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

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: $\underline{M} \text{ of } HCl = \frac{\text{mol HCl}}{\text{L HCl solution}} \leftarrow = 48.90\text{ mL } (0.04890\text{L})$

1 - Convert 125.0 mL of carbon dioxide gas to moles using ideal gas equation

2 - Convert moles carbon dioxide gas to moles hydrochloric acid using chemical equation

3 - Divide mol HCl / 0.04890 L solution to get molar concentration.

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① $PV = nRT$

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

$P = 0.950\text{ atm}$

$V = 125.0\text{ mL} = 0.1250\text{L}$

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

$T = 290.2\text{ K}$

$n = ?\text{ mol } CO_2$

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

$2\text{ mol HCl} = \text{mol } CO_2$

2

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

③ $$\underline{M}_{HCl} = \frac{0.009972038\text{ mol HCl}}{0.04890\text{L}} = \boxed{0.204\ \underline{M}\ HCl}$$

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?

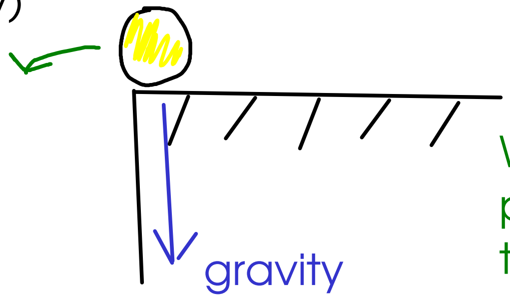
  - energy is the ability to do "work"

motion of matter

Kinds of energy?

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

- 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

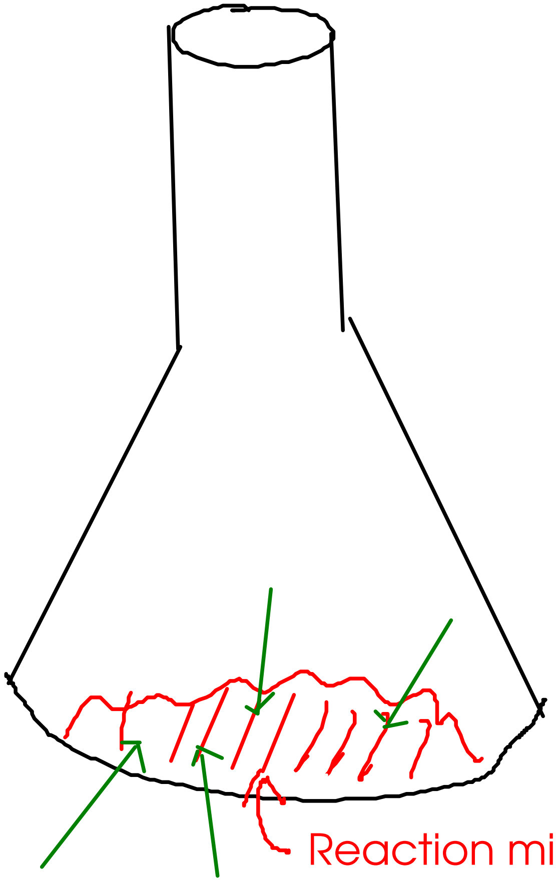
SURROUNDINGS: everything else

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

Reaction demonstration:

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

Observations:
- * Reaction vessel is COLD
- * Odor (Ammonia?)
- * Liquid formed (water?)

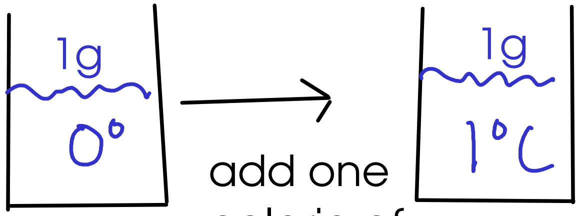


ENERGY flows from the SURROUNDINGS (flask, our hands, etc.) to the SYSTEM. This is an example of an ENDOTHERMIC chemical reaction:

