

Organic Chemistry: The Chemistry Of Carbon

Método de avaliação de QOG (2022-2023):

- 75% da classificação para a componente teórica da disciplina
- 25% da classificação para a componente prática da disciplina.
- Cada uma das componentes não pode ter avaliação final inferior a 9,5 valores (classificação de 0 a 20 valores).

Avaliação da componente teórica:

- 2 testes (factores de ponderação para o 1º e 2º testes respectivamente: 40% + 60%).
Nota mínima no 2º teste 8 valores.
Média final ponderada igual ou maior que 9,5 valores.

Avaliação da componente prática da UC:

Os alunos farão trabalho em grupos de 2, sendo a avaliação individual.

Critérios obrigatórios:

1- É obrigatório cada aluno ter caderno de laboratório.

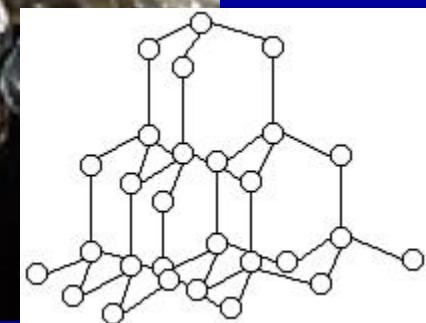
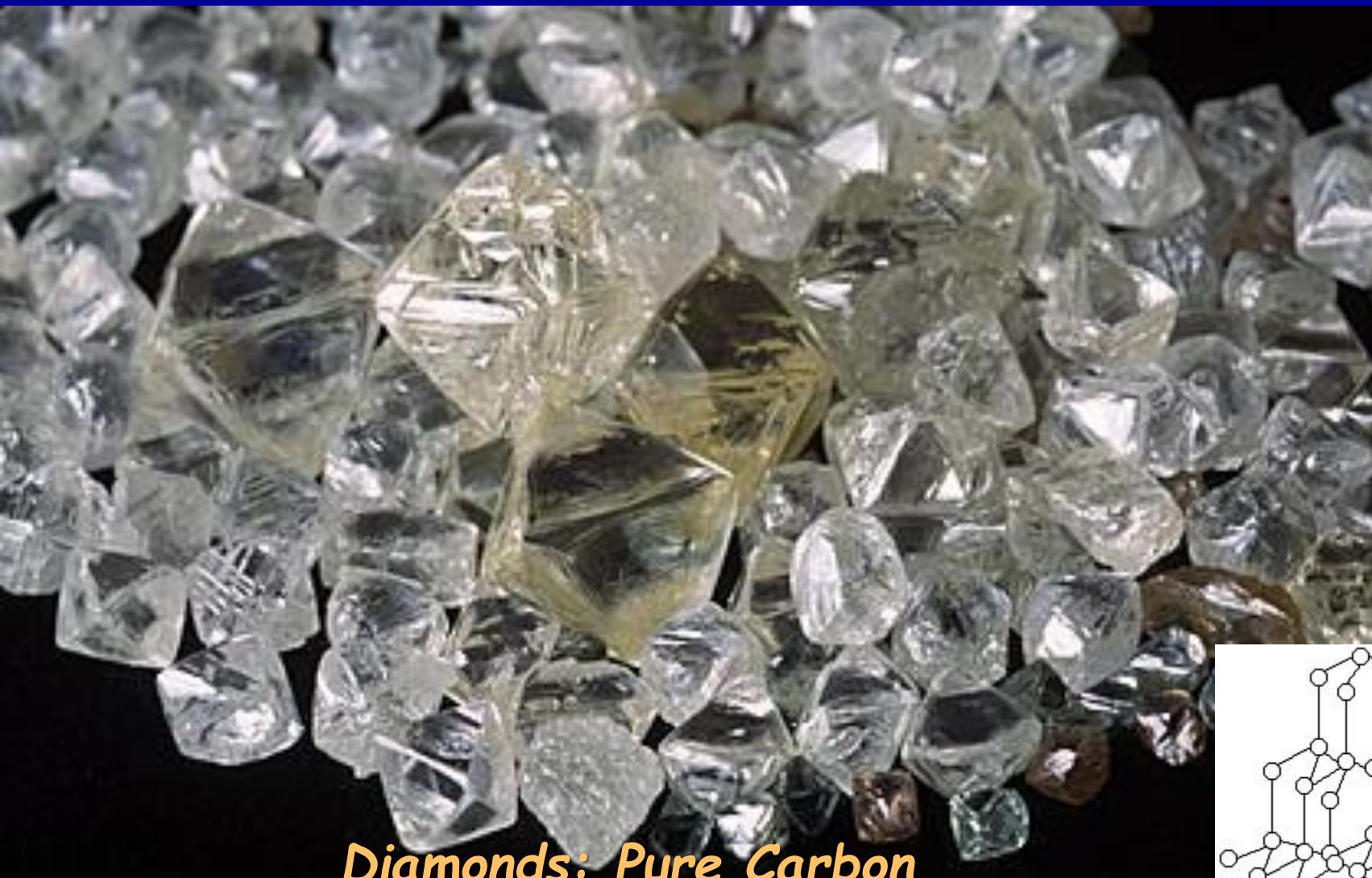
Nota 1: sem caderno de laboratório o aluno está impedido de frequentar as aulas práticas

2 - É obrigatória a presença em todas as aulas de laboratório (presenciais).

Nota: a não presença nas aulas de laboratório tem como consequência a NÃO FREQUÊNCIA a QOG.

Avaliação quantitativa da componente prática - média aritmética dos minitestes. Nota final igual ou superior a 9,5 valores.

Organic Chemistry: The Chemistry Of Carbon



Organic Chemicals



Mmmmmmmmmmmmmmmhhhh!!!!



Public Fear Of Chemistry

THE CHAR 'N' CHIPS

HALF CHICKEN AND CHIPS 10.90

QUARTER CHICKEN AND CHIPS 7.90

THE CHIPS

SMALL: 3.50

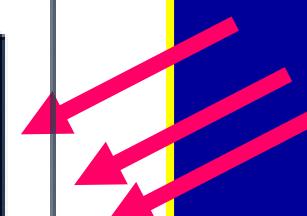
MEDIUM: 5.00

LARGE: 7.00

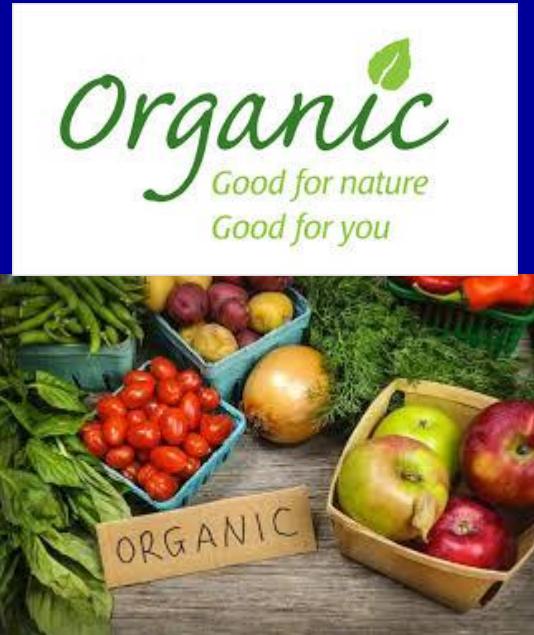
SALTS - PLAIN, CHICKEN, CHILLI

SAUCES - TOMATO, BBQ, RIOLO, SWEET CHILLI

OUR ROTISSERIE CHICKENS
ARE COMPLETELY FREE RANGE
NO STEROIDS, NO CHEMICALS
NO HORMONES

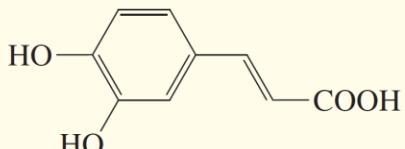


The Obsession With “Natural”



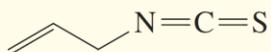
Hello ???! Nature Is Vicious...

Natural Plant Pesticides and Their Occurrence (in ppm)



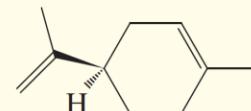
Caffeic acid
(Carcinogen)

Apple, carrot, celery, grapes, lettuce, potato (50–200); basil, dill, sage, thyme, and other herbs (>1000); coffee (roasted beans, 1800)



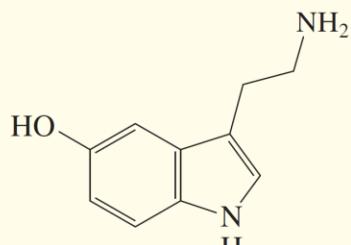
Allyl isothiocyanate
(Carcinogen)

Cabbage (35–590); cauliflower (12–66); Brussels sprouts (110–1560); brown mustard (16,000–72,000); horseradish (4500)



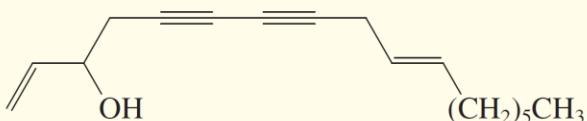
(R)-Limonene
(Carcinogen)

Orange juice (31); black pepper (8000)



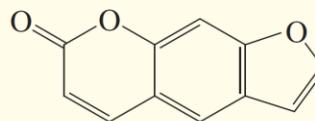
Serotonin
(Neurotransmitter,
vasoconstrictor)

Carrot (10–20)



Carotatoxin
(Neurotoxin)

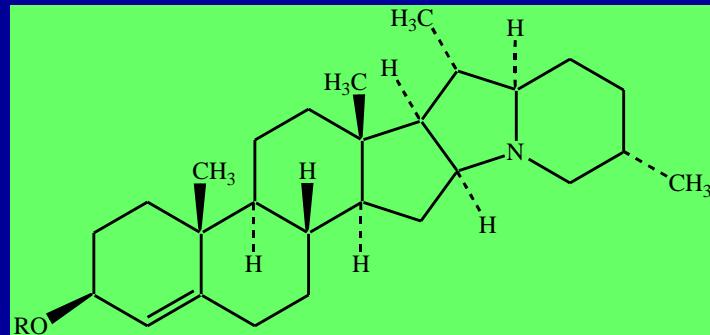
Parsley (11,000–112,000);
celery (1,300–46,000)



Psoralen
(Carcinogen)

Banana (15,000)

Chemical Protection In Nature



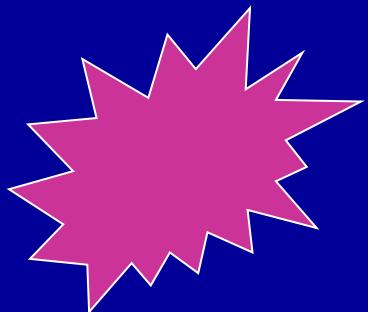
Solanine (R = trisaccharide)



