

Section 1

Atoms and Molecules and their Functional Properties

Stoichiometry | converting | empirical formula | limiting reactants

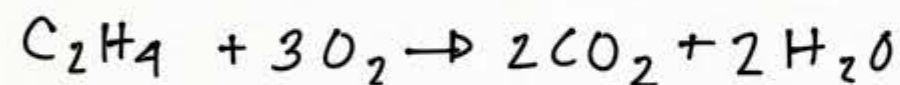
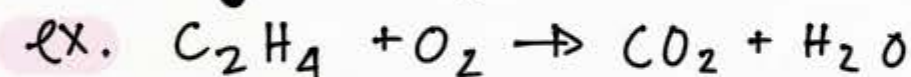
Tips when converting (g → mol / mol → g / mol → mol)

Make sure you try to cancel out any units you don't want.

Include the element when computing.

$$\text{ex. } 2 \text{ g } \cancel{\text{N}_2} \cdot \frac{1 \text{ mol } \cancel{\text{N}_2}}{28.02 \text{ g } \cancel{\text{N}_2}} \cdot \frac{3 \text{ mol } \text{H}_2}{1 \text{ mol } \cancel{\text{N}_2}} = 0.214 \text{ mol H}_2$$

Limiting Reagent



given 3.0 mol O_2 and 119 g C_2H_4 , what is the limiting reagent when forming CO_2 ?

$$119 \text{ g } \text{C}_2\text{H}_4 \cdot \frac{1 \text{ mol } \text{C}_2\text{H}_4}{28.06 \text{ g } \text{C}_2\text{H}_4} = 4.24 \text{ mol } \text{C}_2\text{H}_4$$

$$4.24 \text{ mol } \cancel{\text{C}_2\text{H}_4} \cdot \frac{2 \text{ mol } \text{CO}_2}{1 \text{ mol } \cancel{\text{C}_2\text{H}_4}} = 8.48 \text{ mol } \text{CO}_2$$

$$3.0 \text{ mol } \cancel{\text{O}_2} \cdot \frac{2 \text{ mol } \text{CO}_2}{3 \text{ mol } \cancel{\text{O}_2}} = 2 \text{ mol } \text{CO}_2$$

$$2 \text{ mol } \text{CO}_2 < 8.48 \text{ mol } \text{CO}_2 \rightarrow$$

O_2 is the limiting reagent

Empirical Formula

1. change % to grams → assuming 100 %
2. g → mol for all elements
3. divide each answer (moles) from above by the smallest answer.
4. multiply to get whole #'s
Rule: multiply 0.5 by 2
multiply 0.33/0.66 by 3
multiply 0.25/0.75 by 4
5. put the final # moles you calculated in the formula

Useful Unit Conversions / Numbers

Volume

$$1 \text{ g} = 1 \text{ mL}$$
$$1 \text{ mL} = 0.001 \text{ L} \rightarrow \frac{\times}{1000}$$
$$\text{STP} \rightarrow 22.4 \text{ L}$$

Mass

$$1 \text{ g} = 0.001 \text{ kg} \rightarrow \frac{\times}{1000}$$
$$1 \text{ kg} = 1000 \text{ g} \rightarrow \times \cdot 1000$$

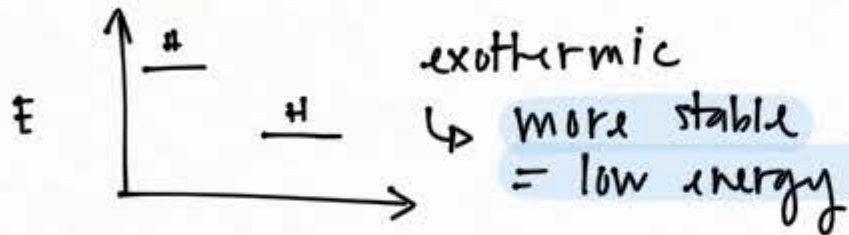
Constants

$$R = 8.3145 \text{ J/mol}\cdot\text{K}$$
$$N_A = 6.0221 \cdot 10^{23} / \text{mol}$$
$$k_B = \frac{8.3145 \text{ J/mol}\cdot\text{K}}{6.0221 \cdot 10^{23} / \text{mol}}$$
$$= 1.38 \cdot 10^{-23} \text{ J/K}$$
$$8.3145 \cdot 10^{-2} \text{ L bar/K}\cdot\text{mol}$$
$$8.20578 \cdot 10^{-2} \text{ L atm/K}\cdot\text{mol}$$
$$62.364 \text{ L Torr/K}\cdot\text{mol}$$

