147 $25\bar{0}0$ 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 2500 L 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 using formula weight.

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① $PV = nRT$ $\quad n = \dfrac{PV}{RT}$

$P = 1.00\ \text{atm} \qquad V = 25\bar{0}0\ \text{L} \qquad R = 0.08206\ \dfrac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}$

$T = 25.0\,^{\circ}\text{C} = 298.2\ \text{K}$

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

$\text{mol}\ Cl_2 = 2\ \text{mol}\ HCl$

HCl: H: 1×1.008
Cl: 1×35.45

$35.458\ \text{g}\ HCl = \text{mol}\ HCl$

$\text{kg} = 10^3\ \text{g}$

② ③

$$102.1646983\ \text{mol}\ Cl_2 \times \frac{2\ \text{mol}\ HCl}{\text{mol}\ Cl_2} \times \frac{35.458\ \text{g}\ HCl}{\text{mol}\ HCl} \times \frac{\text{kg}}{10^3\ \text{g}} = \boxed{7.45\ \text{kg}\ HCl}$$

Calculate the mass of 22650* L of oxygen gas at 25.0 C and 1.18 atm pressure.

$\uparrow O_2$

*Volume of a 10'x10'x8' room

1 - Convert 22650 L oxygen gas to moles using ideal gas equation.

2 - Convert moles gas to mass using formula weight.

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① $PV = nRT$

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

$P = 1.18 \text{ atm}$

$V = 22660 \text{ L}$

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

$T = 25.0°C = 298.2 K$

$$n_{O_2} = \frac{(1.18 \text{ atm})(22660 \text{ L})}{\left(0.08206 \frac{L\cdot atm}{mol\cdot K}\right)(298.2 \text{ K})} = 1092.222357 \text{ mol } O_2$$

$32.00 \text{ g } O_2 = \text{mol } O_2$

$$1092.222357 \text{ mol } O_2 \times \frac{32.00 \text{ g } O_2}{\text{mol } O_2} = \boxed{35\bar{0}00 \text{ g } O_2}$$

35.0 kg

~77 lb

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

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 M of HCl solution:

$$M_{HCl} = \frac{\text{mol } HCl}{\text{L solution}} \leftarrow 48.90 \text{ mL} = 0.04890 \text{ L}$$

1 - Convert 125.0 mL of carbon dioxide gas to moles using ideal gas equation.
2 - Convert moles carbon dioxide to moles HCl using chemical equation.
3 - Caclulate molarity of HCl by dividing moles HCl and volume (in L) of HCl solution.

---

①

$PV = nRT$

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

$P = 0.950 \text{ atm}$ $V = 125.0 \text{ mL} = 0.1250 \text{ L}$

$R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$ $T = 290.2 \text{ K}$

$$n_{CO_2} = \frac{(0.950 \text{ atm})(0.1250 \text{ L})}{\left(0.08206 \frac{L \cdot atm}{mol \cdot K}\right)(290.2 \text{ K})} = 0.0049866019 \text{ mol } CO_2$$

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

②

$$0.0049866019 \text{ mol } CO_2 \times \frac{2 \text{ mol } HCl}{\text{mol } CO_2} = 0.0099732038 \text{ mol } HCl$$

③

$$M_{HCl} = \frac{\text{mol } HCl}{\text{L solution}} = \frac{0.0099732038 \text{ mol } HCl}{0.04890 \text{ L}} = \boxed{0.204 \text{ M } HCl}$$

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?

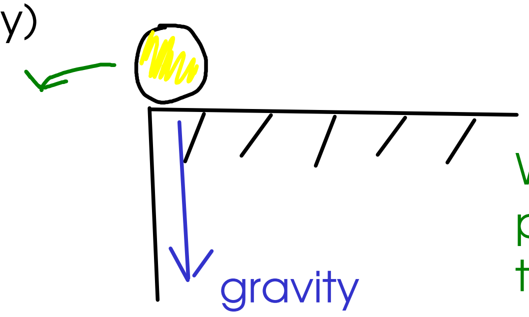
  - energy is the ability to do "work"

motion of matter

Kinds of energy?