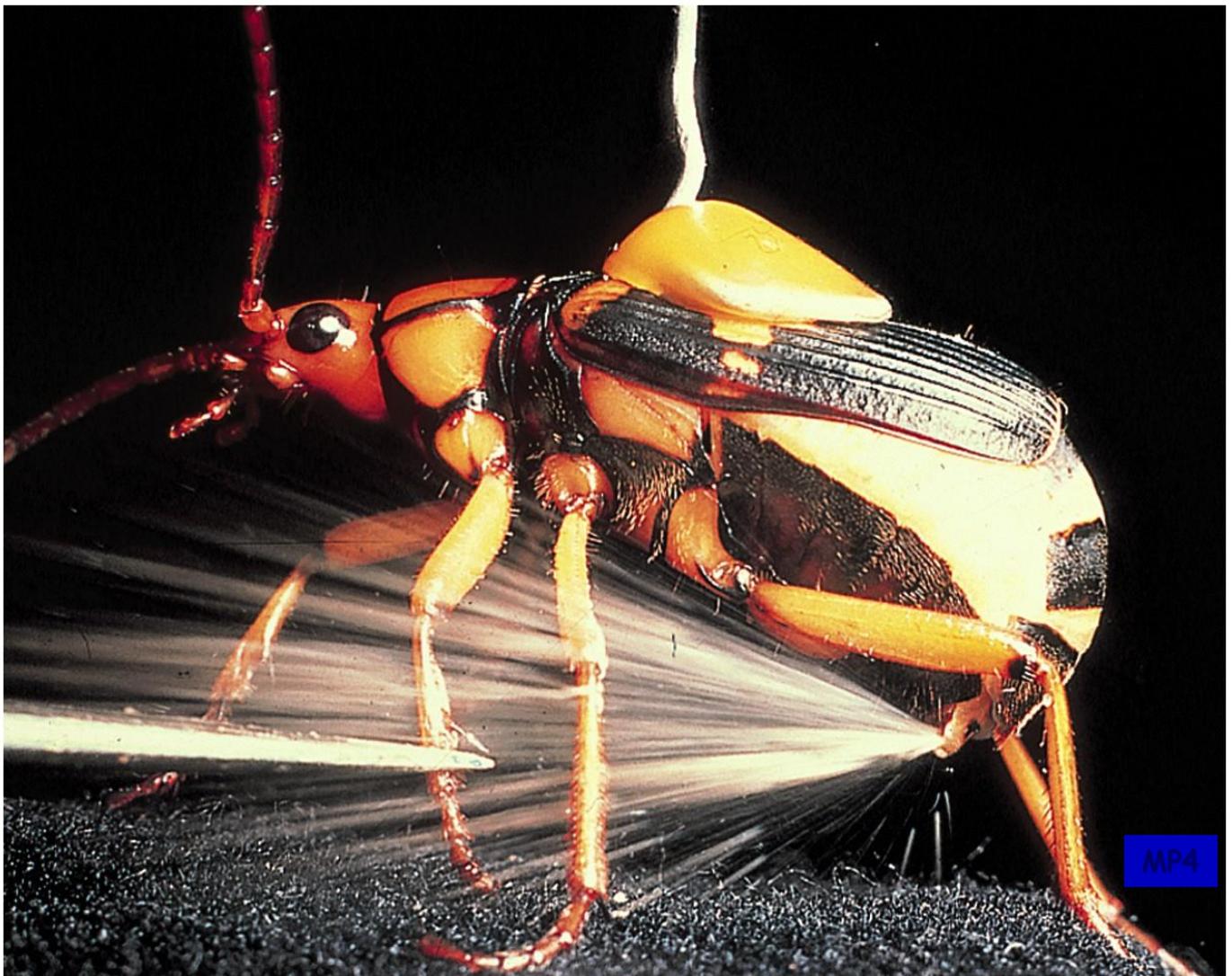
Nausea, diarrhea, vomiting,
cardiac dysrhythmia,
hallucinations, paralysis,
hypothermia, and death

Chemical Warfare In Nature

The Bombardier Beetle



Benzoquinone,
hydrogen
peroxide,
 100°C



The Californian Sea Hare Defends Itself From Predators With Sticky Ink



Aplysia californica

Nature Is The Biggest Polluter



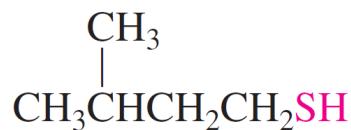


Kincade fire
Oct. 23, 2019

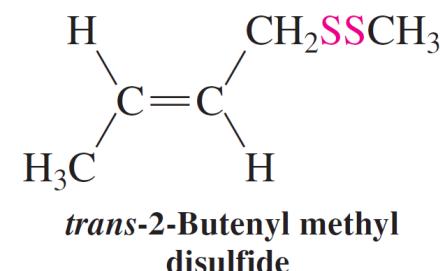
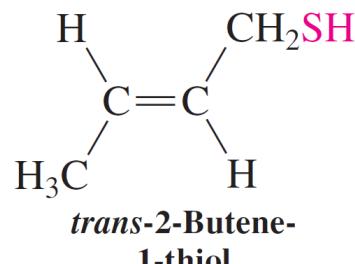
Thiols (And Sulfides) Stink...

Decomposing food, passing gas, power plants, natural gas additive methanethiol, stink bombs, waste water, feces, some chemistry departments.....

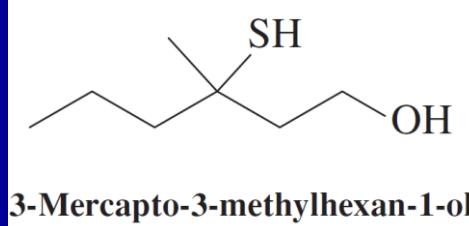
Skunk chemical defense:



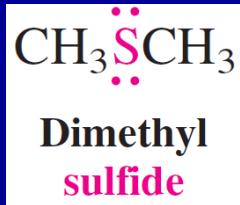
3-Methyl-1-butanethiol



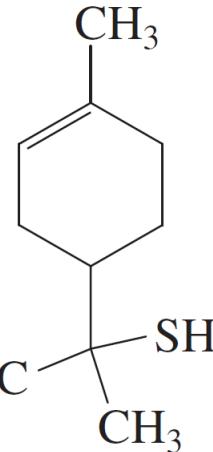
Body odour:



...But May Be Very Pleasant In Low Concentrations

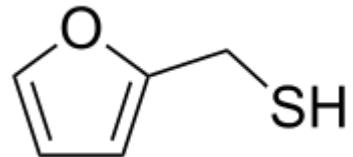


Black tea



Grapefruit

(*R,S*)-2-(4-Methyl-3-cyclohexenyl)-2-propanethiol



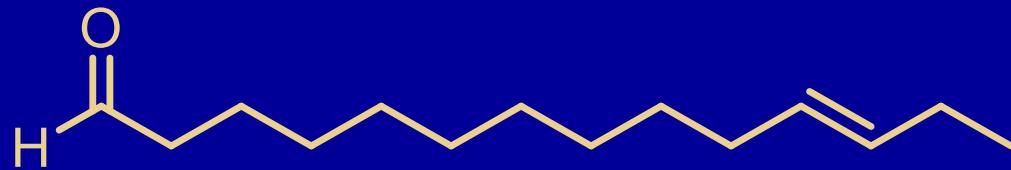
2-Furanylmethanethiol

Roasted coffee

Can be tasted at
the 10^{-5} ppb
level!!!

1 mg in 10 million liters

Pheromones: Chemical Communication



(E)-11-tetradecenal

Sex pheromone of the spruce budworm, the most destructive pest to the spruce and fir forests of North America



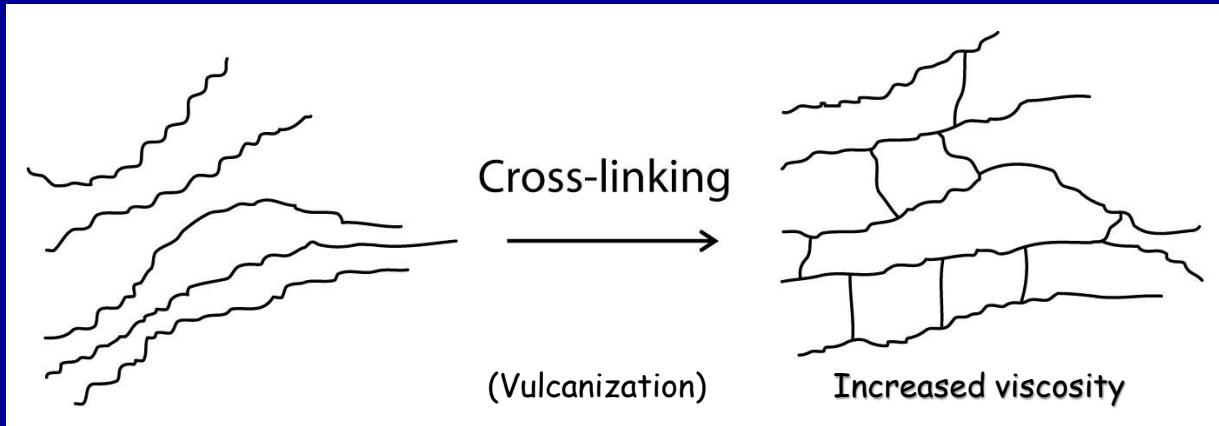
Kenai Peninsula, Alaska



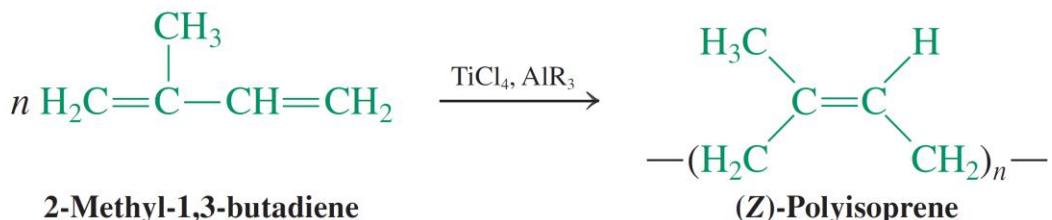
The Holy Grail: Human Sex Pheromones



Polymers

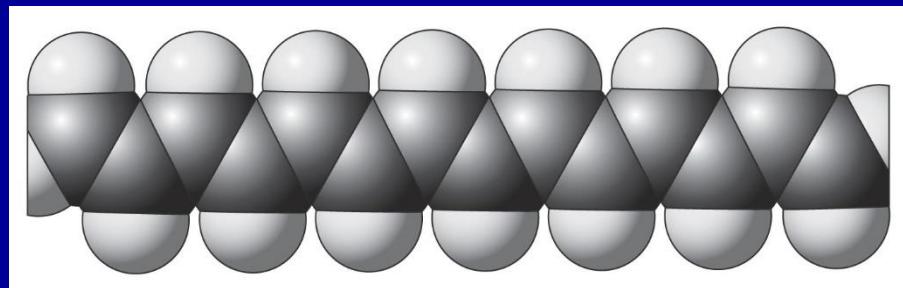
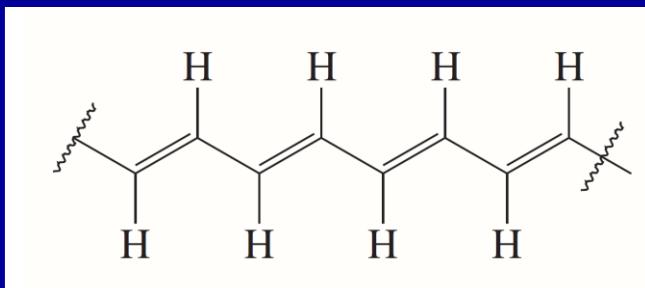


Latex: polyisoprene



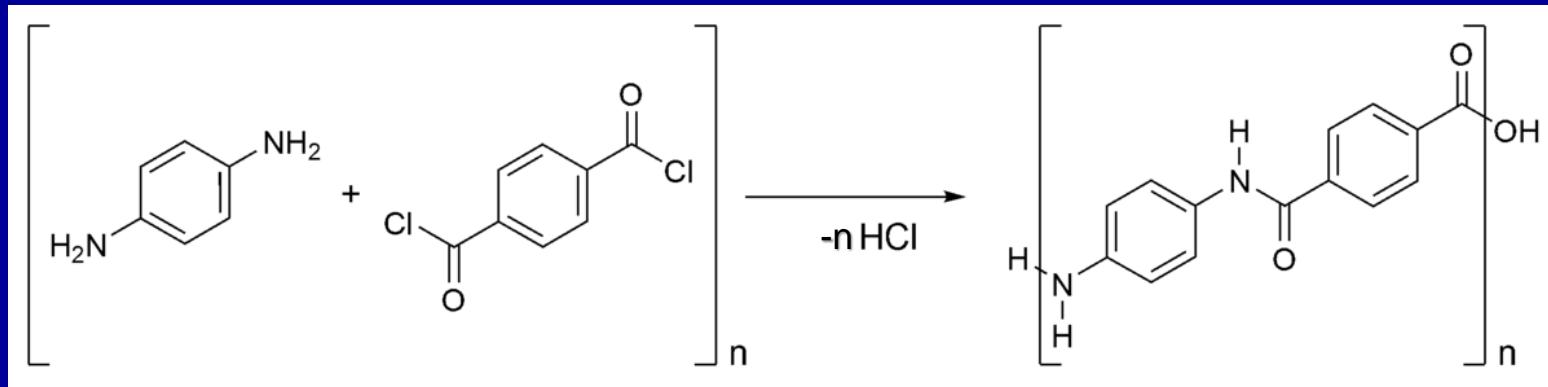
Extraction of latex from a tree,
for use in rubber production

Polyacetylene: Organic Conductors



Heeger, MacDiarmid, Shirakawa, Nobel prize 2000

Organic Polymers Harder Than Metal



The polyamide Kevlar

Bulletproof!

