

$$FW_{\text{NH}_4\text{NO}_3} = 80.0434 \text{ g/mol}$$



At 300°C , ammonium nitrate violently decomposes to produce nitrogen gas, oxygen gas, and water vapor. What is the total volume of gas that would be produced at 1.00 atm by the decomposition of 15.0 grams of ammonium nitrate?

To simplify this problem, find the TOTAL MOLES of gas rather than using the individual substances!

- 1 - Convert 15.0 g of ammonium nitrate to moles using formula weight
- 2 - Convert moles ammonium nitrate to moles gas using chemical equation
- 3 - Convert moles gas to volume using ideal gas equation

$$80.0434 \text{ g NH}_4\text{NO}_3 = 1 \text{ mol NH}_4\text{NO}_3 \quad | \quad 2 \text{ mol NH}_4\text{NO}_3 = 7 \text{ mol gas}$$

$$15.0 \text{ g NH}_4\text{NO}_3 \times \frac{1 \text{ mol NH}_4\text{NO}_3}{80.0434 \text{ g NH}_4\text{NO}_3} \times \frac{7 \text{ mol gas}}{2 \text{ mol NH}_4\text{NO}_3} = 0.655894 \text{ mol gas}$$

$$V = \frac{nRT}{P} \quad \left\{ \begin{array}{l} n = 0.655894 \text{ mol} \quad R = 0.08206 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}} \quad V = ??? \\ T = 300^\circ\text{C} = 573 \text{ K} \quad P = 1.00 \text{ atm} \end{array} \right.$$

$$V = \frac{(0.655894 \text{ mol}) \left(0.08206 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}\right) (573 \text{ K})}{(1.00 \text{ atm})} = 30.8 \text{ L gas}$$

- The empirical gas laws (including the ideal gas equation) do not always apply.
 - The gas laws don't apply in situations where the assumptions made by kinetic theory are not valid.
 - When would it be FALSE that the space between gas molecules is much larger than the molecules themselves?
 - at high pressure, molecules would be much closer together!
 - When would it be FALSE that attractive and repulsive forces would be negligible?
 - at high pressure, attractions and repulsions should be stronger!
 - at low temperature, attractions and repulsions have a more significant affect on the paths of molecules



- The gas laws are highly inaccurate near the point where a gas changes to liquid!
- In general, the lower the pressure and the higher the temperature, the more IDEAL a gas behaves.

¹⁴³van 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 molecular size

attempts to account for attractive / repulsive forces

* "a" and "b" are experimentally determined parameters that are different for each gas. p211

He: $a = 0,0346$, $b = 0,0238$ tiny, no special attractive forces

H₂O: $a = 5,537$, $b = 0,03049$ small, but strong attractions between molecules

CH₃CH₂OH: $a = 12,56$ $b = 0,08710$ 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 using ideal gas equation
- 2 - Convert moles chlorine gas to moles HCl using chemical equation
- 3 - Convert moles HCl to mass using formula weight

$$PV = nRT$$

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

$$P = 1.00 \text{ atm} \quad R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \quad V = 2500 \text{ L}$$

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

$$n = ???$$

$$\textcircled{1} \quad n = \frac{PV}{RT} = \frac{(1.00 \text{ atm})(2500 \text{ L})}{\left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}\right)(298.2 \text{ K})} = 102.1647 \text{ mol Cl}_2$$

$$\text{mol Cl}_2 = 2 \text{ mol HCl} \quad | \quad 36.461 \text{ g HCl} = \text{mol HCl} \quad | \quad \text{kg} = 10^3 \text{ g}$$

$$102.1647 \text{ mol Cl}_2 \times \underbrace{\frac{2 \text{ mol HCl}}{\text{mol Cl}_2}}_{\textcircled{2}} \times \underbrace{\frac{36.461 \text{ g HCl}}{\text{mol HCl}} \times \frac{\text{kg}}{10^3 \text{ g}}}_{\textcircled{3}} = \boxed{7.45 \text{ kg HCl}}$$

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



* Volume of a 10'x10'x8' room

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

$$PV = nRT$$

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

$$P = 1.18 \text{ atm}$$

$$V = 22650 \text{ L}$$

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

$$n = ?$$

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

$$\textcircled{1} \quad n = \frac{(1.18 \text{ atm})(22650 \text{ L})}{\left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}\right)(298.2 \text{ K})} = 1092.222 \text{ mol O}_2$$

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

$$1092.222 \text{ mol O}_2 \times \frac{32.00 \text{ g O}_2}{\text{mol O}_2} = 35000 \text{ g O}_2$$

$$\boxed{\begin{array}{l} 35,0 \text{ kg} \\ \text{or} \\ 77 \text{ lb} \end{array}}$$



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: $\underline{M \text{ of HCl}} = \frac{\text{moles HCl}}{\text{L solution}} \leftarrow 0.04890 \text{ L}$

- 1 - Convert volume of carbon dioxide to moles using ideal gas equation
- 2 - Convert moles carbon dioxide to moles HCl using chemical equation
- 3 - Divide moles HCl / 0.04890 L solution to find molarity

$n = \frac{PV}{RT}$	$P = 0.950 \text{ atm}$	$T = 290.2 \text{ K}$	$n = ?$
	$V = 125.0 \text{ mL} = 0.1250 \text{ L}$	$R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}$	

$$\textcircled{1} \quad n_{\text{CO}_2} = \frac{(0.950 \text{ atm})(0.1250 \text{ L})}{(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}})(290.2 \text{ K})} = 0.0049866 \text{ mol CO}_2$$

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

$$0.0049866 \text{ mol CO}_2 \times \frac{2 \text{ mol HCl}}{\text{mol CO}_2} = 0.0099732 \text{ mol HCl}$$

$$\textcircled{3} \quad M_{\text{HCl}} = \frac{0.0099732 \text{ mol HCl}}{0.04890 \text{ L}} = \boxed{0.204 \text{ M HCl}}$$

- 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"

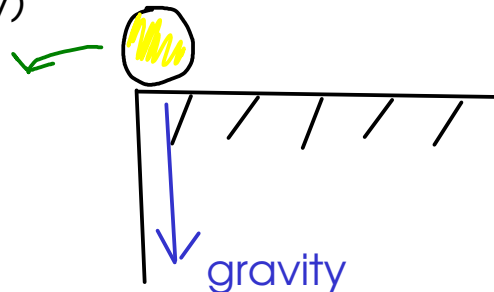
↑
└ motion of matter

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)

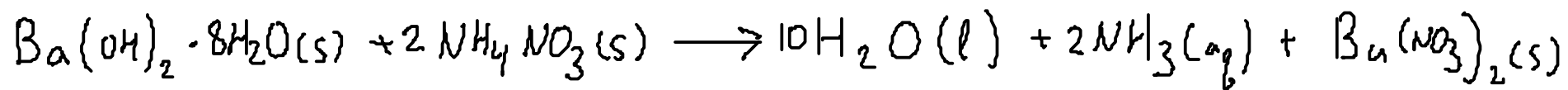
Q: heat

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

Reaction demonstration:



Observations:

- * Reaction vessel is COLD
- * Liquid
- * Odor (ammonia)