Chemical Bonding | Coulomb's Law | IE and EA | Lewis Structure | Resonance | Dipole / Polarity | Formal Charge | VSEPR Theory

Coulomb's Law

$$= k \frac{q_1 q_2}{r^2} \quad \text{or} \quad (231 \text{ aJ} \cdot \text{pm}) \frac{q_1 q_2}{d}$$



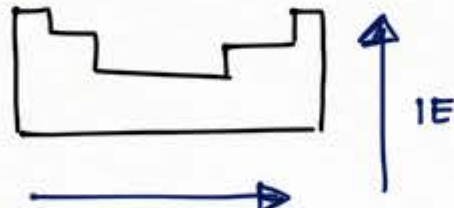
Ionization Energy

energy needed to yank an electron out of a shell.

the closer the e^- is to the proton, the stronger its attraction \Rightarrow higher IE.



closer = higher IE (attraction)



farther = lower IE

Connections:

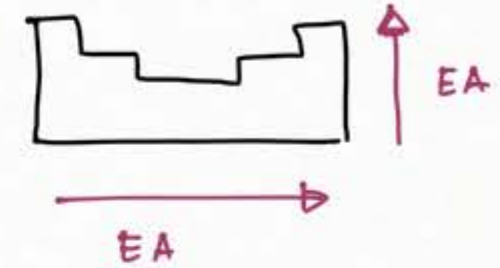
High IE

Low IE

- smaller critical Distance
- larger critical distance
- larger lattice energy
- smaller lattice energy \rightarrow

Electron Affinity

the energy released when accepting e^-
exothermic process



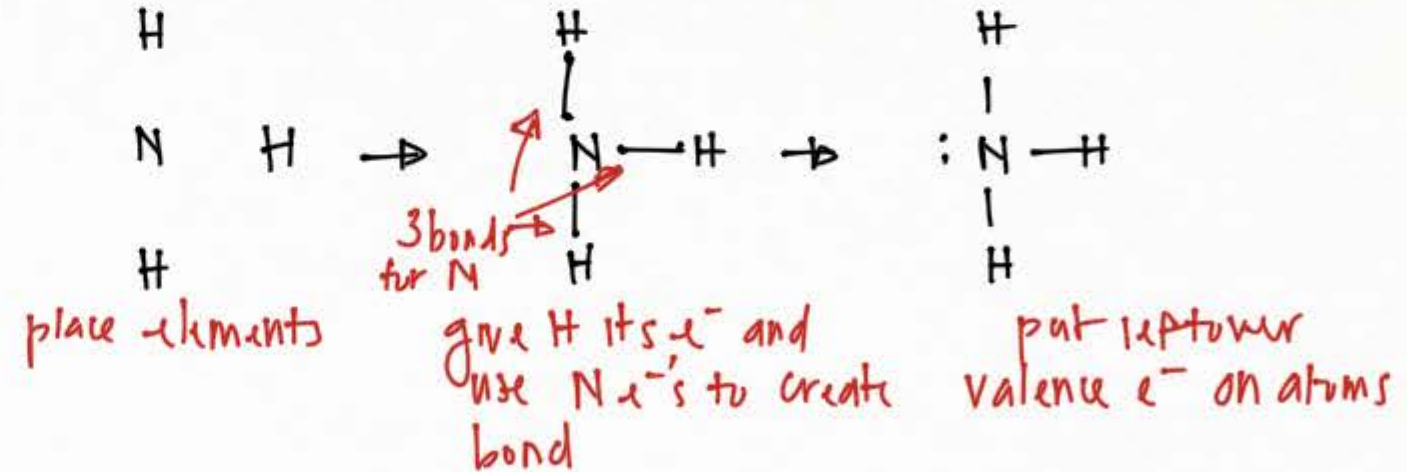
Lewis Structure

Trends:

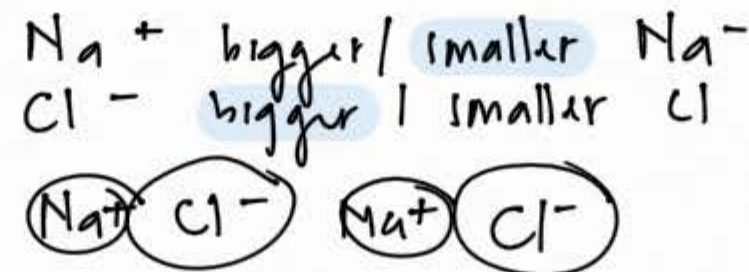
| likely # bonds | 2 | 3 | 4 | 3 | 2 | 1 |
|----------------|----|---|---|---|---|---|
| element | Be | B | C | N | O | F |
| valence e^- | 2 | 3 | 4 | 5 | 6 | 7 |