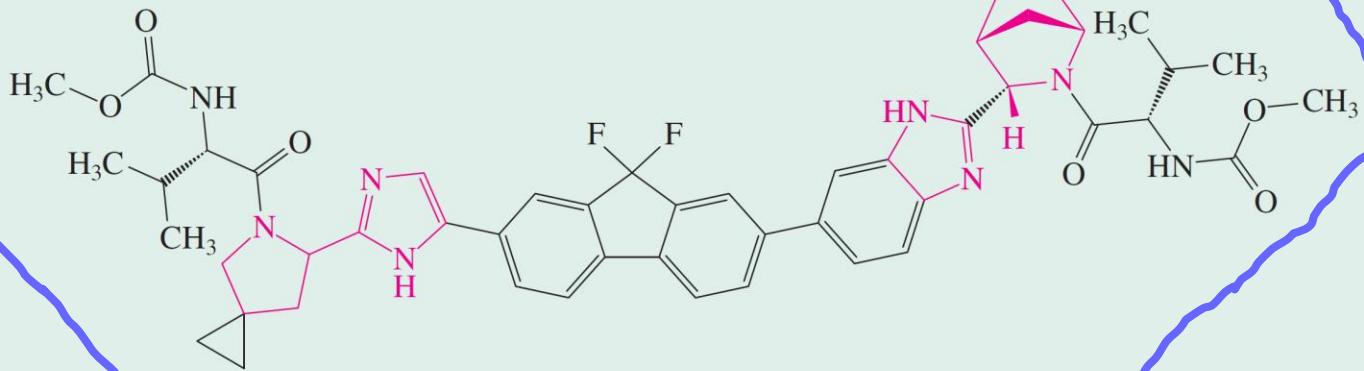


Medicines

Table 25.1

Top Ten Small Molecule U.S. Prescription Drugs (Ranked by 2016 Sales)^a by Generic and, in Parentheses, Selected Brand Names^b

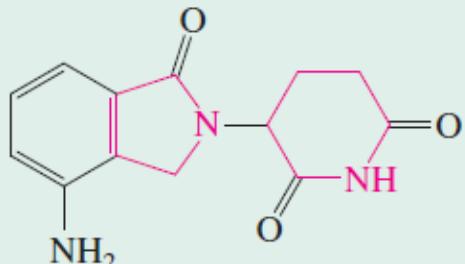
1. Ledipasvir and sofosbuvir mixture (Harvoni)



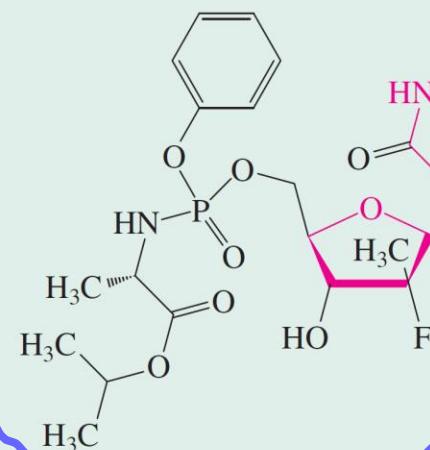
Ledipasvir

Cure for Hepatitis C

2. Lenalidomide (Revlimid)

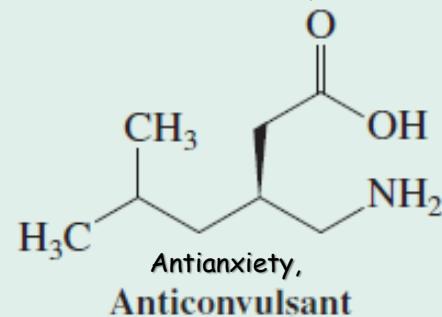


Anticancer



Sofosbuvir

5. Pregabalin (Lyrica)

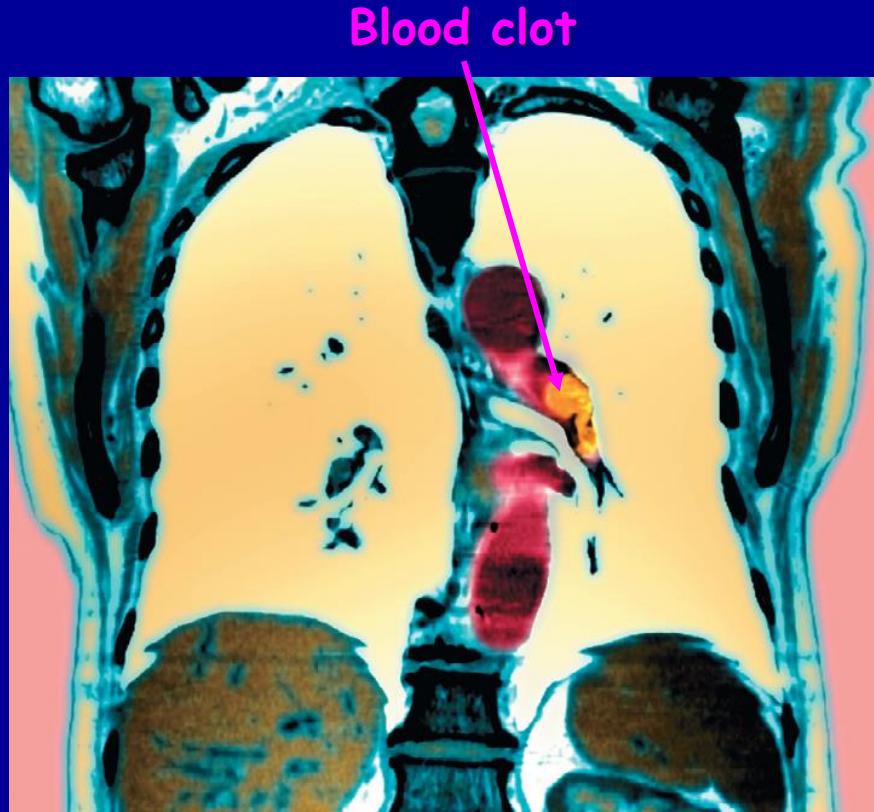


Antianxiety,
Anticonvulsant

Aspirin: the Most Successful Drug of All Times



Worldwide consumption
40,000 tons/year



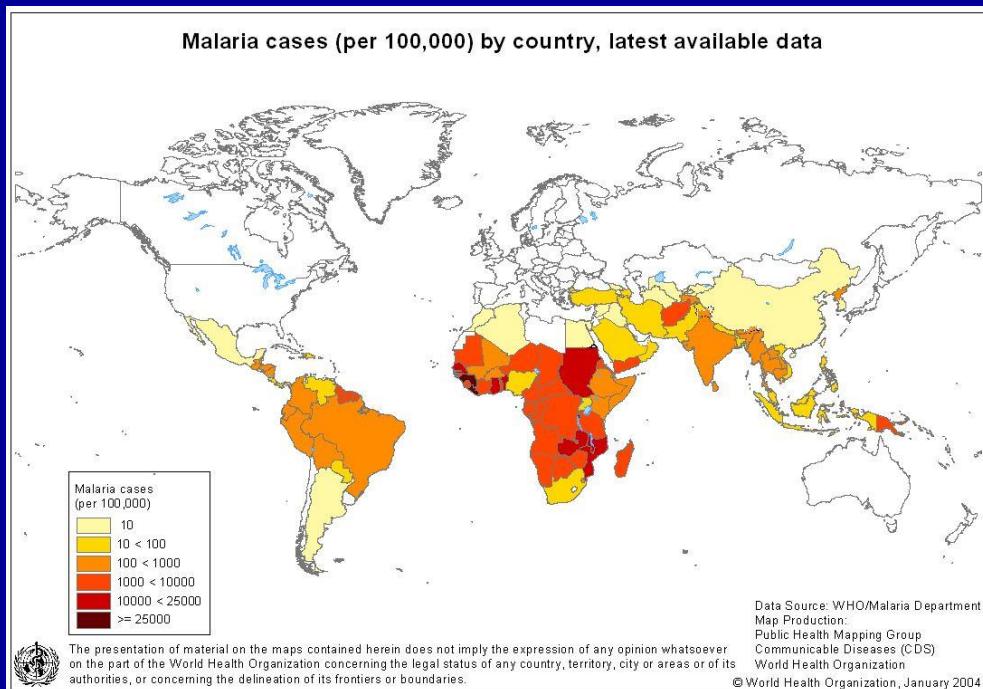
Analgesic, antipyretic,
anti-inflammatory, antiplatelet

Quinine: the First Antimalarial

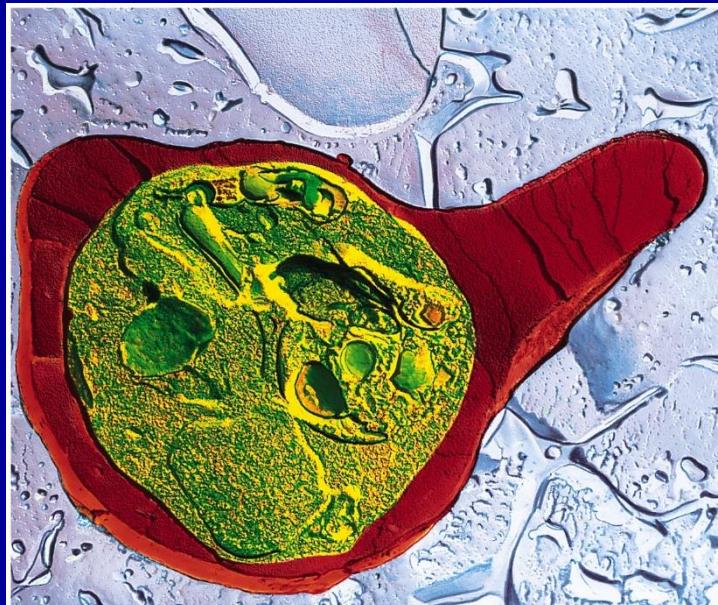


Anopheles mosquito

Mosquito

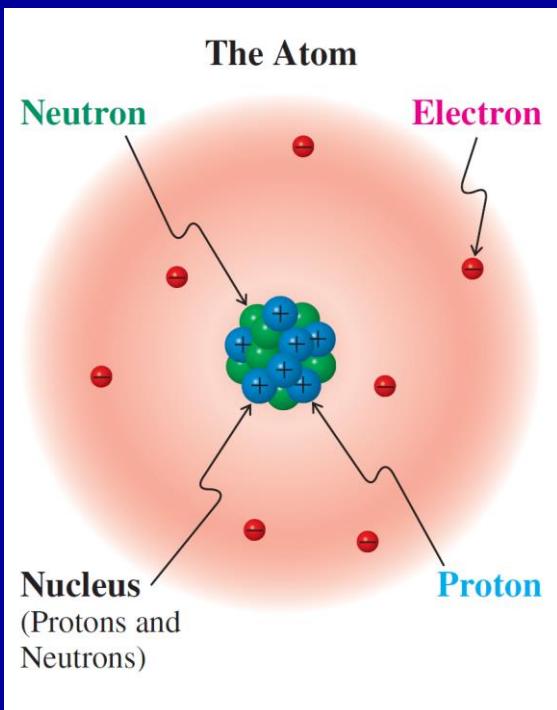


Worldwide 150–300 million cases of malaria;
1/2 million deaths; 2/3 are children under 15

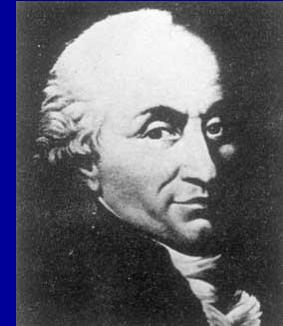


Malaria *Plasmodium* parasites (green) infect a blood cell

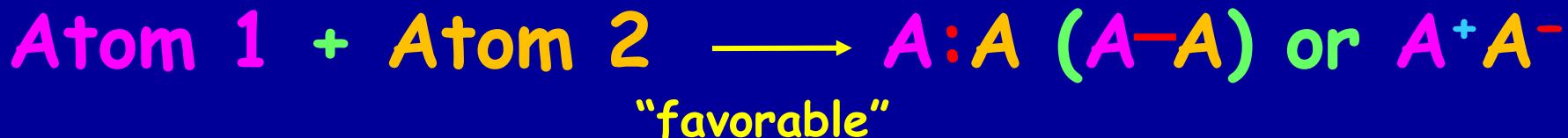
Chapter 1: Bonding



Classical view of atom (Bohr)



