

## 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

$$PV = nRT \quad ] \text{ Ideal gas equation}$$

$$\left( P + \frac{n^2 a}{V^2} \right) (V - nb) = nRT \quad ] \text{ van der Waals equation}$$

attempts to account for attractive / repulsive forces

attempts to account for molecular size

\* "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<sub>2</sub>O:  $a = 5,537$ ,  $b = 0,03049$  small, but strong attractions between molecules

CH<sub>3</sub>CH<sub>2</sub>OH:  $a = 12,56$   $b = 0,08710$  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?



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

$$\textcircled{1} \quad PV = nRT \quad \left| \quad P = 1.00 \text{ atm} \quad V = 2500 \text{ L} \quad R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \right.$$

$$n = \frac{PV}{RT} \quad \left| \quad T = 25.0^\circ\text{C} = 298.2 \text{ K} \right.$$

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

$$\textcircled{2} \text{ mol Cl}_2 = 2 \text{ mol HCl} \quad \textcircled{3} \text{ HCl} - \text{H} : 1 \times 1.008$$

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

$$\textcircled{2} \quad 36.458 \text{ g HCl} = \text{mol HCl}$$

$$102.1646983 \text{ mol Cl}_2 \times \frac{2 \text{ mol HCl}}{\text{mol Cl}_2} \times \frac{36.458 \text{ g HCl}}{\text{mol HCl}} = 7450 \text{ g HCl}$$

Problem wants kg, so ...

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



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?

1 - Convert 48.90 mL of HCl solution to moles. Use MOLARITY.

2 - Convert moles HCl to moles carbon dioxide gas. Use CHEMICAL EQUATION.

3 - Convert moles carbon dioxide gas to PRESSURE. Use IDEAL GAS EQUATION.

$$\textcircled{1} 0.250 \text{ mol HCl} = \text{L} \quad \textcircled{2} 2 \text{ mol HCl} = \text{mol CO}_2 \quad \text{mL} = 10^{-3} \text{L}$$

$$48.90 \text{ mL} \times \frac{10^{-3} \text{ L}}{\text{mL}} \times \frac{0.250 \text{ mol HCl}}{\text{L}} \times \frac{\text{mol CO}_2}{2 \text{ mol HCl}} = 0.006125 \text{ mol CO}_2$$

$$\textcircled{3} \begin{array}{l} PV = nRT \\ P = \frac{nRT}{V} \end{array} \quad \begin{array}{l} n = 0.006125 \text{ mol CO}_2 \quad R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \\ T = 290.2 \text{ K} \quad V = 50.0 \text{ mL} = 0.0500 \text{ L} \end{array}$$

$$P = \frac{(0.006125 \text{ mol CO}_2)(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}})(290.2 \text{ K})}{0.0500 \text{ L}} =$$

$$= \boxed{2.9 \text{ atm}}$$

- 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"

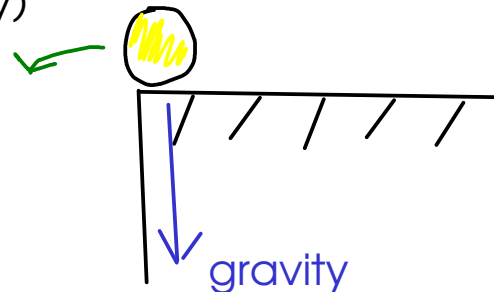
↑  
motion of matter

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.

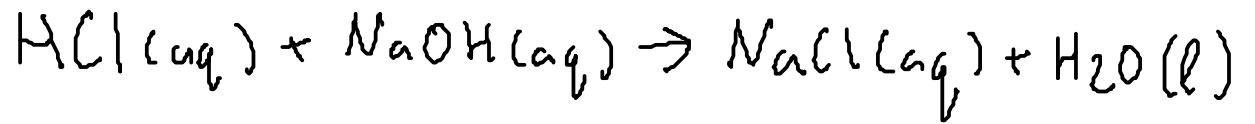
- We measure energy transfer ... which is called HEAT. (HEAT is the flow of energy from an area of higher temperature to an area of lower temperature)

*Q: heat*

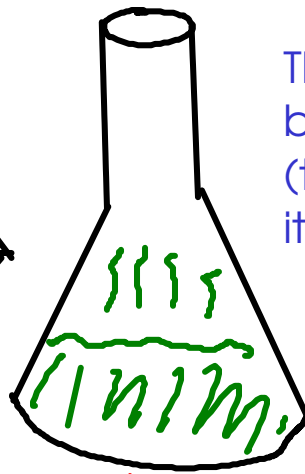
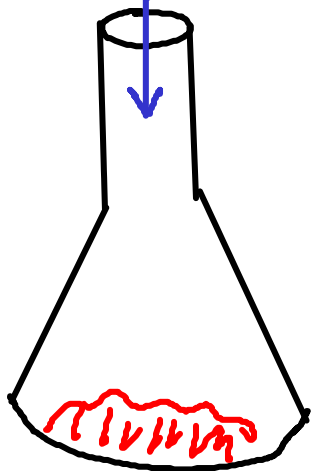
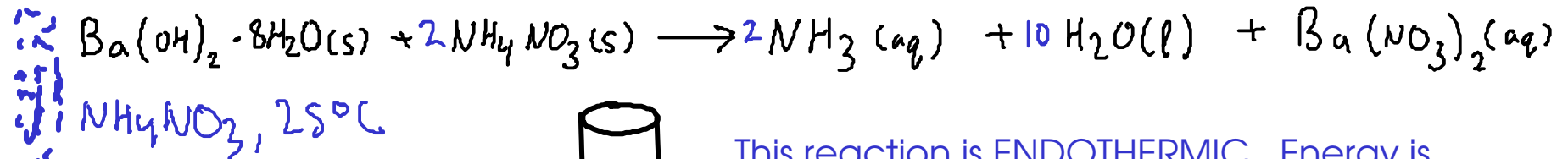
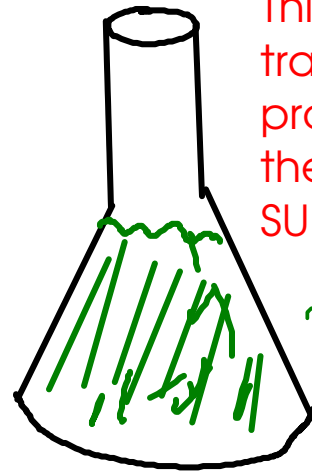
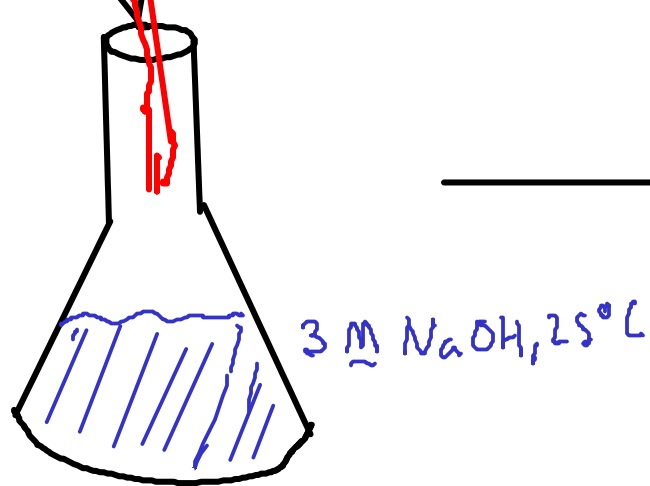
SYSTEM: the object or material under study

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



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)



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