loses e^- gains e^-

N: 5 val e^- H: 1 val e^-



$$IE - EA > 0$$

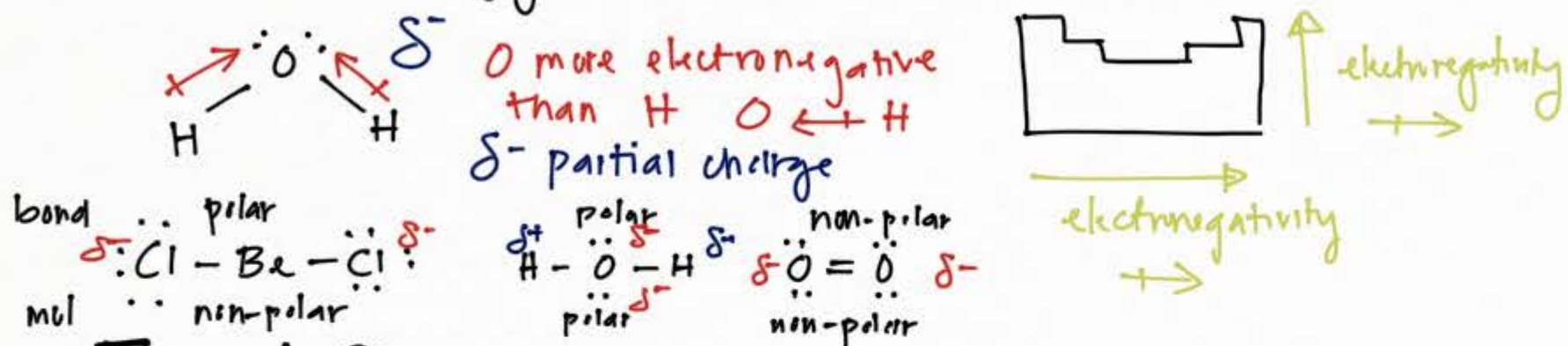


Resonance Structures

1. consider compounds with a double bond.

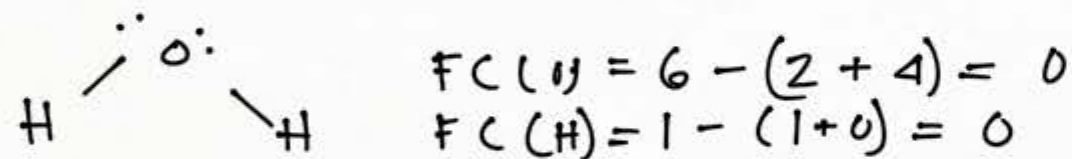
Dipole Moment / Polarity

electronegativity is directly related to ionization energy



Formal Charges

$$FC(\text{element}) = \text{valence } e^- - (\text{bond pairs} + \text{lon } e^-)$$



VSEPR Theory

Steric number (SN): # of electron domains, where one electron domain can be a lone pair, or single / double / triple bond.