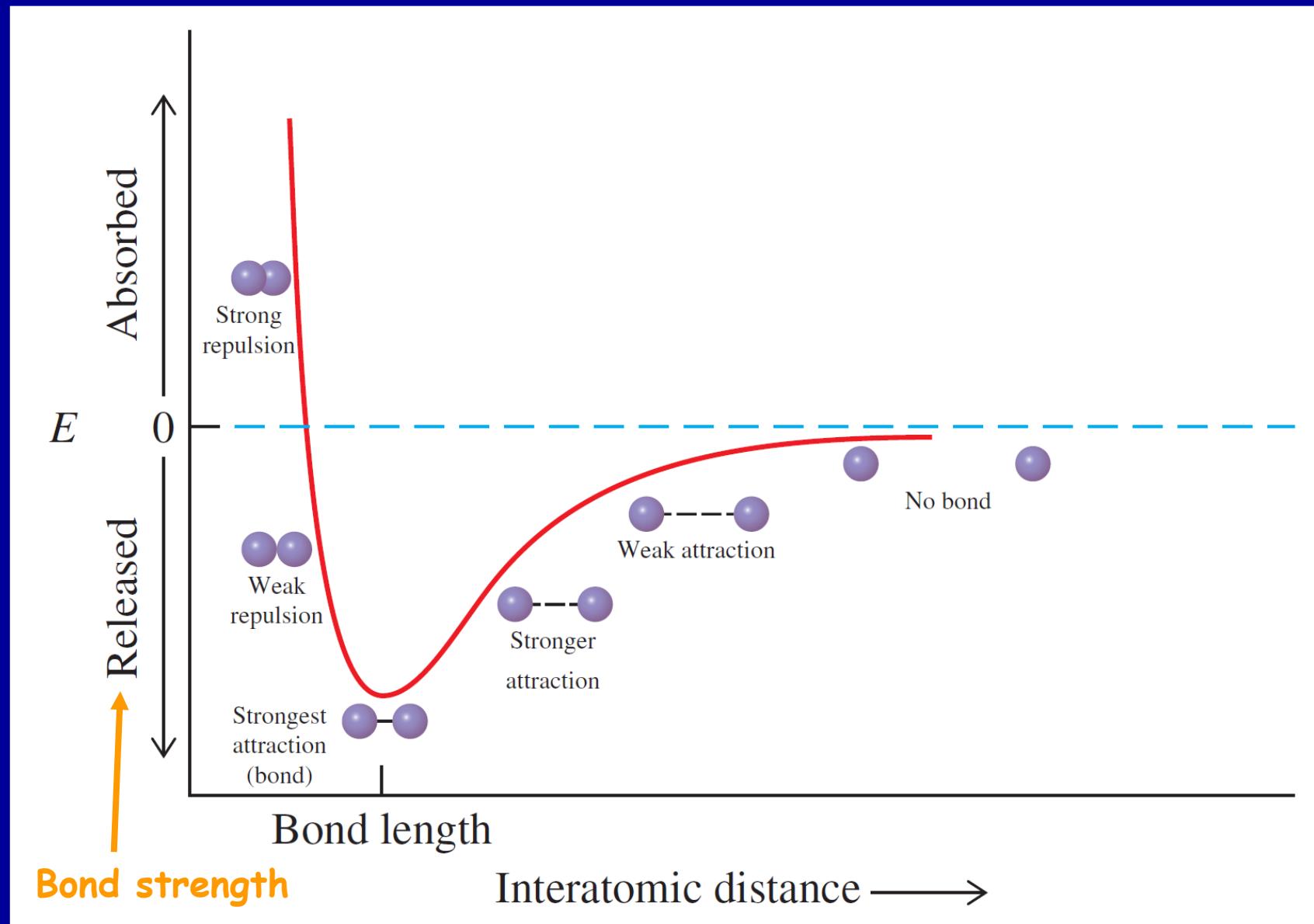
Charles Augustin
de Coulomb
1736-1806



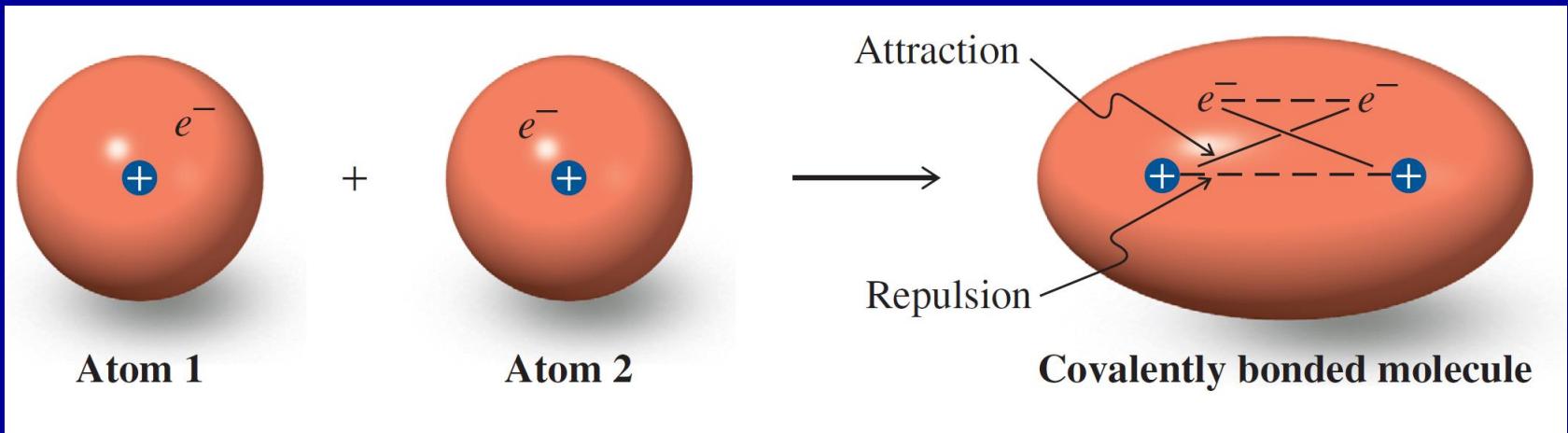
"Rules":

1. Opposite charges attract each other (Coulomb)
2. Electrons spread out in space (delocalization)

Bond Strength And Length



Covalent Bonding: Sharing Electrons

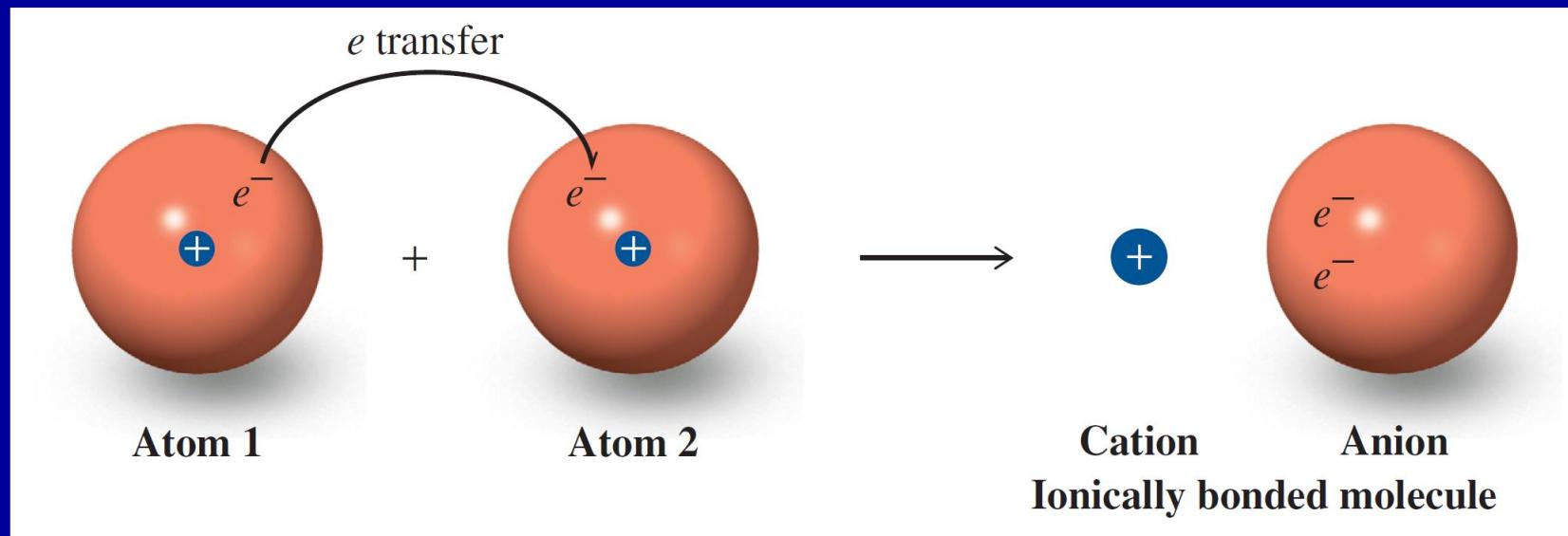


Dimensions:

Nuclear diameter $\sim 10^{-15}$ m	}	five orders of magnitude
Electronic orbit $\sim 10^{-10}$ m		

Mass ratio proton : electron = ~ 1800

Ionic Bonding: “No” Sharing of Electrons



Who donates and who accepts?

Periodic Table of the Elements

The Periodic Table is organized into groups (families) and periods (rows). Groups are labeled with Roman numerals (IA, IIA, IIIA, IVA, VVA, VIA, VIIA, VIIIA) and the noble gases He, Ne, Ar, Kr, Xe, and Rn. The table includes the following elements:

- Group 1 (IA):** Hydrogen (H), Lithium (Li), Sodium (Na), Potassium (K), Rubidium (Rb), Cesium (Cs), Francium (Fr).
- Group 2 (IIA):** Beryllium (Be), Magnesium (Mg), Calcium (Ca), Strontium (Sr), Barium (Ba), Radon (Rn).
- Group 3 (IIIA):** Scandium (Sc), Titanium (Ti), Vanadium (V), Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Gallium (Ga), Germanium (Ge), Arsenic (As), Selenium (Se), Bromine (Br), Krypton (Kr).
- Group 4 (IVB):** Boron (B), Carbon (C), Nitrogen (N), Oxygen (O), Phosphorus (P), Sulfur (S), Chlorine (Cl), Argon (Ar).
- Group 5 (VIB):** Nitrogen (N), Oxygen (O), Fluorine (F), Neon (Ne).
- Group 6 (VIIA):** Nitrogen (N), Oxygen (O), Fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I), Xenon (Xe).
- Group 7 (VIIIA):** Helium (He).
- Group 8 (VIII):** Iron (Fe), Cobalt (Co), Nickel (Ni), Rhodium (Rh), Ruthenium (Ru), Osmium (Os), Iridium (Ir), Platinum (Pt), Gold (Au), Hg, Tl, Pb, Bi, Po, At.
- Group 9 (VIIIB):** Cobalt (Co), Rhodium (Rh), Ruthenium (Ru), Osmium (Os), Iridium (Ir), Platinum (Pt), Gold (Au), Hg, Tl, Pb, Bi, Po, At.
- Group 10 (VIIIB):** Iron (Fe), Cobalt (Co), Nickel (Ni), Rhodium (Rh), Ruthenium (Ru), Osmium (Os), Iridium (Ir), Platinum (Pt), Gold (Au), Hg, Tl, Pb, Bi, Po, At.
- Group 11 (IB):** Sodium (Na), Potassium (K), Rubidium (Rb), Cesium (Cs).
- Group 12 (IIB):** Magnesium (Mg), Calcium (Ca), Strontium (Sr), Barium (Ba).
- Group 13 (IIIA):** Boron (B), Carbon (C), Nitrogen (N), Oxygen (O), Phosphorus (P), Sulfur (S).
- Group 14 (IVB):** Silicon (Si), Germanium (Ge), Arsenic (As), Selenium (Se).
- Group 15 (VVA):** Nitrogen (N), Oxygen (O), Fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I).
- Group 16 (VI):** Oxygen (O), Fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I).
- Group 17 (VIIA):** Fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I).
- Group 18 (VIIIA):** Helium (He).

