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

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 molar concentration (M) of HCl: $M_{HCl} = \dfrac{\text{mol HCl}}{\text{L HCl Solution}}$

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 solution by dividing mol HCl and volume HCl.

(1) $PV = nRT$

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

$P = 0.950\text{ atm}$ $T = 290.2\text{ K}$

$R = 0.08206\ \dfrac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}$ $V = 125.0\text{ mL} = 0.1250\text{ L}$

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

2 mol HCl = mol CO_2

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

$$M = \frac{0.009972\text{ mol HCl}}{0.04890\text{ L}} = 0.204\text{ M HCl}$$

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"

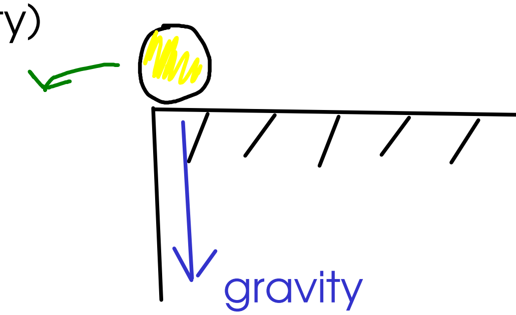
    ↑ motion of matter

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!

- 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)

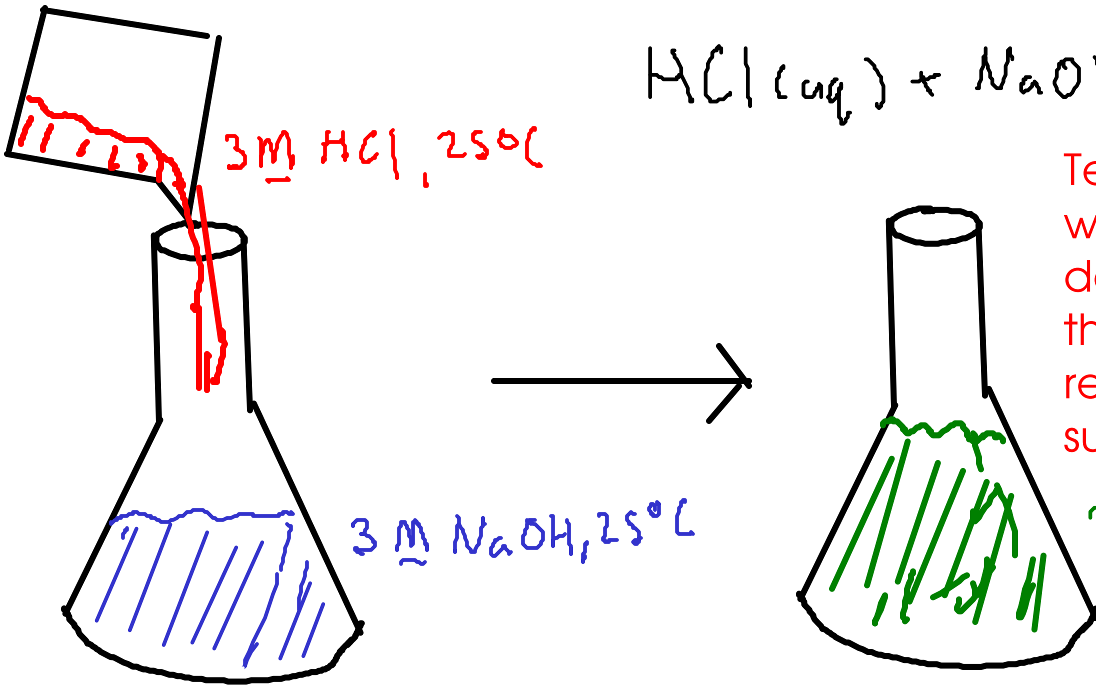
Q : heat

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

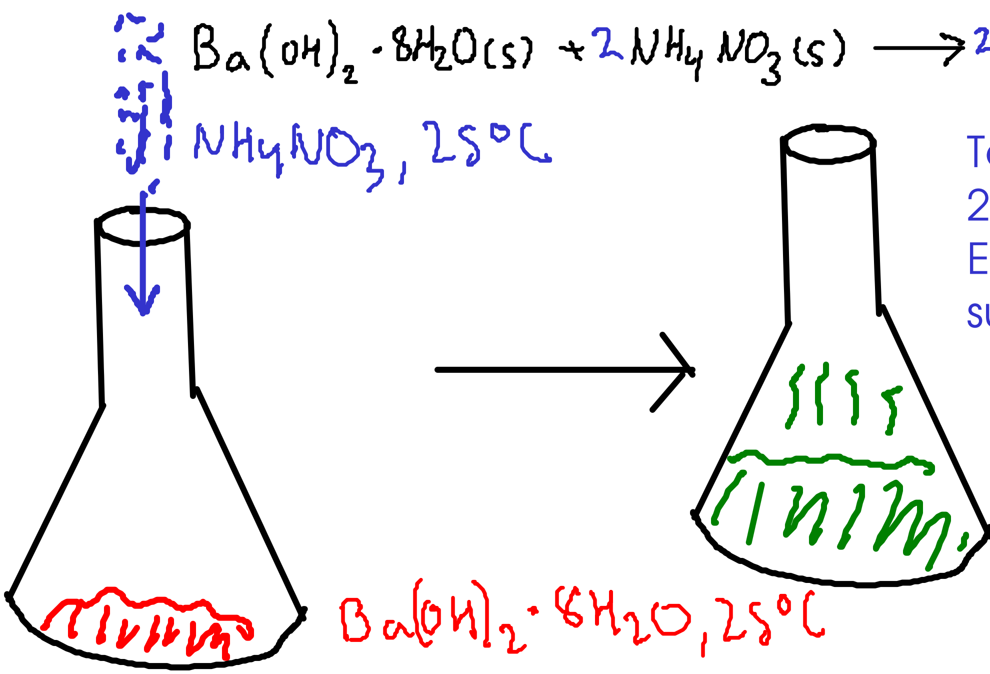
$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(\ell)$$



