

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?



- 1 - Convert volume of 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 HCl using formula weight. (And a gram->kg conversion)

$$\textcircled{1} \quad PV = nRT \quad \left| \quad P = 1.00 \text{ atm} \quad V = 2500 \text{ L} \right.$$

$$n = \frac{PV}{RT} \quad \left| \quad R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \quad T = 25.0^\circ\text{C} = 298.2 \text{ K} \right.$$

$$n_{\text{Cl}_2} = \frac{(1.00 \text{ atm})(2500 \text{ L})}{\left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}\right)(298.2 \text{ K})} = 102.1646983 \text{ mol Cl}_2$$

$$\text{mol Cl}_2 = 2 \text{ mol HCl}$$

$$\text{H: } 1 \times 1.008$$

$$\text{Cl: } 1 \times 35.45$$

$$36.458 \text{ g HCl} = \text{mol HCl}$$

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

$$102.1646983 \text{ mol Cl}_2 \times \frac{2 \text{ mol HCl}}{\text{mol Cl}_2} \times \frac{36.458 \text{ g HCl}}{\text{mol HCl}} \times \frac{\text{Kg}}{10^3 \text{ g}} = \boxed{7.45 \text{ kg HCl}}$$

②
③

Calculate the mass of <sup>\*</sup>22650 L of oxygen gas at 25.0 C and 1.18 atm pressure.



\* Volume of a 10'x10'x8' room

- 1 - Convert volume oxygen gas to moles using ideal gas equation.
- 2 - Convert moles oxygen gas to mass using formula weight.

$$\textcircled{1} \quad PV = nRT \quad \left| \quad \begin{array}{l} P = 1.18 \text{ atm} \\ V = 22650 \text{ L} \end{array} \quad \begin{array}{l} R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \\ T = 25.0^\circ\text{C} = 298.2 \text{ K} \end{array} \right.$$

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

$$n_{\text{O}_2} = \frac{(1.18 \text{ atm})(22650 \text{ L})}{\left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}\right)(298.2 \text{ K})} = 1092.222357 \text{ mol O}_2$$

$$\textcircled{2} \quad 32.00 \text{ g O}_2 = \text{mol O}_2$$

$$1092.222357 \text{ mol O}_2 \times \frac{32.00 \text{ g O}_2}{\text{mol O}_2} = \boxed{35000 \text{ g O}_2} \sim 77 \text{ lb} \quad \begin{array}{l} 35.0 \text{ kg} \\ \sim 77 \text{ lb} \end{array}$$



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:

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

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 - Calculate molarity of HCl: moles HCl / volume HCl

---

$$\textcircled{1} n = \frac{PV}{RT}$$

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

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

$$n_{\text{CO}_2} = \frac{(0.950 \text{ atm})(0.1250 \text{ L})}{\left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}\right)(290.2 \text{ K})} = 0.0049866019 \text{ mol CO}_2$$


---

$$\textcircled{2} 2 \text{ mol HCl} = \text{mol CO}_2$$

$$0.0049866019 \text{ mol CO}_2 \times \frac{2 \text{ mol HCl}}{\text{mol CO}_2} = 0.0099732038 \text{ mol HCl}$$

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

- 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"

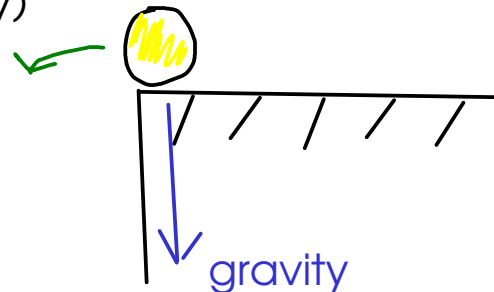
↑  
motion of matter

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.

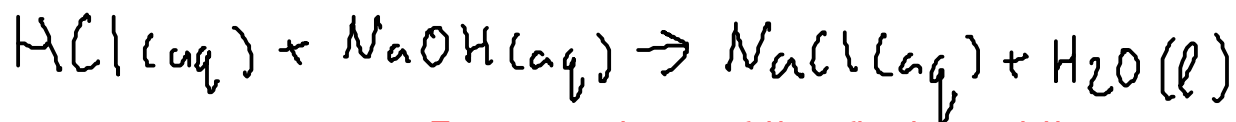
- We measure energy transfer ... which is called HEAT. (HEAT is the flow of energy from an area of higher temperature to an area of lower temperature)