Each element cell contains the following information:

- Atomic Number:** The element's position in the periodic table.
- Symbol:** The standard one- or two-letter symbol for the element.
- Name:** The full name of the element.
- Atomic Weight:** The element's mass number.
- Electrons per shell:** The number of electrons in each shell, starting from 1 for the first shell.
- State of matter (color of name):** Solid (blue), Liquid (green), Gas (yellow).
- Subcategory:** Metal (red), Metalloid (orange), Nonmetal (purple).
- Properties:**
 - Alkali metals (red)
 - Alkaline earth metals (orange)
 - Transition metals (purple)
 - Post-transition metals (pink)
 - Noble gases (yellow)
 - Actinides (purple)
 - Reactive nonmetals (purple)
 - Noble gases (yellow)
 - Unknown chemical properties (grey)

Partial Periodic Table

TABLE 1-1 Partial Periodic Table

Period (or row)	Halogens							Noble gases
First	H ¹							He ²
Second	Li ^{2,1}	Be ^{2,2}	B ^{2,3}	C ^{2,4}	N ^{2,5}	O ^{2,6}	F ^{2,7}	Ne ^{2,8}
Third	Na ^{2,8,1}	Mg ^{2,8,2}	Al ^{2,8,3}	Si ^{2,8,4}	P ^{2,8,5}	S ^{2,8,6}	Cl ^{2,8,7}	Ar ^{2,8,8}
Fourth	K ^{2,8,8,1}						Br ^{2,8,18,7}	Kr ^{2,8,18,8}
Fifth							I ^{2,8,18,18,7}	Xe ^{2,8,18,18,8}

Note: The superscripts indicate the number of electrons in each principal shell of the atom.

Valence electrons
(where the action is)

Especially stable
electron counts

Duet

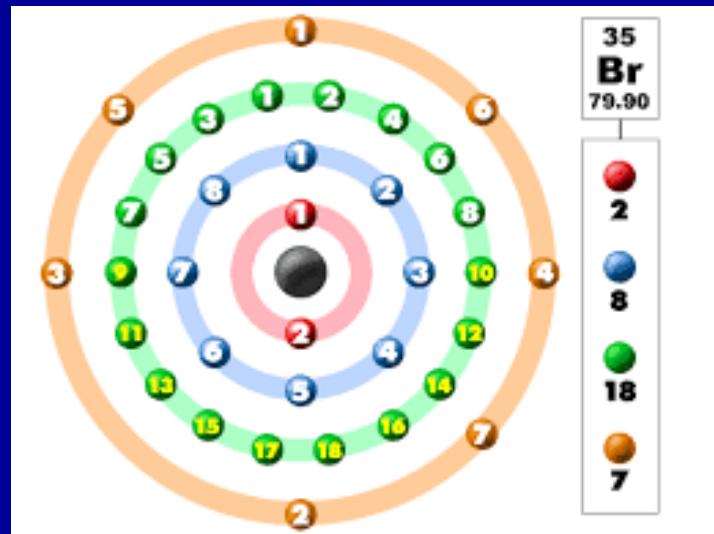
Octets

1s²

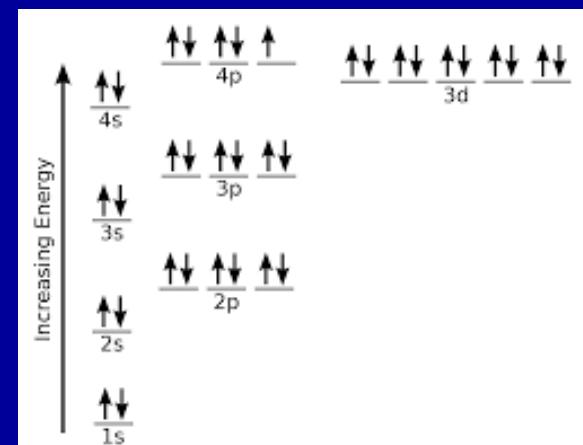
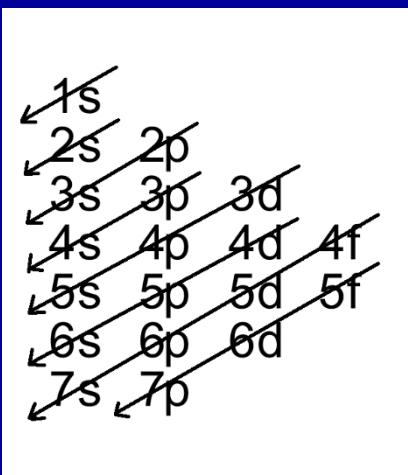
Number of electrons in the orbital

Shape of the orbital

What shell the orbital is in



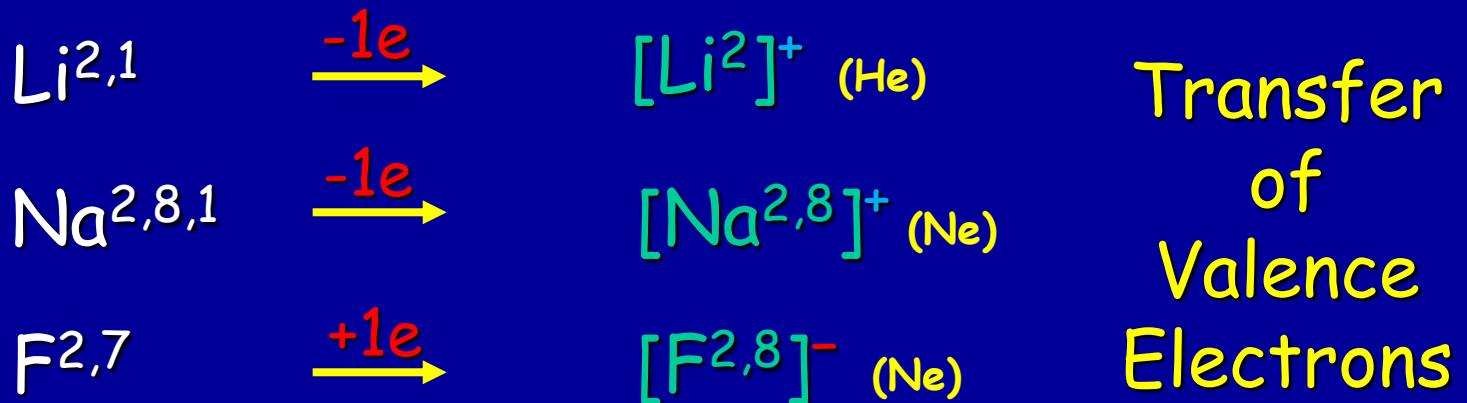
$1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \ 3d^{10} \ 4s^2 \ 4p^5$



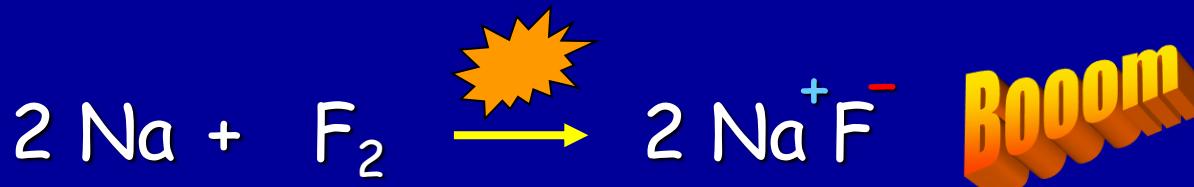
Why Do Elements React?

Aim → Noble Gas Configuration

1. "Ionic" Bonds



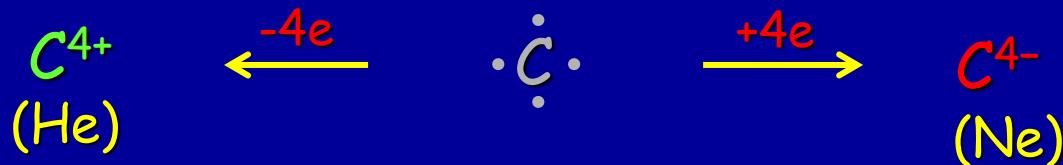
Therefore:



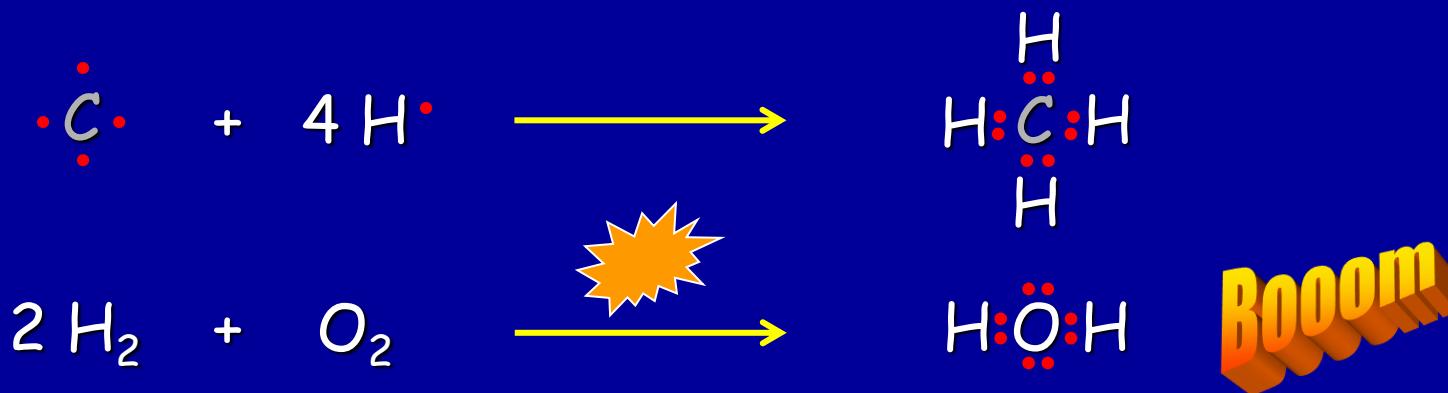
2. "Covalent" Bonds

Elements in the "middle" of the periodic table have a problem with electron affinity (EA) and ionization potential (IP):

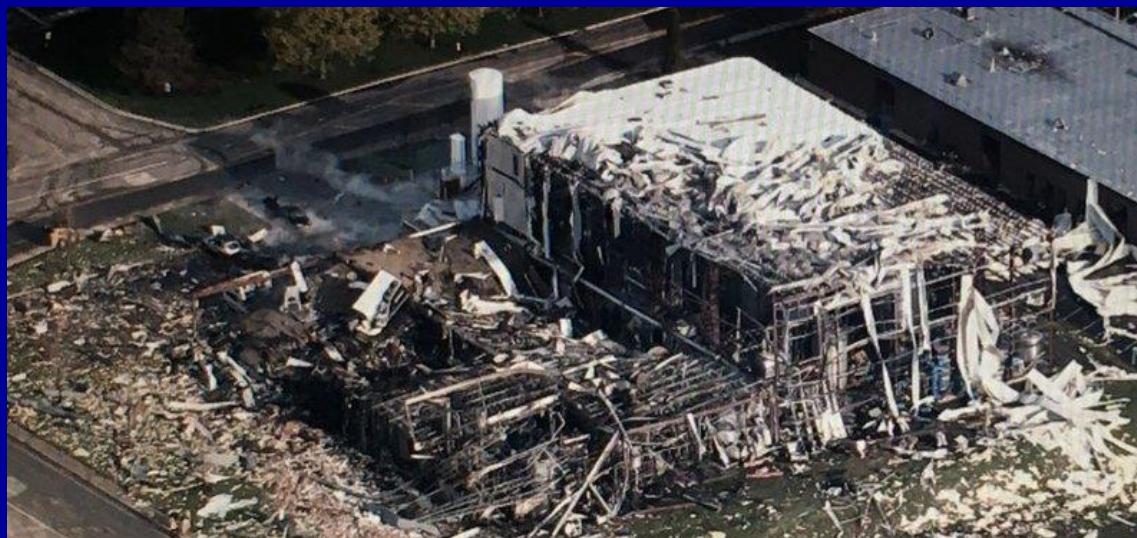
Show only
valence e



Compromise: electron-sharing



Leaking and uncontained hydrogen led to an explosion that killed four workers and seriously injured a fifth: May 3, 2019, at AB Specialty Silicones in Waukegan, Illinois.