Temperature of the flask and the water it contains rises from 25 degrees to 40 degrees. Therefore, the reaction is EXOTHERMIC - the reaction tranfers energy to the surroundings.

3 M $NaCl + H_2O$, 40°C

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

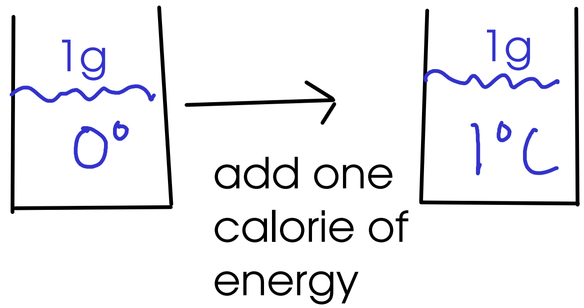


Temperature of the surroundings decreases from 25 degrees to less than zero. The reaction is ENDOTHERMIC - it absorbs energy from the surroundings!

NH_3, H_2O, $Ba(NO_3)_2(aq)$, < 0°C

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.

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

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

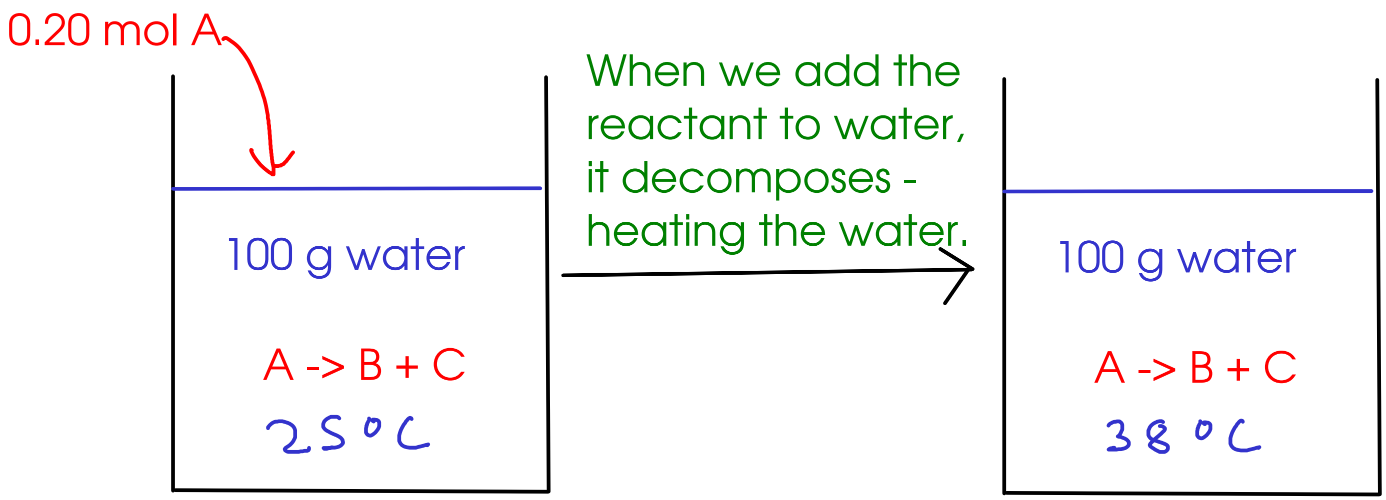
E_K: kinetic energy; m: mass; v: velocity

4.184 J = 1 cal

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

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,

$$Q_r + Q_w = 0$$

(Q_r: reaction; Q_w: water)

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

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

155 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,

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

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

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