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

- 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)

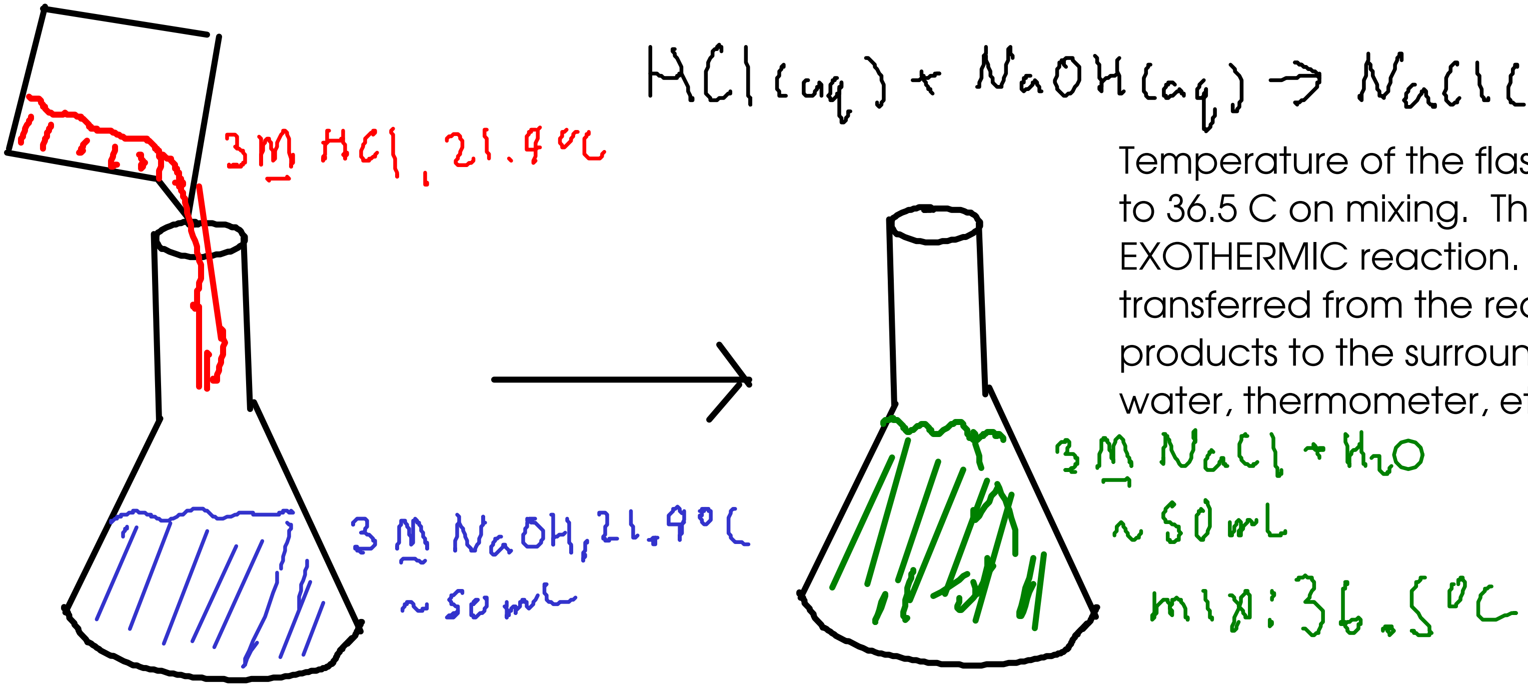
Q : heat

SYSTEM: the object or material under study

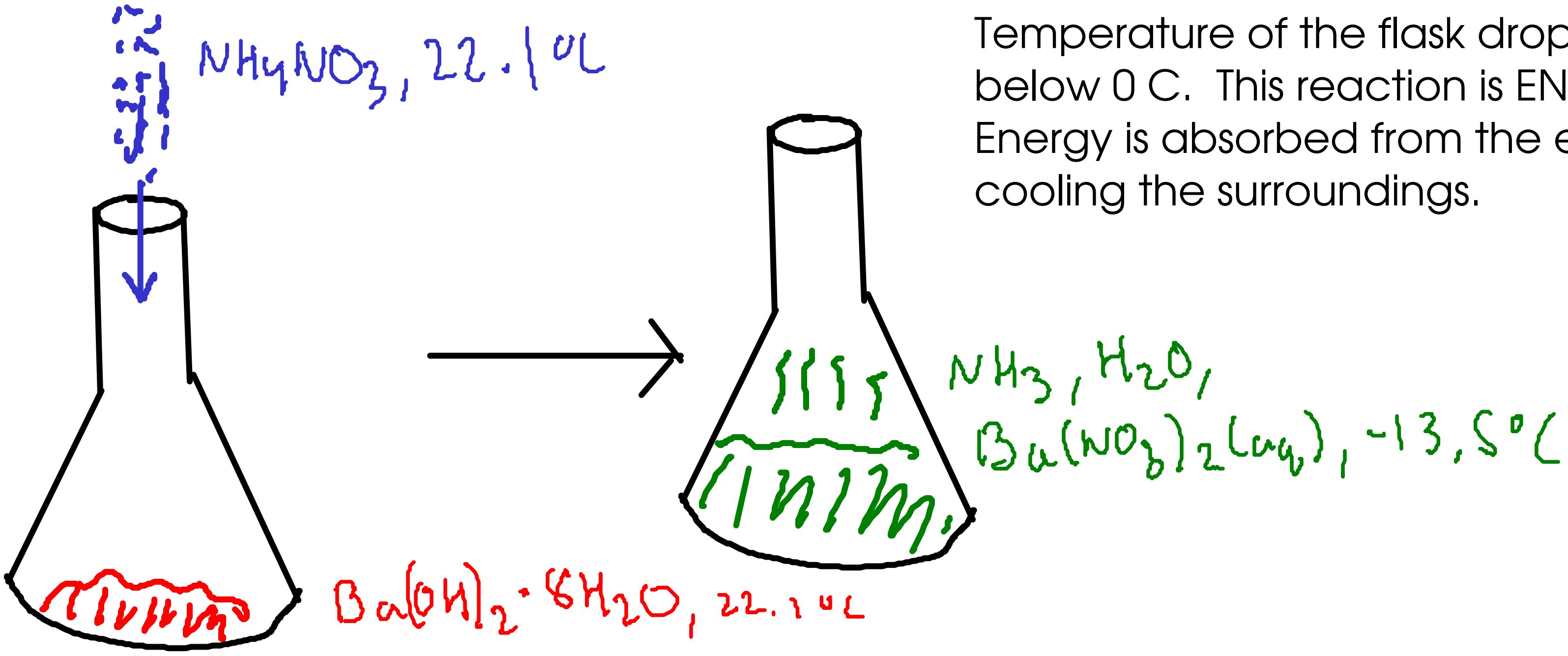
SURROUNDINGS: everything else

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

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



Temperature of the flask goes up to 36.5 C on mixing. This is an EXOTHERMIC reaction. Energy is transferred from the reactants/ products to the surroundings (flask, water, thermometer, etc.)

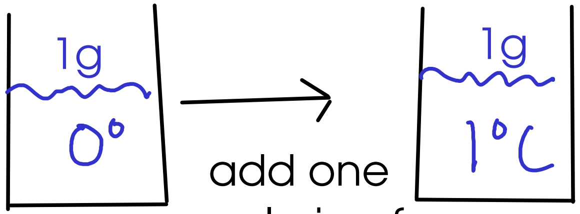


Temperature of the flask drops to well below 0 C. This reaction is ENDOTHERMIC, Energy is absorbed from the envoirnment, cooling the surroundings.