The Hindenburg

Lakehurst, NJ, May 6, 1937



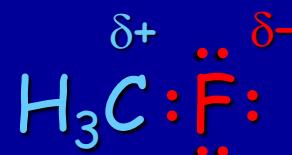
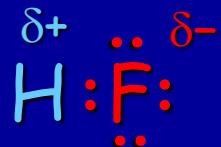
3. Most Bonds Are "Between" Covalent and Ionic:

→ Polar Covalent

→ dipole



Examples:



Linus Pauling
1901-1994

Table 1-2 Electronegativities of Selected Elements

Increasing electronegativity

Increasing electronegativity							
		H					
		2.2					
Li	Be	B	C	N	O	F	
1.0	1.6	2.0	2.6	3.0	3.4	4.0	
Na	Mg	Al	Si	P	S	Cl	
0.9	1.3	1.6	1.9	2.2	2.6	3.2	
K						Br	
0.8						3.0	
I						I	
						2.7	

The Shape Of Molecules

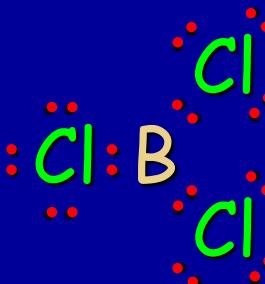
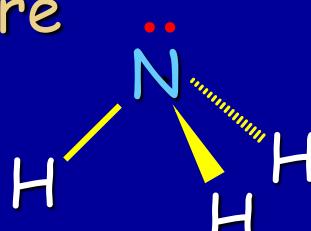
Is Controlled By Valence Electron Repulsion

Diatomics: linear (of course), e.g. H:H Li:H :F:F:

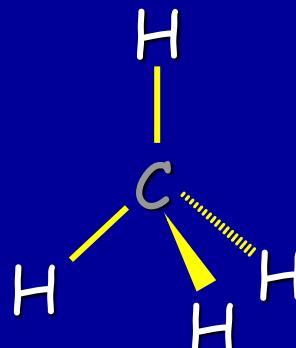
Triatomics: either linear, e.g. :F:Be:F: not :F:Be:F:
or bent, when there are lone e-pairs, e.g. H:O:H

Tetraatomics: either trigonal, e.g.

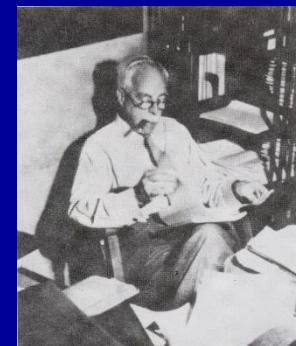
or pyramidal, when there
are lone e-pairs, e.g.



Pentaatomics: tetrahedral, e.g.



How To Distribute Valence Electrons: Lewis Structures



Gilbert N. Lewis
(1875–1946)

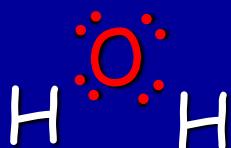
Rule 1: Draw molecular skeleton (usually given)



Rule 2: Count total number of valence electrons

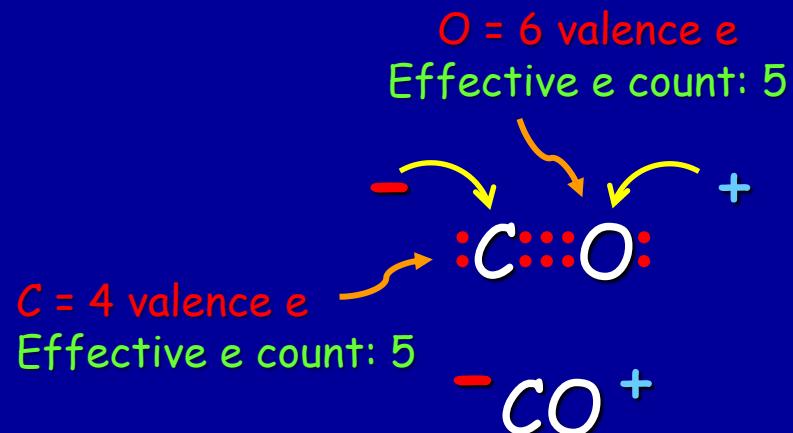
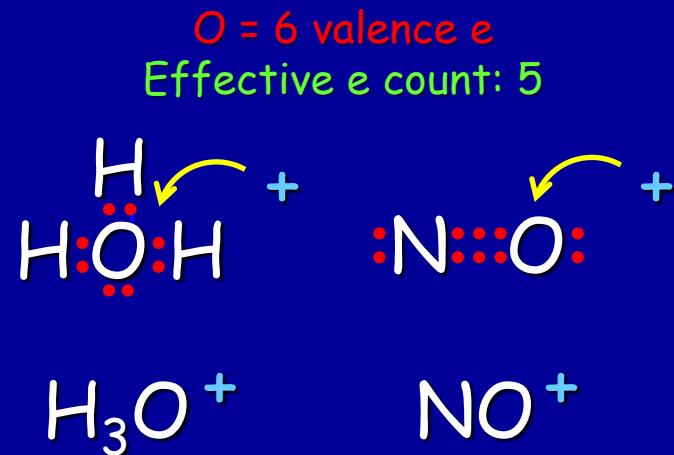


Rule 3: Octet (Duet) Rule: Structure is best if we can provide octets (duets for H) around all atoms



Rule 4: Take care of charges, if any. Charges occur when the formal "effective" electron count around the nucleus differs from its **valence electron count**.

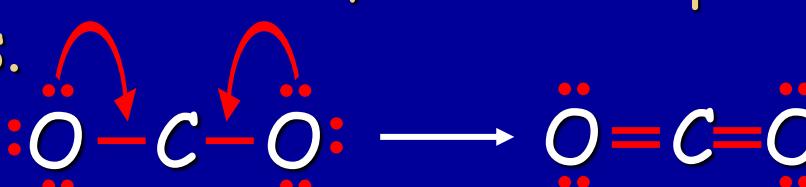
Valence electron count: Rule 2 (# of valence electrons).
"Effective" electron count: Each (single) bond (two shared electrons) counts as 1e; lone pairs count as 2e.



Example: CO_2

1. Atom arrangement: O C O
2. Valence electrons: O 6e, C 4e \longrightarrow 16e total
3. Octet rule
4. Charges

Shortcut:

1. Connect all bonded atoms with "2e line". $\text{O}-\text{C}-\text{O}$
2. If there are e left, add them as lone pairs to any atom to give it an octet. Continue until no e left. $\begin{array}{c} \cdot\cdot \\ :\text{O} \\ \cdot\cdot \end{array} - \text{C} - \begin{array}{c} \cdot\cdot \\ :\text{O} \\ \cdot\cdot \end{array}$
3. If some atoms lack octet, move lone pairs into shared positions.
 $\begin{array}{c} \cdot\cdot \\ :\text{O} \\ \cdot\cdot \end{array} - \text{C} - \begin{array}{c} \cdot\cdot \\ :\text{O} \\ \cdot\cdot \end{array} \longrightarrow \begin{array}{c} \cdot\cdot \\ \ddot{\text{O}} \\ \cdot\cdot \end{array} = \text{C} = \begin{array}{c} \cdot\cdot \\ \ddot{\text{O}} \\ \cdot\cdot \end{array}$
4. Charges: none.

Resonance

Movement of **electron pairs** gives rise to other Lewis structures: **Resonance forms**

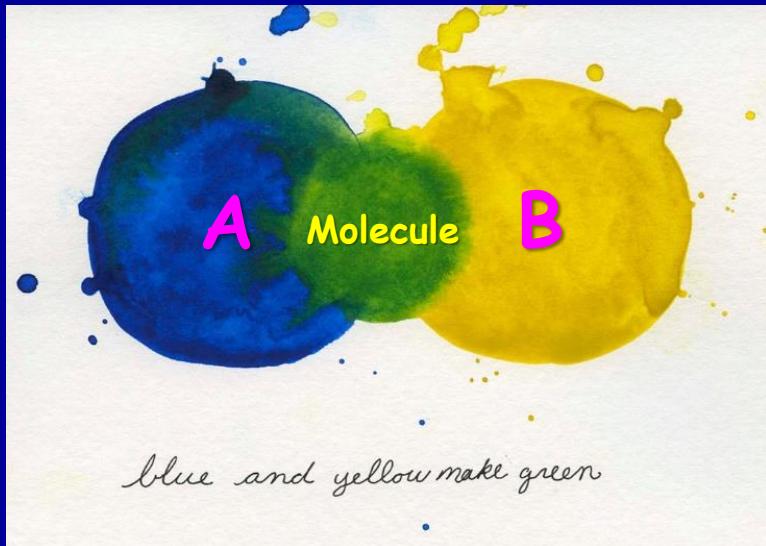
Molecule is a superposition of these forms

Form A \longleftrightarrow form B

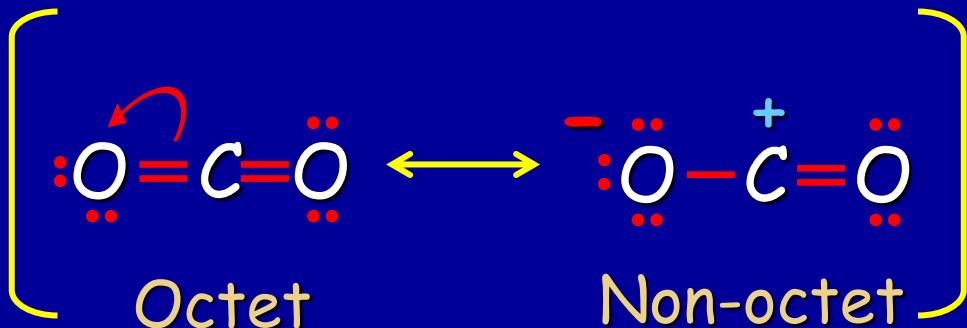
move electron pairs

Note rules for drawing resonance forms:

1. square brackets
2. double-headed arrow



Example:

