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.

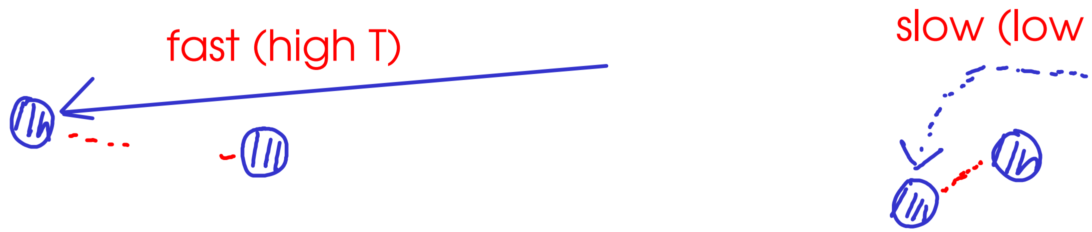
    - When would it be FALSE that the space between gas molecules is much larger than the molecules themselves?

      - 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. 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?

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

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

① $PV = nRT$, $n = \frac{PV}{RT}$ | $P = 1.00\ \text{atm}$, $V = 25\bar{0}0\ L$, $R = 0.08206\ \frac{L\cdot atm}{mol\cdot K}$, $T = 25.0°C = 298.2\ K$

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

② $mol\ Cl_2 = 2\ mol\ HCl$

③ HCl – H: 1×1.008
Cl: 1×35.45
36.458 g HCl = mol HCl

$$102.1646983\ mol\ Cl_2 \times \frac{2\ mol\ HCl}{mol\ Cl_2} \times \frac{36.458\ g\ HCl}{mol\ HCl} = 7450\ g\ Cl_2$$

Convert to kilograms since the problem specifies kg units... $Kg = 10^3 g$

$$7450\ g \times \frac{Kg}{10^3\ g} = \boxed{7.45\ Kg\ HCl}$$

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

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. User MOLARITY. (0.250 M)
2 - Convert moles HCl to moles carbon dioxide. Use CHEMICAL EQUATION.
3 - Convert moles carbon dioxide to pressure. Use IDEAL GAS EQUATION, PV=nRT

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(1) 0.250 mol HCl = L ; mL = 10^{-3} L (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)

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(3) $PV = nRT$

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

$n = 0.0061125\,mol\,CO_2$ $T = 290.2\,K$

$R = 0.08206\,\frac{L \cdot atm}{mol \cdot K}$ $V = 50.0\,mL = 0.0500\,L$

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

ENERGY

- thermodynamics: the study of energy transfer

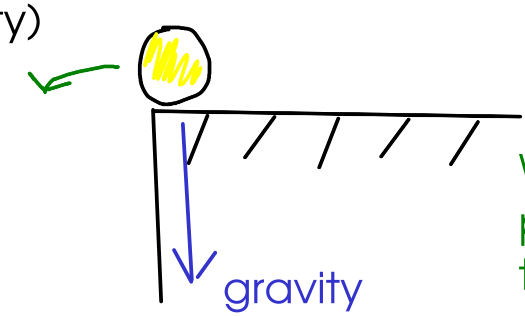
Conservation of energy: Energy may change form, but the overall amount of energy remains constant. "first law of thermodynamics"

- ... but what IS energy?
    - energy is the ability to do "work"
        - ↳ motion of matter

Kinds of energy?

