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

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

nb 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

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?

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

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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 HCl using FORMULA WEIGHT

① $PV = nRT$ | $P = 1.00\ atm \quad V = 2500\ L$

$n = \frac{PV}{RT}$ | $R = 0.08206\ \frac{L \cdot atm}{mol \cdot K} \quad T = 25.0^\circ C = 298.2\ K$

$$n = \frac{(1.00\ atm)(2500\ L)}{\left(0.08206\ \frac{L \cdot atm}{mol \cdot K}\right)(298.2\ K)} = 102.1646983\ mol\ Cl_2$$

② $mol\ Cl_2 = 2\ mol\ HCl$ ③ HCl – H: 1 x 1.008, Cl: 1 x 35.45 → $36.458\ g\ HCl = mol\ HCl$ | $kg = 10^3\ g$

$$102.1646983\ \cancel{mol\ Cl_2} \times \frac{2\ \cancel{mol\ HCl}}{\cancel{mol\ Cl_2}} \times \frac{36.458\ g\ HCl}{\cancel{mol\ HCl}} \times \frac{kg}{10^3\ g} = \boxed{7.454\ kg\ HCl}$$

② ③

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

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?

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1 - Convert 48.90 mL of HCl solution to moles. Use MOLARITY.
2 - Convert moles HCl to moles carbon dioxide. Use CHEMICAL EQUATION.
3 - Convert moles carbon dioxide to gas pressure. Use IDEAL GAS EQUATION.

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① $0.250\ mol\ HCl = L$ $\quad mL = 10^{-3} L$ $\quad$ ② $2\ mol\ HCl = mol\ CO_2$

$$48.90\ mL \times \frac{10^{-3}\ L}{mL} \times \frac{0.250\ mol\ HCl}{L} \times \frac{mol\ CO_2}{2\ mol\ HCl} = 0.0061125\ mol\ CO_2$$

① ②

③ $PV = nRT$

$$P = \frac{nRT}{V}$$

$n = 0.0061125\ mol\ CO_2$ $\quad R = 0.08206\ \frac{L\text{-}atm}{mol\ K}$ $\quad T = 290.2\ K$ $\quad V = 50.0\ mL = 0.0500\ L$

$$P = \frac{(0.0061125\ mol\ CO_2)\left(0.08206\ \frac{L\text{-}atm}{mol\ K}\right)(290.2\ K)}{(0.0500\ L)} = \boxed{2.91\ atm}$$

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

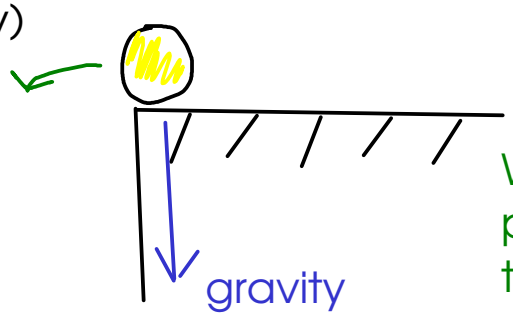
Kinds of energy?

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

mass

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.

