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 grams of hydrochloric acid could be produced if all the chlorine reacts?

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

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

① $PV = nRT$ | $P = 1.00\ atm \quad V = 2500\ L \quad T = 25.0°C = 298.2\ K$

$n = \frac{PV}{RT}$ | $R = 0.08206\ \frac{L \cdot atm}{mol \cdot K}$

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

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② $mol\ Cl_2 = 2\ mol\ HCl$ ③ $HCl - H: 1 \times 1.008$

$Cl: 1 \times 35.45$

$36.458\ g\ HCl = mol\ HCl$

$$102.1646983\ mol\ Cl_2 \times \frac{2\ mol\ HCl}{mol\ Cl_2}\ (②) \times \frac{36.458\ g\ HCl}{mol\ HCl}\ (③) = \boxed{7450\ g\ HCl}$$

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

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 gas. Use CHEMICAL EQUATION.
3 - Convert moles carbon dioxide gas to PRESSURE. Use IDEAL GAS EQUATION.

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

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

① ②

③ $PV = nRT$

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

$n = 0.0061125\ mol\ CO_2$ $R = 0.08206 \frac{L\text{-}atm}{mol\cdot K}$

$T = 290.2\ K$ $V = 50.0\ mL = 0.0500\ L$

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

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

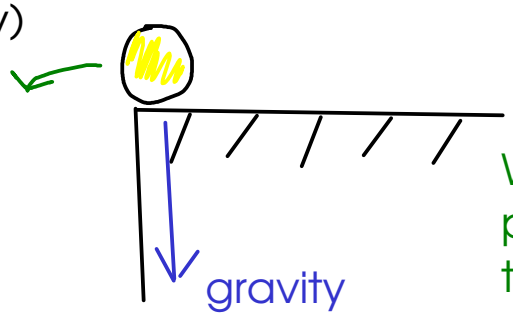
Kinds of energy?

- 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.

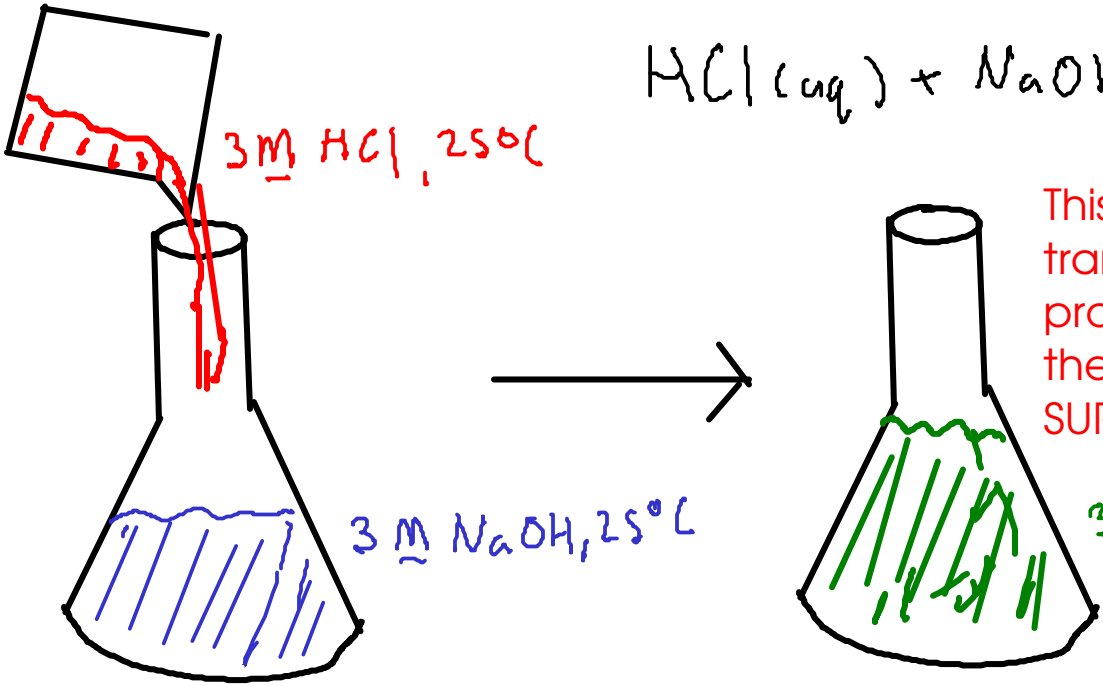
- We measure energy transfer ... which is called HEAT. (HEAT is the flow of energy from an area of higher temperature to an area of lower temperature)