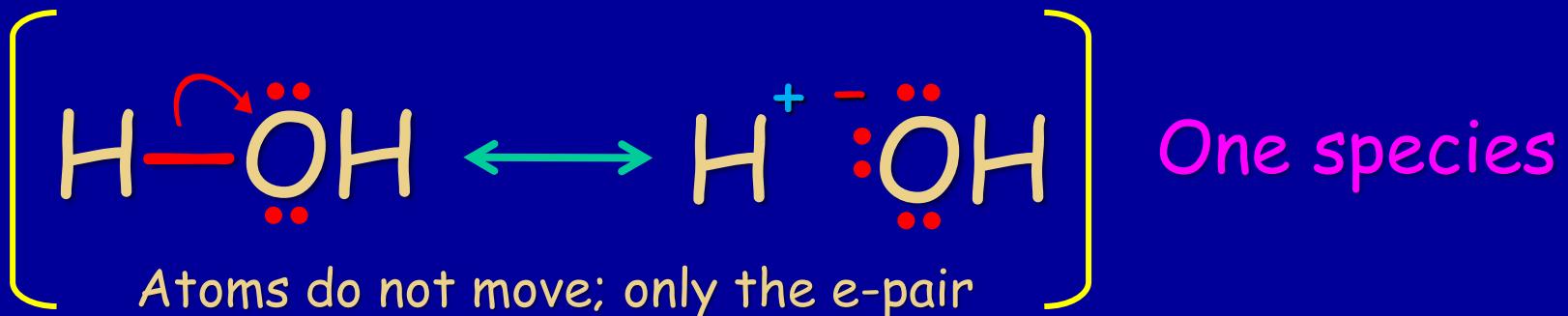




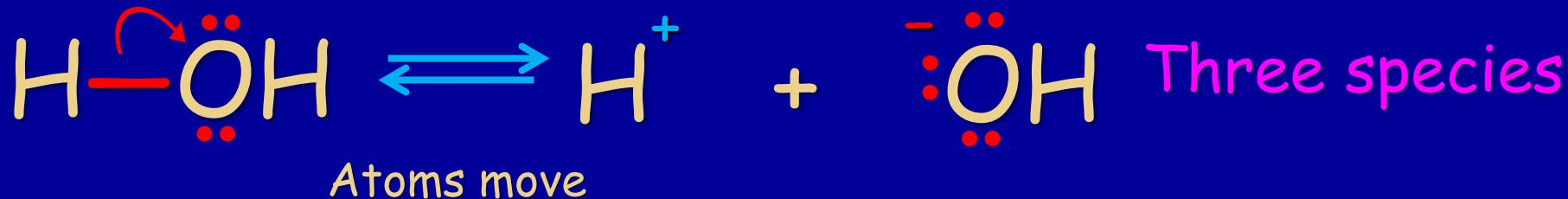
Female horse + male donkey = mule

Resonance Forms Are Not Equilibria

Resonance: the O-H bond

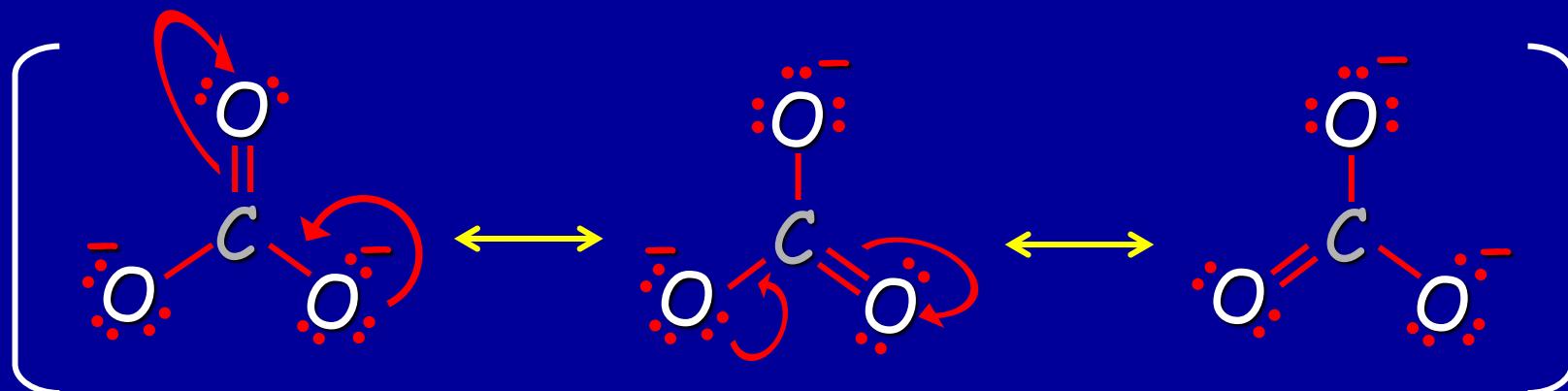


Equilibrium: water dissociation

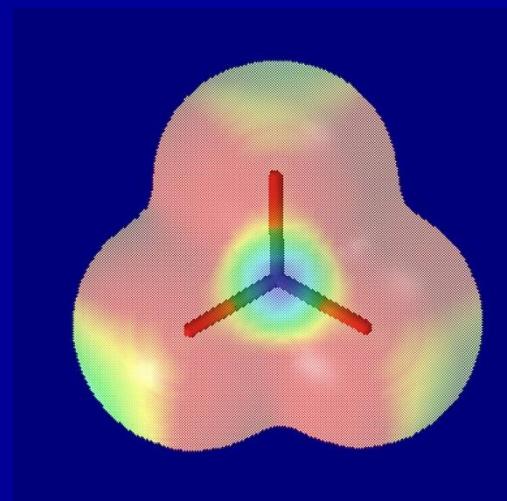


Resonance Forms

Best when all forms are octets:
Carbonate, CO_3^{2-} . All forms are equivalent



The carbonate ion is delocalized: *symmetrical!*



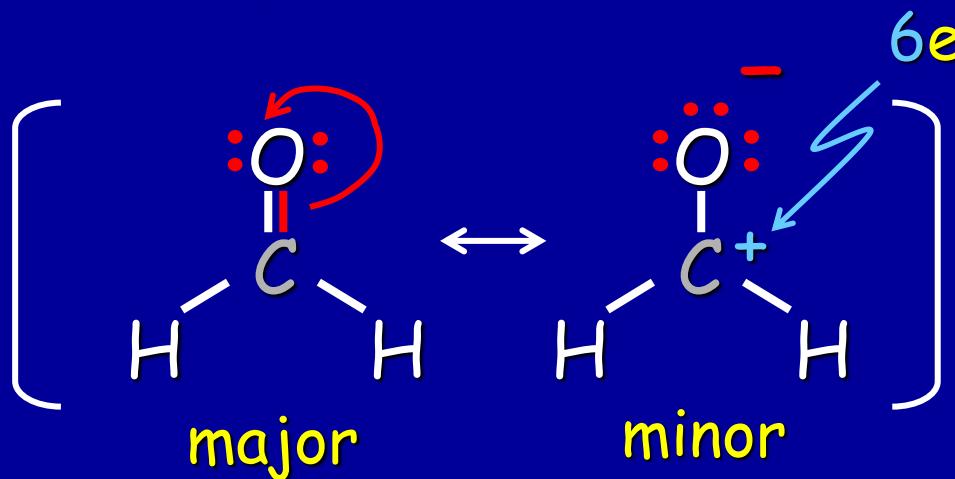
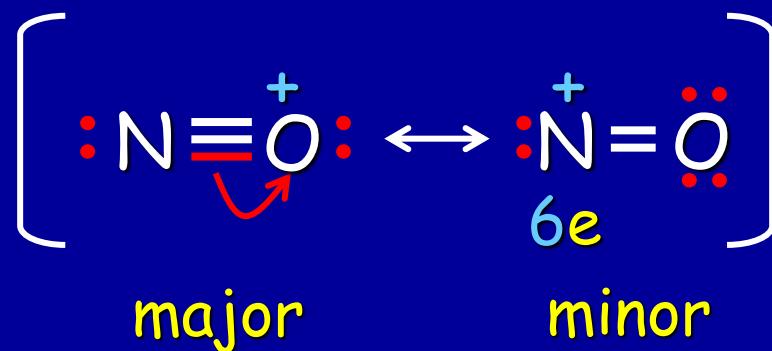
Electrostatic Potential Map: Red = relatively electron rich
Blue = relatively electron poor

Nonequivalent Resonance Forms

which ones are better?

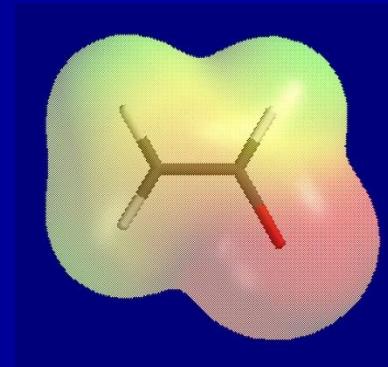
Rules

1. Octet rule (wins over all other rules)

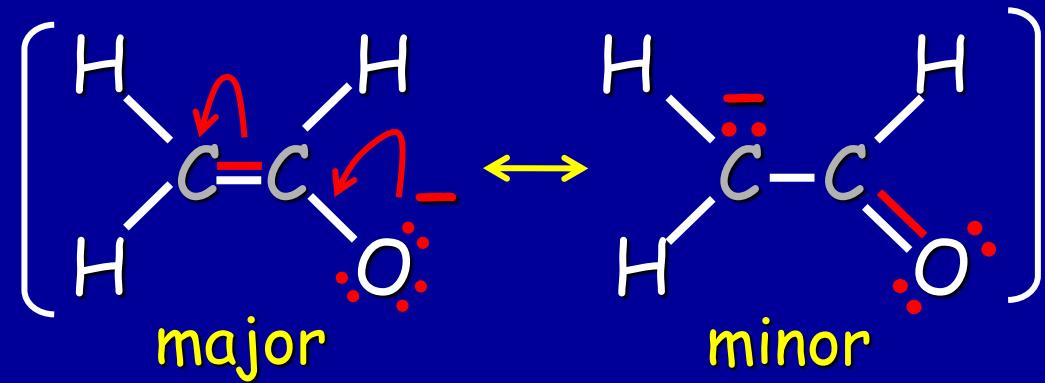


2. When there are two or more forms with complete octets, **electronegativity controls**: the more electronegative atom wants a - charge, rejects a + charge

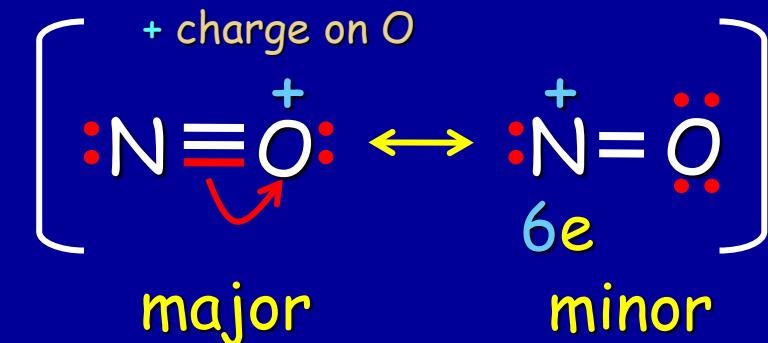
Example: enolate ion



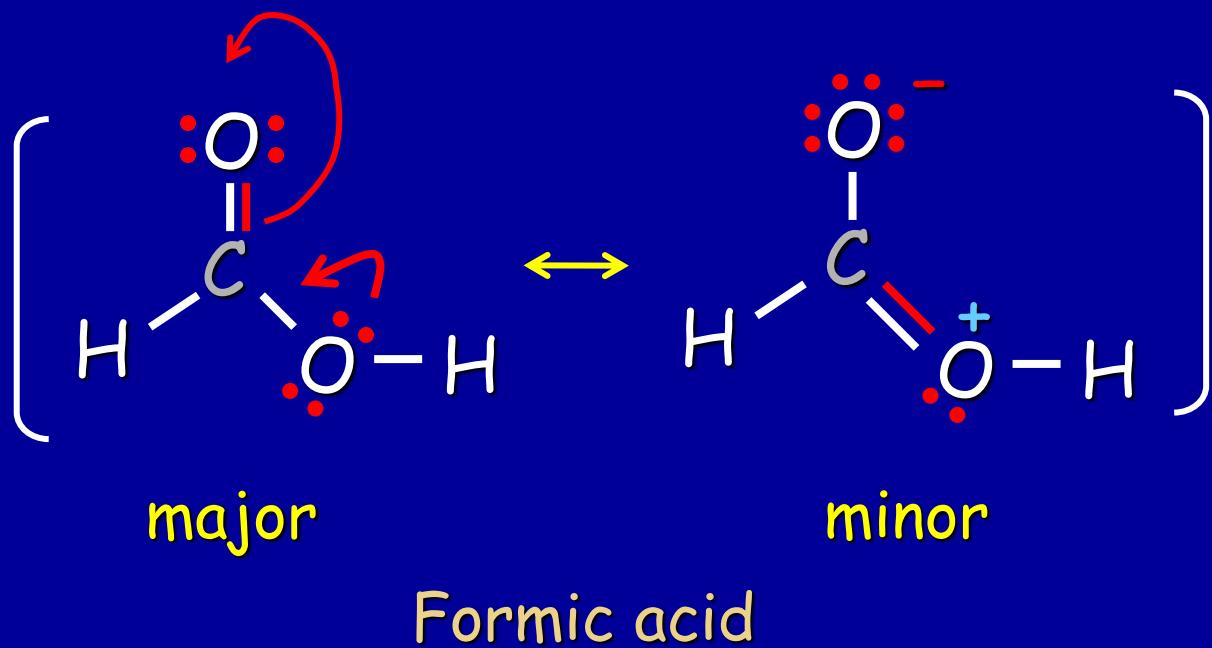
- charge on more e-negative element



But: When in doubt, rule 1 wins!: NO^+

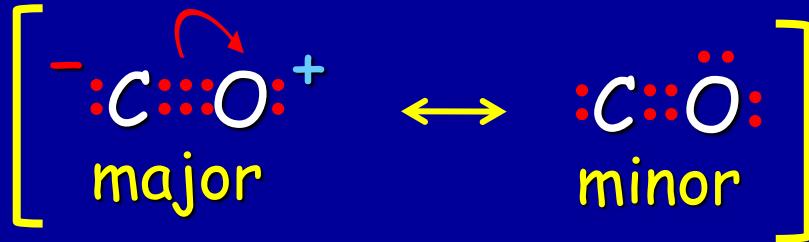


3. Minimum charge separation



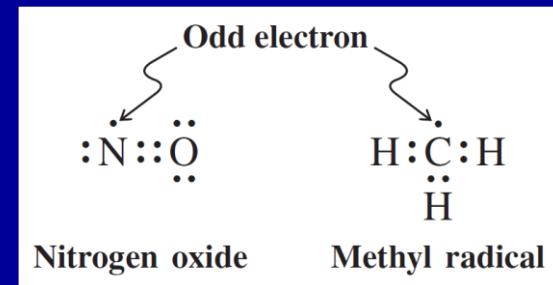
But: When in doubt, rule 1 wins ! Example:

