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

$(V - nb)$: 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 molecuIres

CH_3CH_2OH: a = 12.56 b = 0,08710 larger, and strong attractions between molecules

147 $2\bar{5}00$ 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 2500L 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. (Also, g -> kg conversion)

① $PV = nRT$

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

$P = 1.00\ atm$ $\quad T = 25.0°C = 298.2\ K$

$V = 2\bar{5}00\ L$ $\quad R = 0.08206\ \frac{L \cdot atm}{mol \cdot K}$

$$n_{Cl_2} = \frac{(1.00\ atm)(2\bar{5}00\ L)}{\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(298.2\ K)} = 102.164983\ mol\ Cl_2$$

$mol\ Cl_2 = 2\ mol\ HCl$

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

$Kg = 10^3\ g$

$$102.164983\ mol\ Cl_2 \times \underset{②}{\frac{2\ mol\ HCl}{mol\ Cl_2}} \times \underset{③}{\frac{36.458\ g\ HCl}{mol\ HCl}} \times \frac{Kg}{10^3\ g} = \boxed{7.45\ kg\ HCl}$$

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 - Calculate moles oxygen gas using ideal gas equation.
2 - Convert moles oxygen gas to mass using formula weight.

① $PV = nRT$

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

$P = 1.18\,atm$ $R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$

$V = 22650\,L$ $T = 25.0°C = 298.2\,K$

$$n_{O_2} = \frac{(1.18\,atm)(22650\,L)}{\left(0.08206 \frac{L \cdot atm}{mol \cdot K}\right)(298.2\,K)} = 1092.22235\ mol\ O_2$$

$32.00\,g\ O_2 = mol\ O_2$

$$1092.22235\ mol\ O_2 \times \frac{32.00\,g\ O_2}{mol\ O_2} = 35\bar{0}00\,g\ O_2$$

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 find $M_{HCl} = \frac{\text{mol HCl}}{\text{L HCl solution}}$ ← 48.90 mL = 0.04890 L

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

① $n = \frac{PV}{RT}$

$P = 0.950\ \text{atm}$ $R = 0.08206\ \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}$

$V = 125.0\ \text{mL} = 0.1250\ \text{L}$ $T = 290.2\ \text{K}$

$$n_{CO_2} = \frac{(0.950\ \text{atm})(0.1250\ \text{L})}{\left(0.08206\ \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}\right)(290.2\ \text{K})} = 0.004986019\ \text{mol}\ CO_2$$

mol CO_2 = 2 mol HCl

$$0.004986019\ \text{mol}\ CO_2 \times \frac{2\ \text{mol HCl}}{\text{mol}\ CO_2} = 0.009972038\ \text{mol HCl}$$ ②

$$M_{HCl} = \frac{\text{mol HCl}}{\text{L HCl solution}} = \frac{0.009972038\ \text{mol HCl}}{0.04890\ \text{L}} = \boxed{0.203\ M\ HCl}$$

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?

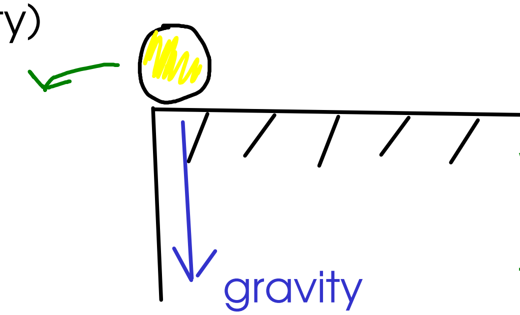
  - energy is the ability to do "work"

    (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!

- What sort of energy concerns chemists? Energy that is absorbed or released during chemical reactions.

- Energy can be stored in chemicals ... molecules and atoms.

INTERNAL ENERGY: "U"

↑ related to the kinetic and potential energy of atoms, molecules, and their component parts.

- We measure energy transfer ... which is called HEAT. (HEAT is the flow of energy from an area of higher temperature to an area of lower temperature)

Q : heat

SYSTEM: the object or material under study

SURROUNDINGS: everything else

Type of process	Energy is ...	Sign of Q	Temp of SURROUNDINGS ...
ENDOTHERMIC	transferred from SURROUNDINGS to SYSTEM	+	decreases
EXOTHERMIC	transferred from SYSTEM to SURROUNDINGS	−	increases