Electron Geometry: based on # of electron domains

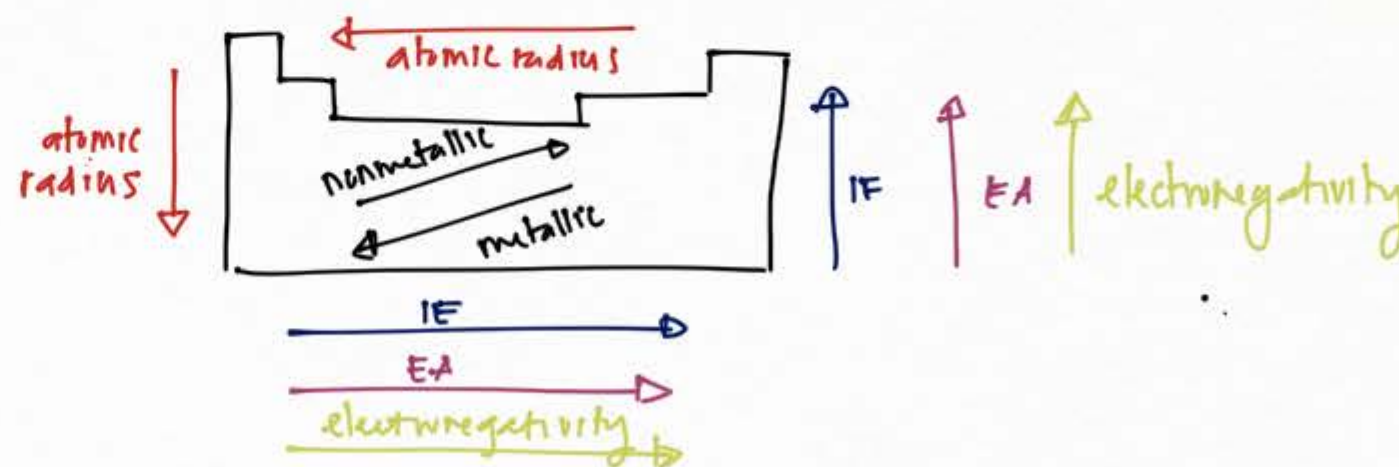
$$LP-LP > LP-bond > bond-bond$$

Molecular Geometry: lone pairs repulse, so they affect the angle of the geometry.

Practice

| Molecule | e^- Domains | Lewis | EG | MG | Bond Angle |
|---------------|---------------|--|-----------------|--------------------|-----------------|
| CH_4 | 4 | $\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{H} \\ \\ \text{H} \end{array}$ | tetrahedral | tetrahedral | 109.5° |
| PF_3 | 4 | $\begin{array}{c} :\ddot{\text{F}}: \\ \\ :\ddot{\text{P}}: \\ \\ :\ddot{\text{F}}: \end{array}$ | tetrahedral | trigonal pyramidal | $< 109.5^\circ$ |
| SF_2 | 4 | $\begin{array}{c} :\ddot{\text{F}}: \\ \\ :\ddot{\text{S}}: \\ \\ :\ddot{\text{F}}: \end{array}$ | tetrahedral | bent | $< 109.5^\circ$ |
| NO_2 | 3 | $:\ddot{\text{O}}-\ddot{\text{N}}=\ddot{\text{O}}:$ | trigonal planar | bent | 120° |
| BH_3 | 3 | $\begin{array}{c} \text{H}-\text{B}-\text{H} \\ \\ \text{H} \end{array}$ | trigonal planar | trigonal planar | 120° |

Periodic Trends



Thermodynamics | Ideal vs Real Gas | Work | Heat | Partial Pressure | Enthalpy | Graham's Law | Kirchhoff's Law

Ideal Gas Law

$$PV = nRT$$

$$\text{Prob}(v) \propto v^2 e^{-\frac{mv^2}{2k_bT}}$$

$$\text{Boltzmann's Probability } e^{-\frac{mv^2}{2k_bT}}$$

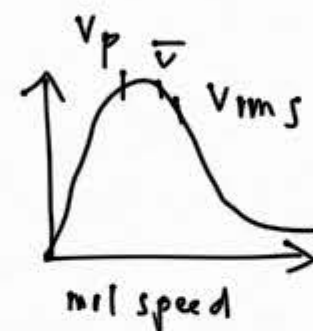
Root means Squared Speed

$$\sqrt{\frac{3k_bT}{m}}$$

$$\sqrt{\frac{8k_bT}{\pi m}} \quad \text{Average velocity}$$

Most Probable Speed

$$\sqrt{\frac{2k_bT}{m}}$$



$$KE = \frac{3}{2} k_bT = \frac{1}{2} m \langle v^2 \rangle \quad PE = \frac{5}{2} k_bT$$

Real Gas Laws

$$P = \frac{nRT}{(V-nb)} - a \left(\frac{n}{V} \right)^2$$

a : attraction \rightarrow polar has higher a
 b : volume

IMFs

London F < Dipole-Induced D < D-D < Ion-D < Ion-Ion

Weaker IMF's = higher vapor pressure = more evap
 Stronger IMF's = lower vapor pressure

Work

$$\Delta U = w + q$$

ΔU : change in internal energy
 w : work done on system
 q : heat added to system

$$\begin{aligned} w > 0 & \text{ on the system} \\ w < 0 & \text{ by the system} \\ w = 0 & \text{ none} \end{aligned}$$

$$w = -P_{\text{ext}} \Delta V \quad P = \frac{nRT}{V}$$

$$P_{\text{total}} = P_x + P_y + \dots$$

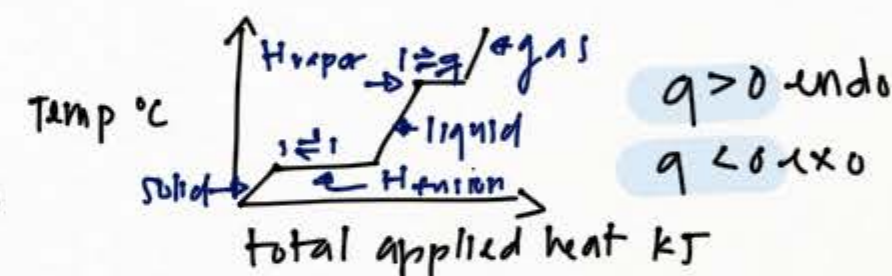
*Tip: add all moles and then plug and play to find P_{total}