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

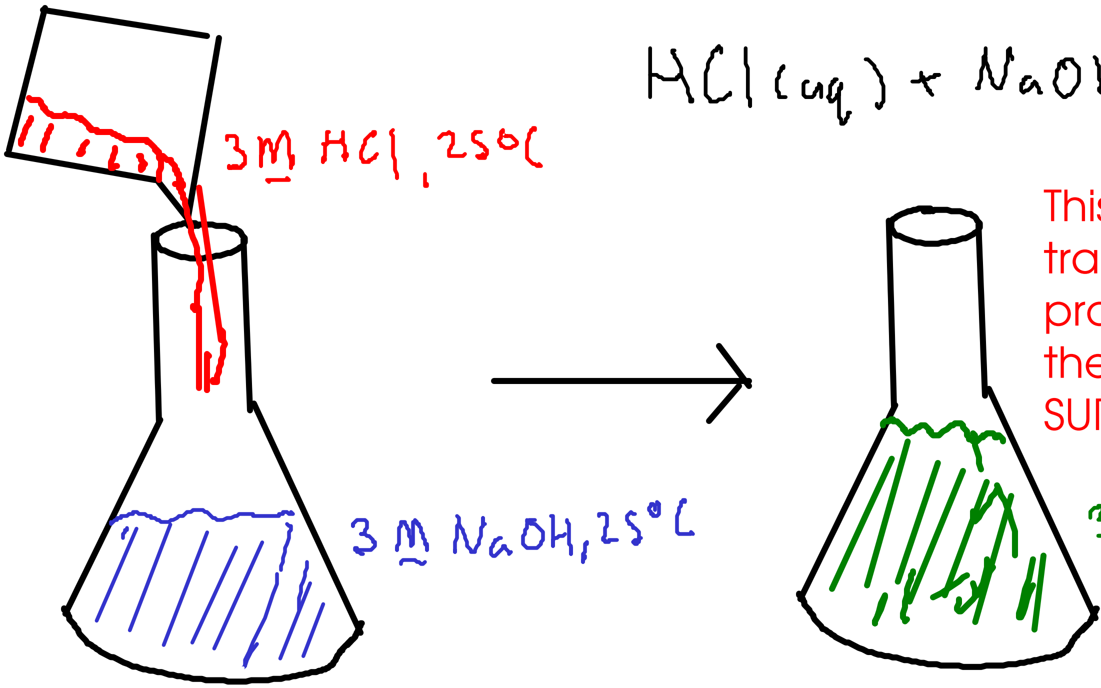
Q : heat

SYSTEM: the object or material under study

SURROUNDINGS: everything else

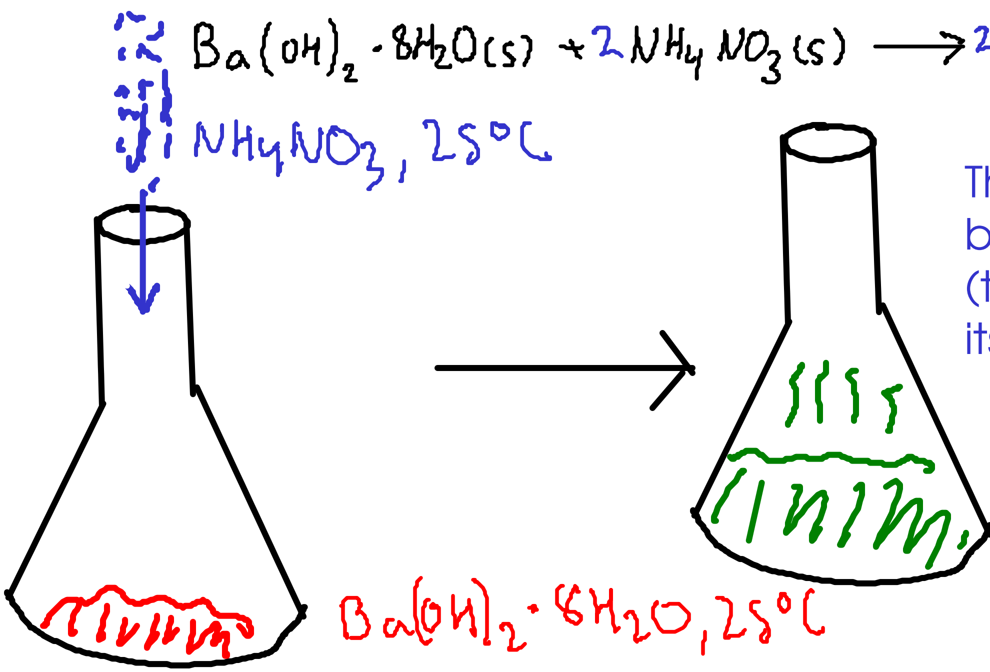
Type of process	Energy is ...	Sign of Q	Temp of SURROUNDINGS ...
ENDOTHERMIC	transferred from SURROUNDINGS to SYSTEM	+	decreases
EXOTHERMIC	transferred from SYSTEM to SURROUNDINGS	—	increases

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



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

$$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4NO_3(s) \rightarrow 2NH_3(aq) + 10H_2O(l) + Ba(NO_3)_2(aq)$$

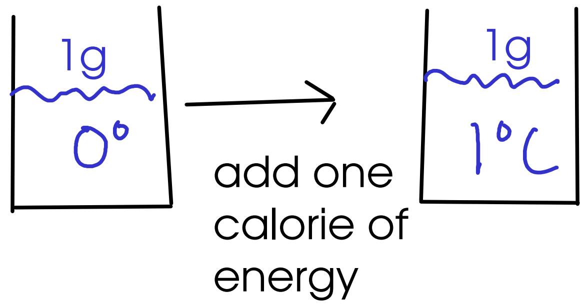


This reaction is ENDOTHERMIC. Energy is being transferred from the room/flask/etc. (the SURROUNDINGS) to the reaction itself (the SYSTEM).

ENERGY UNITS

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

1g ≈ 1mL 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.

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

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

E_K: kinetic energy; m: mass; v: velocity

4.184 J = 1 cal

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