Q : heat

SYSTEM: the object or material under study

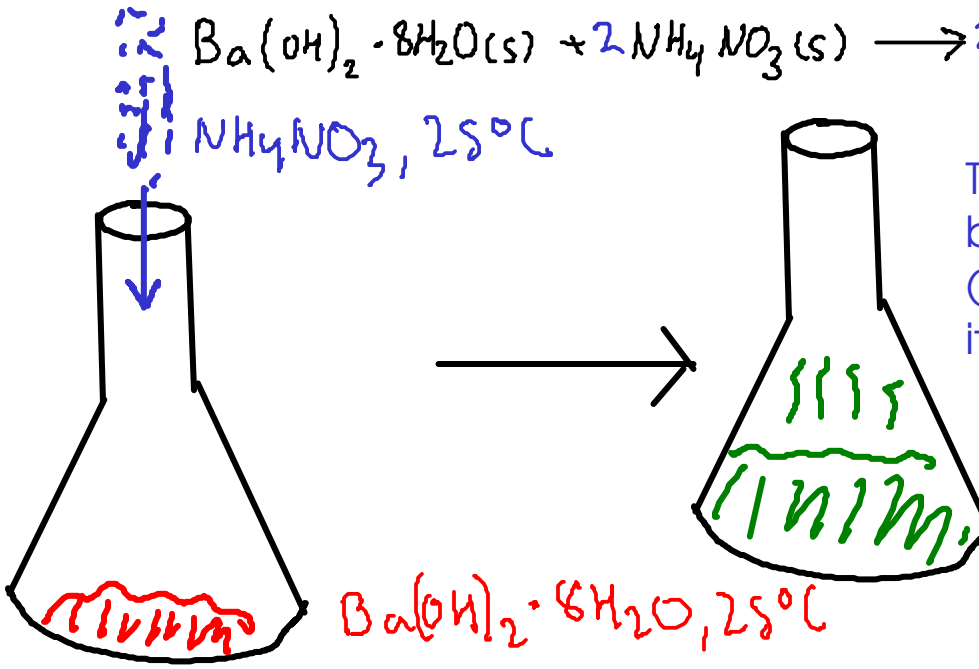
SURROUNDINGS: everything else

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 SYSTEM) to the water in the flask, the flask, etc. (the SURROUNDINGS)

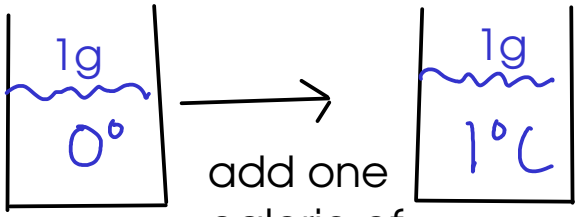


$$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4NO_3(s) \longrightarrow 2NH_3(aq) + 10\,H_2O(\ell) + Ba(NO_3)_2(aq)$$

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

ENERGY UNITS

- calorie (cal): the amount of energy required to change the temperature of one gram of water by one degree Celsius (or Kelvin)



1 g ≈ 1 mL for water

- Calories in food? The "Calorie" that is given on American food labels is actually the kilocalorie (kcal)

- Joule (J): SI unit for energy. It's defined based on the equation for kinetic energy.

$1\ J = 1\ \frac{Kg\ m^2}{s^2}$, from

$E_K = \frac{1}{2} m v^2$

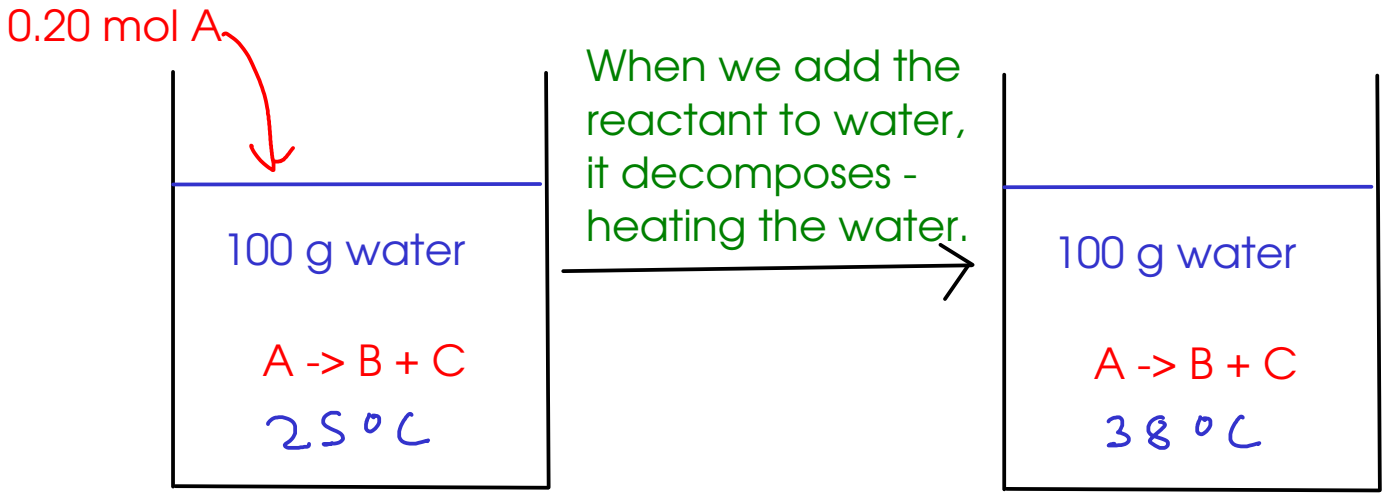
kinetic energy — mass — velocity

4.184 J = 1 cal

- the Joule is a small unit. For most reactions at lab scale, we'll use kilojoules (kJ).

CALORIMETRY

- the measurement of heat. How do we measure heat flow?



... what is Q for this reaction?

Assuming that no heat is lost from the water to the surrounding air,

$$Q_r + Q_w = 0$$

Conservation of energy. The terms add to zero because they have opposite signs.

Q_r: reaction; Q_w: water

... if we knew something about the WATER, we could use that to find the heat of the REACTION!

SPECIFIC HEAT

- a measured quantity. The amount of energy required to change the temperature of one gram of a particular substance by one degree Celsius.

- Specific heat information for common substances is readily available. For water,

$$4.184 \frac{J}{g^{\circ}C} \text{ or } = 1.000 \frac{cal}{g^{\circ}C}$$

$$Q = m \times S \times \Delta T$$

m = mass
s = specific heat
ΔT = Tfinal - Tinitial

This is ALWAYS final temp minus initial temp!

- For objects, like reaction vessels, you might know the HEAT CAPACITY, which is the amount of energy required to change the temperature of an object by one degree Celsius

Units: $J/^{\circ}C$ or $cal/^{\circ}C$

$$Q = C \times \Delta T$$

c = heat capacity