Heat

$$q = \Delta E + P_{\text{ext}} \Delta V = \Delta H$$

Specific Heat Capacity

$$\begin{aligned} q &= m C \Delta T \\ q &= n \Delta H_{\text{fus/vap}} \end{aligned}$$



Graham's Law

$$\frac{\text{Rate}_a}{\text{Rate}_b} = \frac{N_a}{N_b} \left(\frac{m_b}{m_a} \right)^{1/2}$$

*Note: N = # molecules
 n = # moles

Enthalpy

$$\Delta H = \Delta E + P_{\text{ext}} \Delta V$$

$$\Delta H = \Delta H_{\text{products}} - \Delta H_{\text{reactants}}$$

*Tip: $\Delta H_{\text{elemental}} = 0$

Hess's Law Rules

1. Flip the reactions \rightarrow change sign
2. balance equations to cancel \rightarrow apply same calculations to the ΔH .

Special Paths

Adiabatic

- Spontaneous
- $\Delta U = -W$
- $-q = 0$
- $-W = -nR(T_2 - T_1)$

Isothermal

- $\Delta T = 0$
- $q = W$
- $W = nRT \ln \frac{V_2}{V_1}$

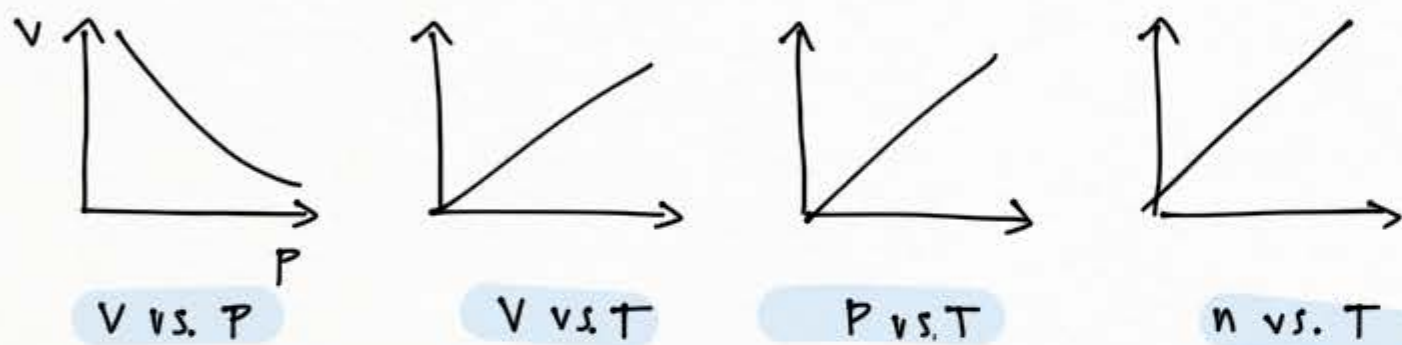
Isochoric

- $\Delta V = 0$
- $W = 0$
- $\Delta U = q$

Isobaric

- $P = \text{constant}$
- $W = P\Delta V$

Ideal Gas Laws Trends



Kirchoff's Law

$$\Delta H_{\text{rxn}}(T_2) = \Delta H_{\text{rxn}}(T_1) - (T_2 - T_1) \Delta C_p$$

Heat and Work Trends

$w > 0$ on system
 $w < 0$ by system

$q > 0$ endothermic
 $q < 0$ exothermic

Compression:

$$\Delta V < 0$$

$$w > 0$$



$$V \downarrow P \uparrow$$

$$U \uparrow$$

$$w = -P\Delta V$$

$$-P(-) = +$$

Expansion:

$$\Delta V > 0$$

$$w < 0$$



$$V \uparrow P \downarrow$$

$$U \downarrow$$

$$w = -P\Delta V$$

$$-P(+)= -$$

Phase Changes

$\text{sol} \rightarrow \text{liq} = \text{melting}$

$\text{liq} \rightarrow \text{sol} = \text{freezing}$

$\text{liq} \rightarrow \text{gas} = \text{boiling}$

$\text{gas} \rightarrow \text{liq} = \text{condensation}$

$\text{sol} \rightarrow \text{gas} = \text{sublimation}$

$\text{gas} \rightarrow \text{sol} = \text{deposition}$

Maximizing Conversion to Product

decrease pressure, concentration of prods
 increase temp, concentration of reagents