*Q: heat*

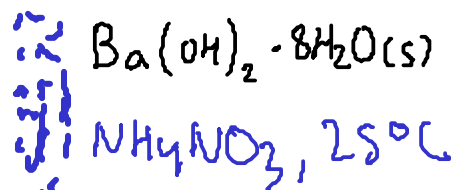
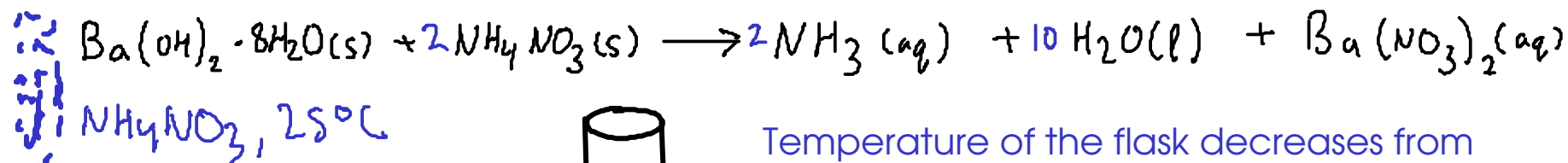
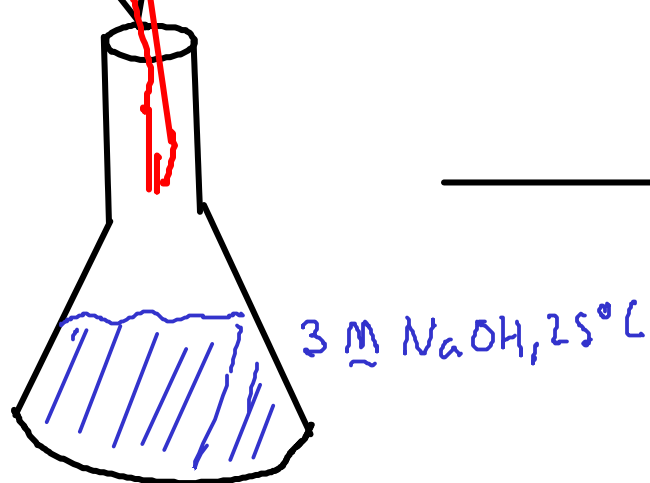
SYSTEM: the object or material under study

SURROUNDINGS: everything else

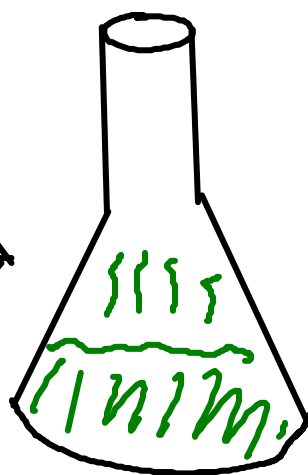
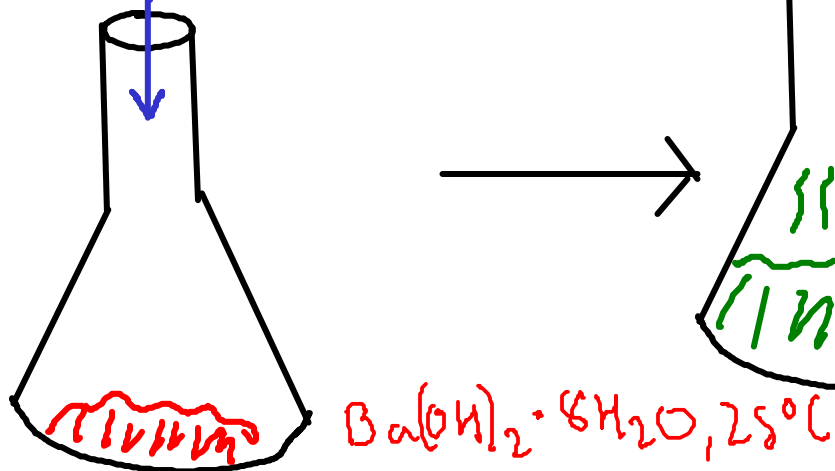
Type of process	Energy is ...	Sign of Q	Temp of SURROUNDINGS ...
ENDOTHERMIC	transferred from SURROUNDINGS to SYSTEM	+	decreases
EXOTHERMIC	transferred from SYSTEM to SURROUNDINGS	-	increases



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

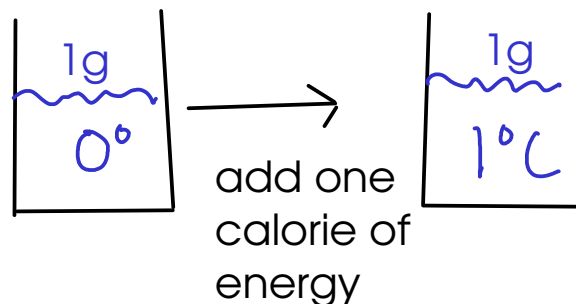


Temperature of the flask decreases from 25 degrees to less than 0°C. This reaction is ENDOTHERMIC - it absorbs energy from the environment!



## ENERGY UNITS

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



$1\text{g} \approx 1\text{mL}$  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.

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

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

kinetic  
energy

mass

velocity

$$4.184\text{ J} = 1\text{ cal}$$

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