A balloon is taken from a room where the temperature is 27.0 C to a freezer where the temperature is -5.0 C. If the balloon has a volume of 3.5 L in the 27.0 C room, what is the volume of the balloon in the freezer. Assume pressure is constant.

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ but $P_1 = P_2$; $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$V_1 = 3.5\,L$

$T_1 = 27.0°C = 300.2\,K$

$V_2 = ?$

$T_2 = -5.0°C = 268.2\,K$

$\frac{(3.5\,L)}{(300.2\,K)} = \frac{V_2}{(268.2\,K)}$

$3.1\,L = V_2$

2.25 L of nitrogen gas is trapped in a piston at 25.0 C and 1.00 atm pressure. If the piston is pushed in so that the gas's volume is 1.00 L while the temperature increases to 31.0 C, what is the pressure of the gas in the piston?

$P_1 = 1.00\,atm$

$V_1 = 2.25\,L$

$T_1 = 25.0°C = 298.2\,K$

$P_2 = ?$

$V_2 = 1.00\,L$

$T_2 = 31.0°C = 304.2\,K$

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$\frac{(1.00\,atm)(2.25\,L)}{(298.2\,K)} = \frac{P_2(1.00\,L)}{(304.2\,K)}$

$2.30\,atm = P_2$

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

↖ O_2

*Volume of a 10'x10'x8' room

O_2: 32.00 g O_2 = mol O_2

1 - Use the IDEAL GAS EQUATION (PV=nRT) to find MOLES of oxygen gas.
2 - Convert the moles of oxygen gas to mass using FORMULA WEIGHT.

$PV = nRT$

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

$P = 1.18\ atm$

$V = 22650\ L$

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

$T = 25.0°C = 298.2\ K$

① $n_{O_2} = \frac{(1.18\ atm)(22650\ L)}{(0.08206\ \frac{L\cdot atm}{mol\cdot K})(298.2\ K)} = 1092.222357\ mol\ O_2$

② 32.00 g O_2 = mol O_2

$1092.222357\ mol\ O_2 \times \frac{32.00\ g\ O_2}{mol\ O_2} = \boxed{35\bar{0}00\ g\ O_2}$ = 35.0 Kg ~77 lb

CHEMICAL CALCULATIONS WITH THE GAS LAWS

$FW_{NaHCO_3} = 84.007\ g/mol$

$$H_2SO_4(aq) + 2NaHCO_3(s) \rightarrow 2H_2O(l) + 2CO_2(g) + Na_2SO_4(aq)$$

Given 25.0 g of sodium bicarbonate and sufficient sulfuric acid, what volume of carbon dioxide gas would be produced at 25.0 C and 0.950 atm pressure?

1 - Convert 25.0 grams sodium bicarbonate to moles. Use FORMULA WEIGHT.
2 - Convert moles sodium bicarbonate to moles carbon dioxide. Use CHEMICAL EQUATION.
3 - Convert moles carbon dioxide to volume. Use IDEAL GAS EQUATION.

(1) $84.007\ g\ NaHCO_3 = mol\ NaHCO_3$ (2) $2\ mol\ NaHCO_3 = 2\ mol\ CO_2$

$$25.0\ g\ NaHCO_3 \times \underbrace{\frac{mol\ NaHCO_3}{84.007\ g\ NaHCO_3}}_{(1)} \times \underbrace{\frac{2\ mol\ CO_2}{2\ mol\ NaHCO_3}}_{(2)} = 0.2975942481\ mol\ CO_2$$

(3) $PV = nRT$

$V = \frac{nRT}{P}$

$n = 0.2975942481\ mol\ CO_2$ $T = 25.0°C = 298.2\ K$

$R = 0.08206\ \frac{L\text{-}atm}{mol\cdot K}$ $P = 0.950\ atm$

$$V = \frac{(0.2975942481\ mol\ CO_2)(0.08206\ \frac{L\text{-}atm}{mol\cdot K})(298.2\ K)}{(0.950\ atm)} = 7.67\ L \text{ of } CO_2 \text{ at } .950\ atm,\ 25.0°C$$

What volume would the gas in the last example problem have at STP?

STP: "Standard Temperature and Pressure" (0 C and 1 atm)

We can convert the answer to the previous problem to a volume at STP using the COMBINED GAS LAW.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$P_1 = 0.950\,atm$ $\quad$ $P_2 = 1\,atm$

$V_1 = 7.67\,L$ $\quad$ $V_2 = ?$

$T_1 = 298.2\,K$ $\quad$ $T_2 = 0°C = 273.2\,K$

$$\frac{(0.950\,atm)(7.67\,L)}{298.2\,K} = \frac{(1\,atm)V_2}{273.2\,K}$$

6.67 L at STP $= V_2$

(Alternate solution: Since we'd already calculated moles of gas, plug that and the pressure and temperature from STP into PV=nRT ...)