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



add one
calorie of
energy

- 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

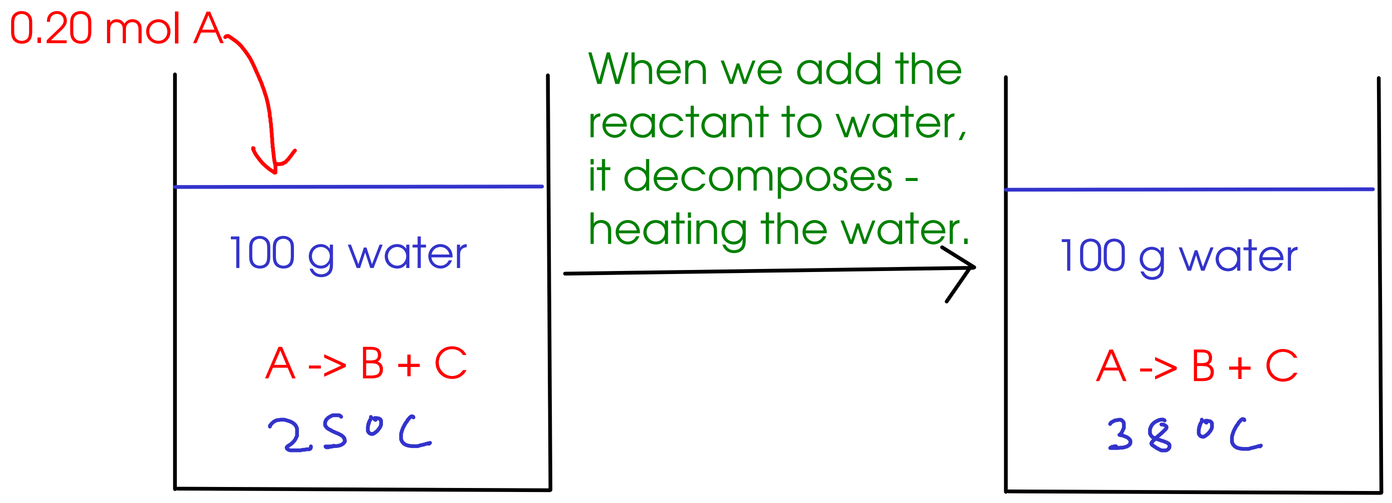
$$\underset{\text{kinetic energy}}{E_K} = \frac{1}{2}\,\underset{\text{mass}}{m}\,\underset{\text{velocity}}{v}^2$$

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,

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

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

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

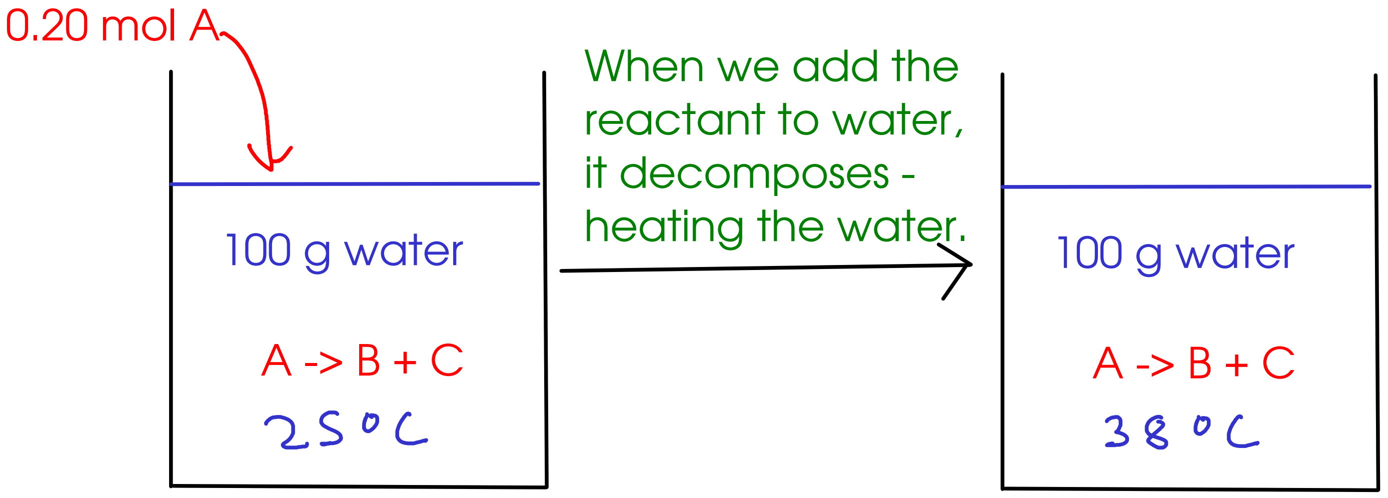
This is ALWAYS final temp minus initial temp!

- 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:

$4.184 \ \mathrm{J/g\,°C}$

$$Q_r + Q_w = 0$$

$$Q_w = m_w \times S_w \times \Delta T_w$$
$$= (100\,\mathrm{g})\left(4.184\,\frac{\mathrm{J}}{\mathrm{g\,°C}}\right)(38\,°\mathrm{C} - 25\,°\mathrm{C})$$
$$= 5439.2\,\mathrm{J}$$

$$Q_r + 5439.2\,\mathrm{J} = 0 \ ; \ Q_r = -5439.2\,\mathrm{J}$$

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

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

This number is usually called the "HEAT OF REACTION"