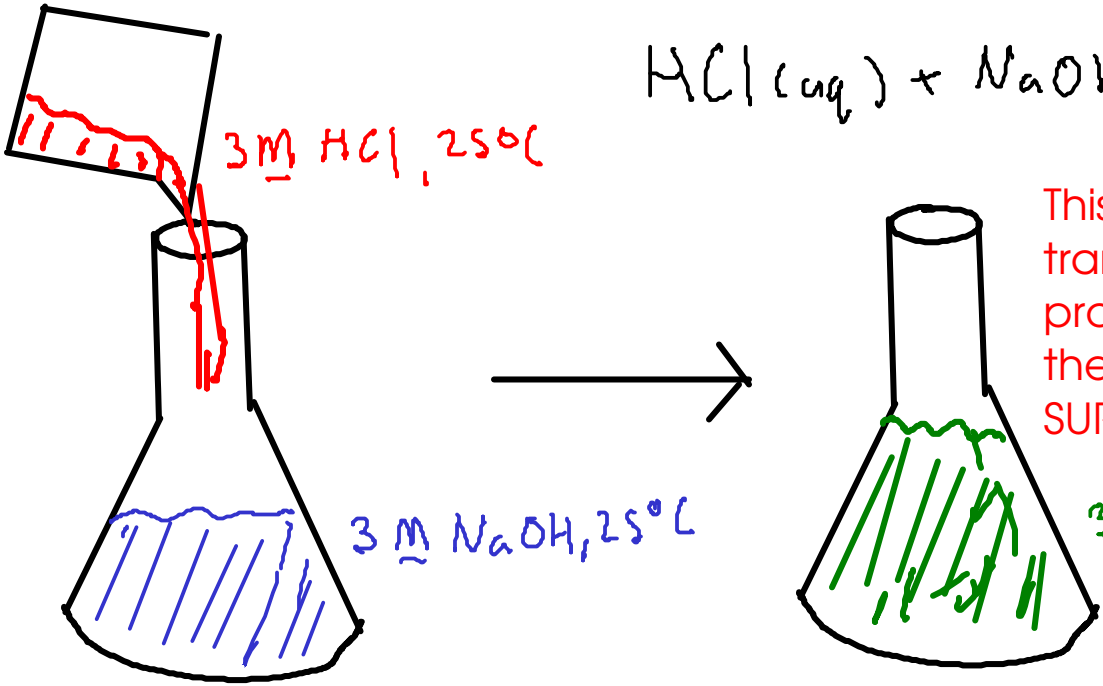
- We measure energy transfer ... which is called HEAT. (HEAT is the flow of energy from an area of higher temperature to an area of lower temperature)

Q : heat

SYSTEM: the object or material under study

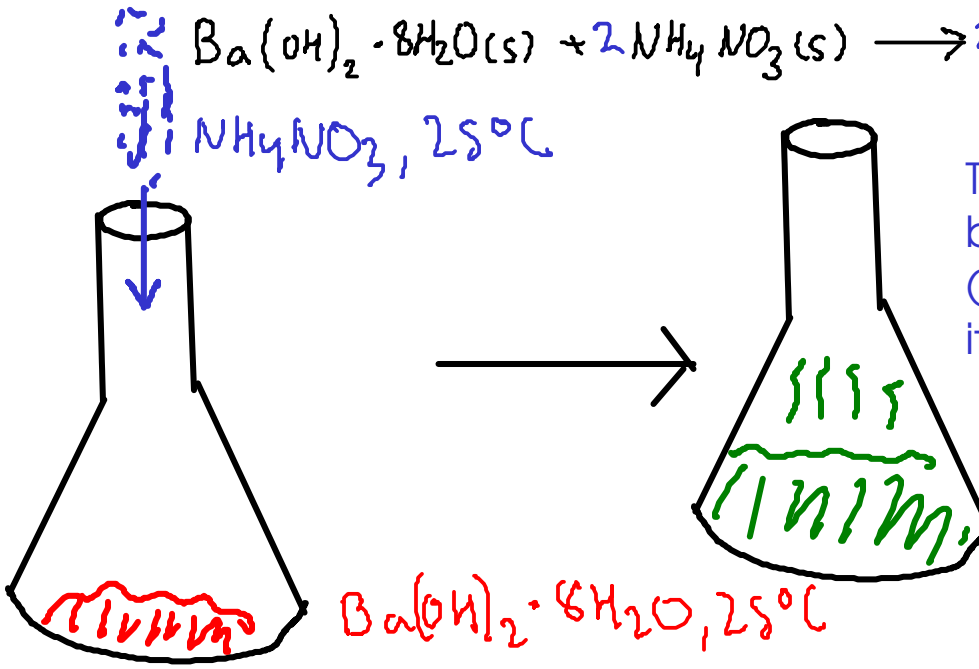
SURROUNDINGS: everything else

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



$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(\ell)$$

This reaction is EXOTHERMIC. Energy is transferred from the reactants and prodicts (the SYSTTEM) to the water in the flask, the flask, etc. (the SURROUNDINGS)



$$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4NO_3(s) \longrightarrow 2NH_3(aq) + 10\,H_2O(\ell) + Ba(NO_3)_2(aq)$$

This reaction is ENDOTHERMIC. Energy is being transferred from the room/flask/etc. (the SURROUNDINGS) to the reaction itself (the SYSTEM).