$Q > 0$

ENERGY UNITS

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



add one calorie of energy

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

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

kinetic energy

mass

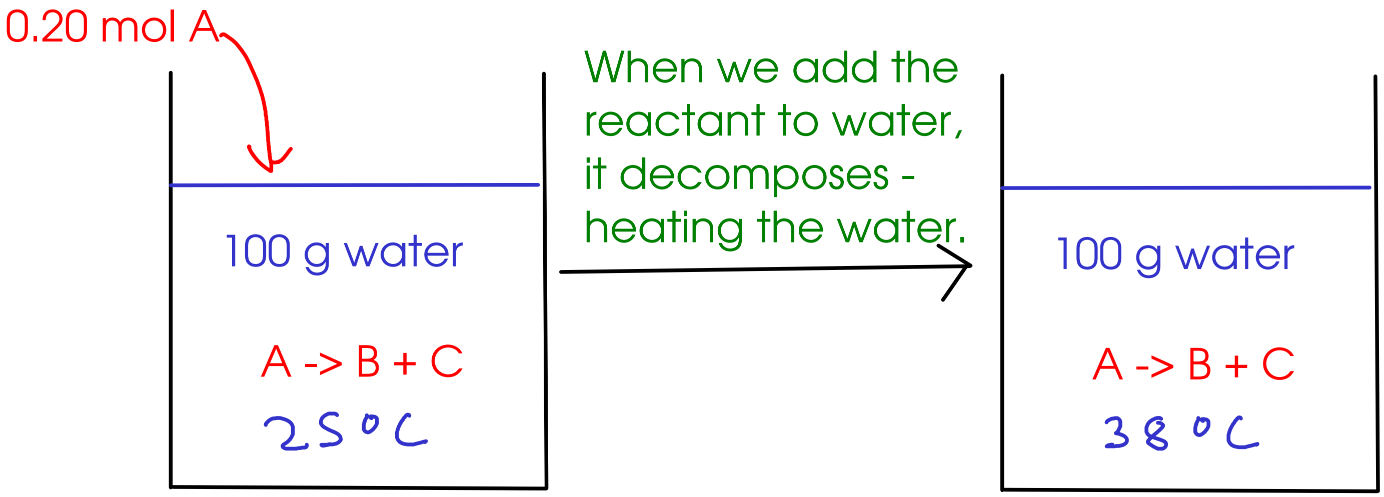
velocity

$$\boxed{4.184\,J = 1\,cal}$$

- 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?



When we add the reactant to water, it decomposes - heating the water.

... what is Q for this reaction?

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

$$\underbrace{Q_r}_{\text{reaction}} + \underbrace{Q_w}_{\text{water}} = 0$$

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!

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,

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

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

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

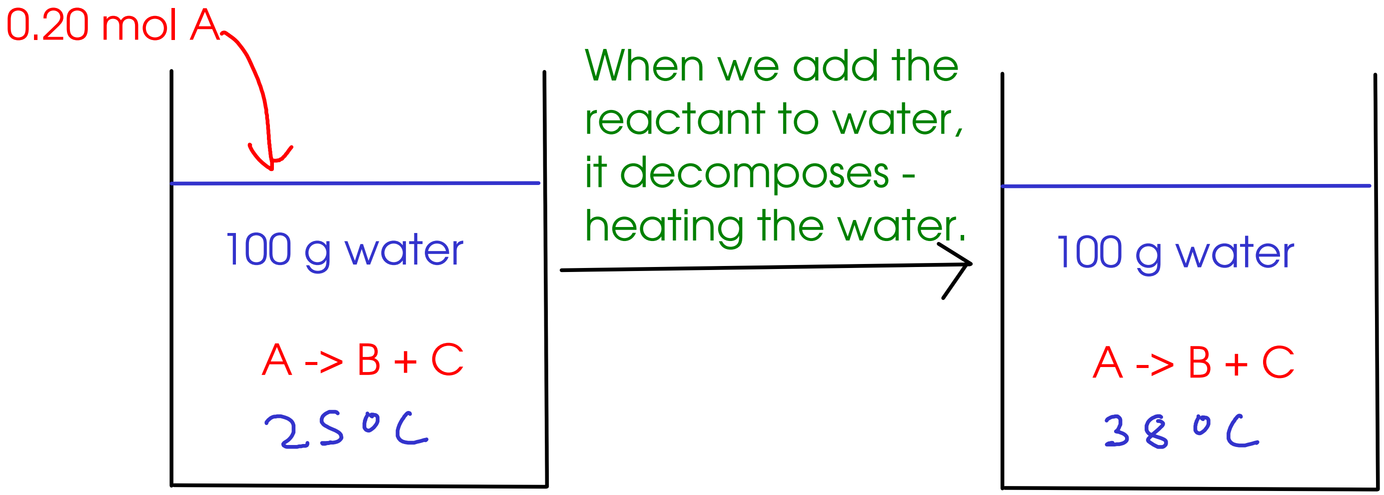
This is ALWAYS final temp minus initial temp!

- 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



When we add the reactant to water, it decomposes - heating the water.

Specific heat of water:

$4.184\ J/g\,°C$

$$Q_r + Q_w = 0$$

$$Q_w = m_w S_w \Delta T_w$$
$$= (100g)(4.184\ J/g\,°C)(38°C - 25°C)$$
$$= 5439.2\,J$$

$$Q_r + 5439.2\,J = 0 \ ; \ Q_r = -5439.2\,J$$

To report the energy change in this reactrion to others, we should express it in terms of heat transfer per mole of something. A different amount of reactant would have a diffferent Q

$$Q_{rxn} = \frac{Q_r}{\text{moles A}} = \frac{-5439.2\,J}{0.20\,mol\ A} = -27000\ J/mol\ A = \boxed{-27\ \frac{kJ}{mol\ A}}$$

This number is often called the "heat of reaction"