04890 L

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① $n = \dfrac{PV}{RT}$

$P = 0.950\text{ atm}$

$V = 125.0\text{ mL} = 0.1250\text{ L}$

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

$T = 290.2\text{ K}$

$$n_{CO_2} = \frac{(0.950\text{ atm})(0.1250\text{ L})}{\left(0.08206\ \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}\right)(290.2\text{ K})} = 0.004986619\text{ mol }CO_2$$

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2 mol HCl = mol CO_2

$$0.004986619\text{ mol }CO_2 \times \frac{2\text{ mol HCl}}{\text{mol }CO_2} = 0.009973238\text{ mol HCl}$$ ②

$$\underline{M}_{HCl} = \frac{\text{mol HCl}}{\text{L HCl solution}} = \frac{0.009973238\text{ mol HCl}}{0.04890\text{ L}} = \boxed{0.204\ \underline{M}\ HCl}$$

ENERGY

- thermodynamics: the study of energy transfer

Conservation of energy: Energy may change form, but the overall amount of energy remains constant. "first law of thermodynamics"

- ... but what IS energy?

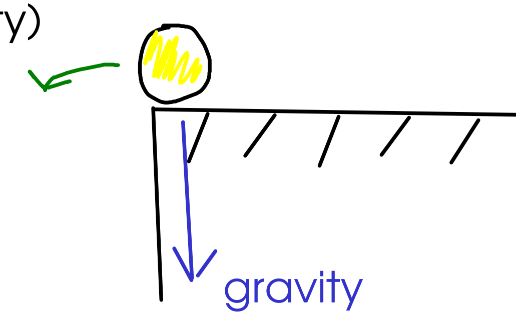
  - energy is the ability to do "work"

    ↑ motion of matter

Kinds of energy?

- Kinetic energy: energy of matter in motion $E_K = \frac{1}{2} m v^2$ (m: mass; v: velocity)

- Potential energy: energy of matter that is being acted on by a field of force (like gravity)



When the ball falls, its potential energy is converted to kinetic!