REAL GASES

- 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.

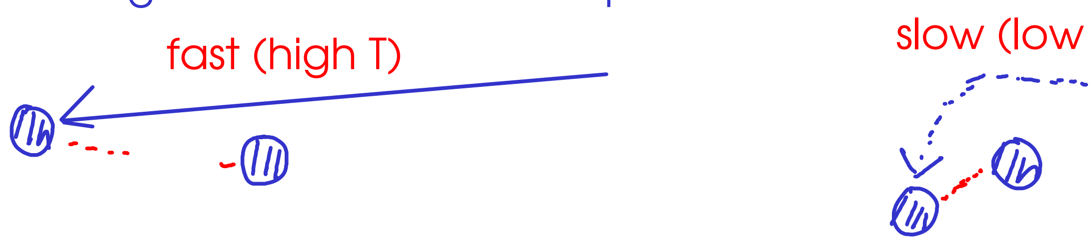
        - When would it be FALSE that the space between gas molecules is much larger than the molecules themselves?

            - 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.

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

$$PV = nRT$$ Ideal gas equation

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

nb: attempts to account for molecular size

$\frac{n^2 a}{V^2}$: attempts to account for attractive / repulsive forces

* "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_2O: a = 5.537, b = 0.03049 small, but strong attractions between moleculres

CH_3CH_2OH: a = 12.56 b = 0.08710 larger, and strong attractions between molecules

$25\bar{0}0$ 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?

$$H_2 + Cl_2 \rightarrow 2\,HCl$$

1 - Convert 2500 L 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.

(1) $PV = nRT$

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

$P = 1.00$ atm $R = 0.08206\ \frac{L\cdot atm}{mol\cdot K}$

$V = 25\bar{0}0$ L $T = 25.0\,°C = 298.2$ K

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

(2) mol Cl_2 = 2 mol HCl

(3) HCl - H: 1 x 1.008
Cl: 1 x 35.45
36.458 g HCl = mol HCl

$$102.1646983\ mol\ Cl_2 \times \overset{(2)}{\frac{2\ mol\ HCl}{mol\ Cl_2}} \times \overset{(3)}{\frac{36.458\ g\ HCl}{mol\ HCl}} = 7450\ g\ HCl$$

$kg = 10^3\ g$

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

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

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 0.250 M HCl to moles. Use MOLARITY.
2 - Covnert moles HCl to moles carbon dioxide. Use CHEMICAL EQUATION.
3 - Convert moles carbon dioxide to pressure. Use IDEAL GAS EQUATION.

---

(1) 0.250 mol HCl = L ; mL = 10^{-3} L (2) 2 mol HCl = mol CO_2

$$48.90\text{ mL} \times \frac{10^{-3}\text{ L}}{\text{mL}} \times \underbrace{\frac{0.250\text{ mol HCl}}{\text{L}}}_{(1)} \times \underbrace{\frac{\text{mol } CO_2}{2\text{ mol HCl}}}_{(2)} = 0.0061125\text{ mol } CO_2$$

---

(3) $PV = nRT$

$P = \dfrac{nRT}{V}$

$n = 0.0061125$ mol CO_2 $T = 290.2$ K

$R = 0.08206\ \dfrac{\text{L-atm}}{\text{mol}\cdot\text{K}}$ $V = 50.0$ mL $= 0.0500$ L

$$P = \frac{(0.0061125\text{ mol } CO_2)(0.08206\ \frac{\text{L-atm}}{\text{mol}\cdot\text{K}})(290.2\text{ K})}{0.0500\text{ L}}$$

$= \boxed{2.91\text{ atm}}$ of CO_2 at 50.0 mL, 290.2 K

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"

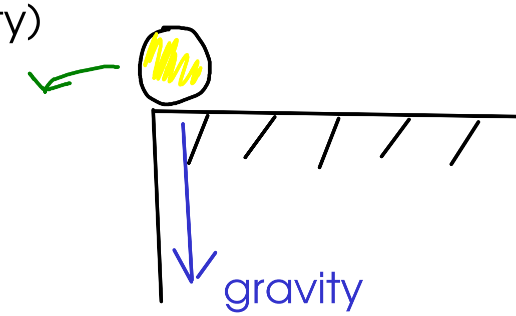
- ... but what IS energy?

  - energy is the ability to do "work" ← motion of matter

Kinds of energy?

- Kinetic energy: energy of matter in motion $E_K = \frac{1}{2} m v^2$ (m = mass, v = 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