Even though
C is less and O is
more electronegative

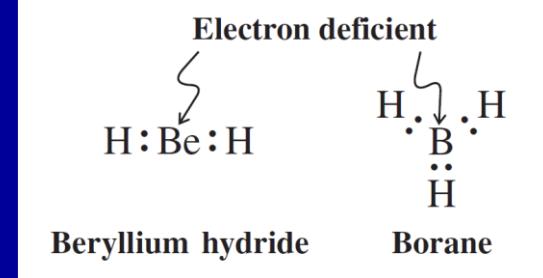


Exceptions To The Octet Rule

1. Radicals



2. Deficiency of electrons



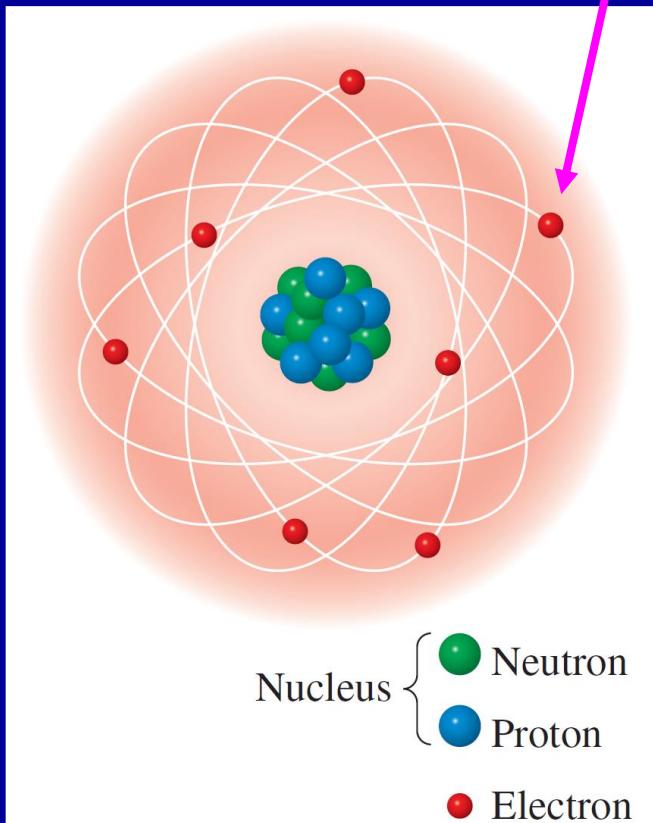
3. Elements beyond the second row ("valence shell expansion")



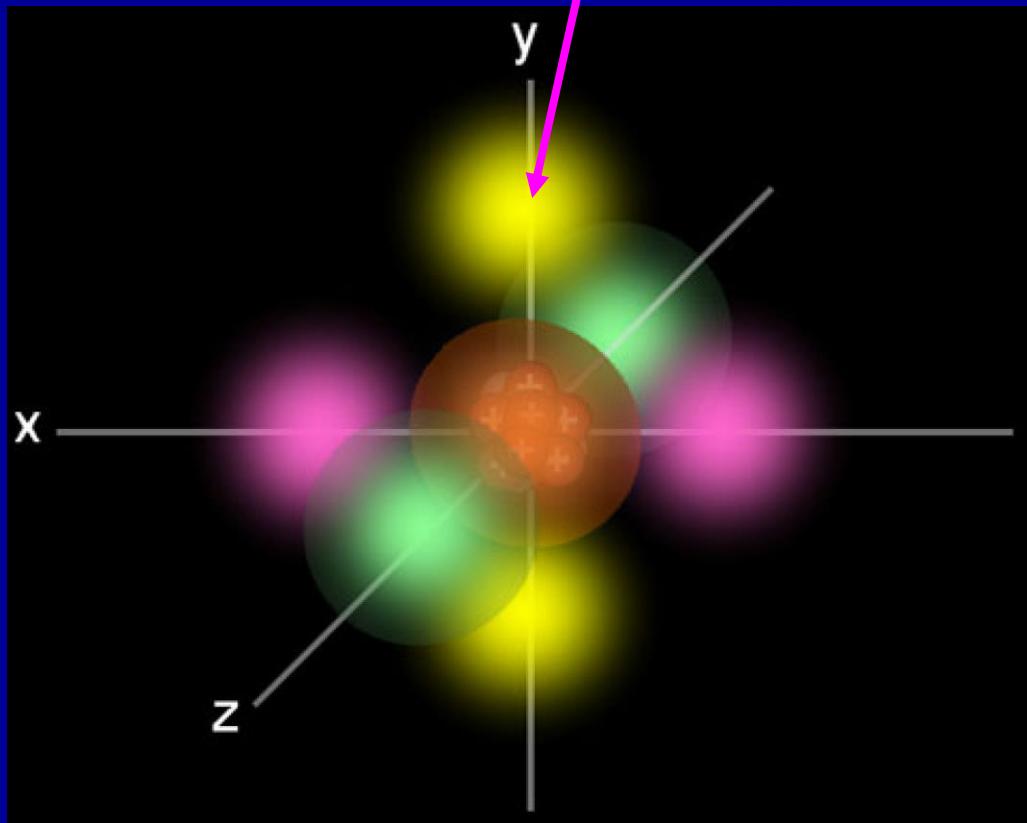
Quantum Mechanics

Light And Objects As Particles Or Waves

Particle



Wave



Classical view

Quantum mechanical view

1900 Planck, Einstein: Light = photons $E = h\nu$

$\nu = c/\lambda$ c (speed of light) = 300,000 km sec⁻¹

h = Planck's constant = 1.34×10^{-34} cal sec

Atoms absorb/emit energy in discrete packages: quanta

1923 DeBroglie: All mass m moving with velocity v has a wavelength $\lambda = h/mv$

1927 Heisenberg: Uncertainty (Δ) principle

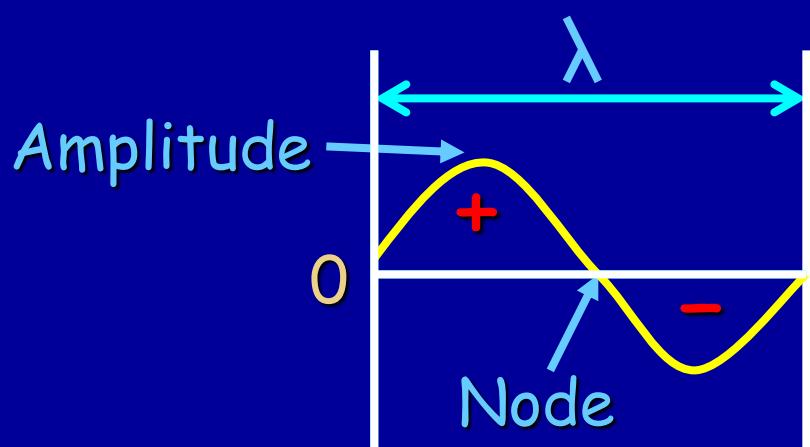
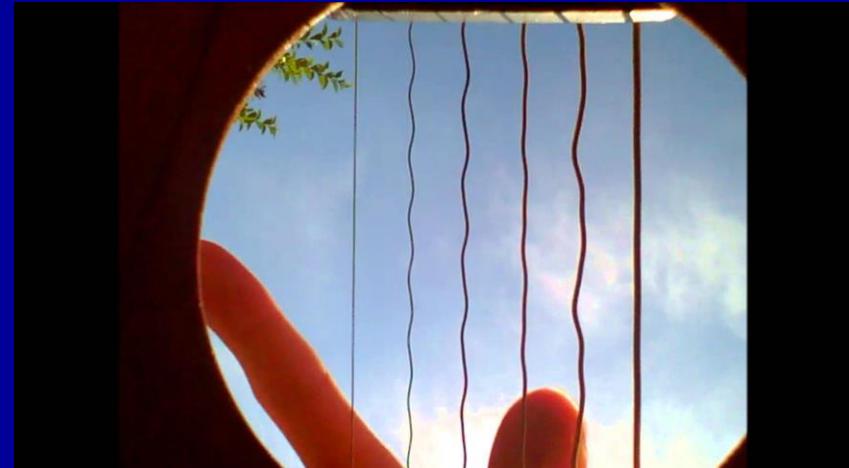
Δ (position) \times Δ (momentum) $> h/4\pi$

1927 Schrödinger: Wave equations for an electron moving around the nucleus. Solutions to wave equations are depicted as three-dimensional spheres: Orbitals. There are several solutions, from low to higher energy.

Square of a value of the wave equation around the atom = probability of finding the electron there.

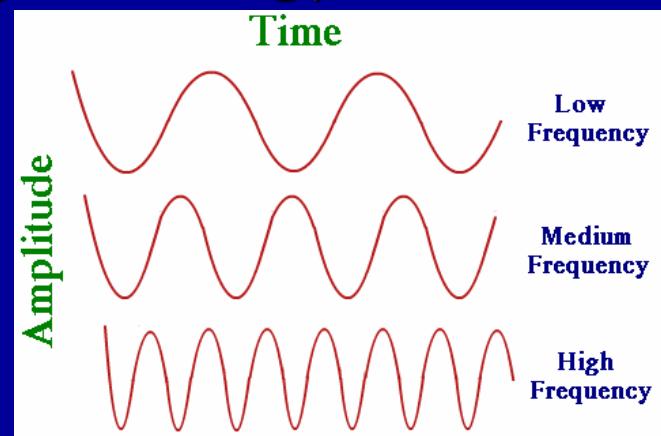
Orbitals

Have spherical (three-dimensional) shape
Contrast to mechanical waves (guitar string, rubber band)



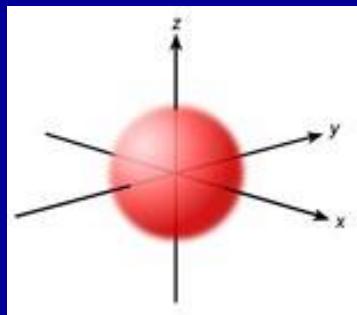
$+/-$ = signs, not charges

Two-dimensional waves:
higher energy = more nodes

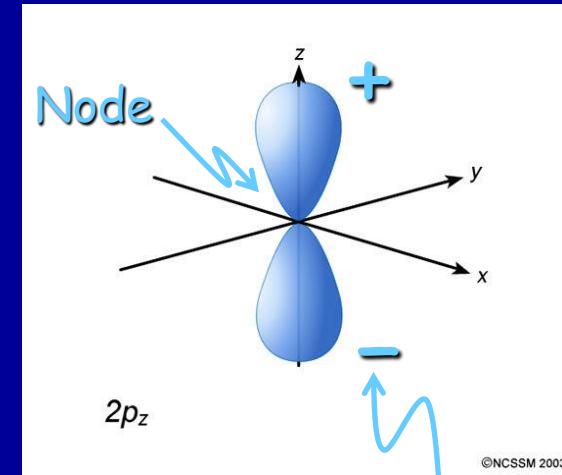


Most Important Orbitals (For Us):

s Orbital
“ball”



p Orbital
spherical
“eight”



Sign of the
wavefunction

Actual solutions: 1s, 2s, 2p_x, 2p_y, 2p_z,
3s, 3p_x, 3p_y, 3p_z, etc.

(increasing energy = more nodes)

#s are related to
classical shells



Correlates with elements in
rows of periodic table

The S Orbitals

y

1s

No node

y

Hydrogen nucleus

x

Sign of wave function
(not a charge)

z

y

2s

Node (the sign of the wave
function changes)

y

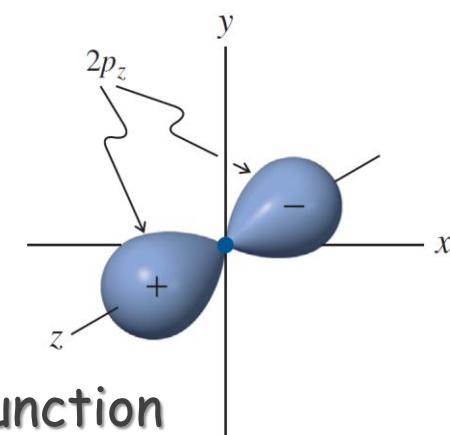
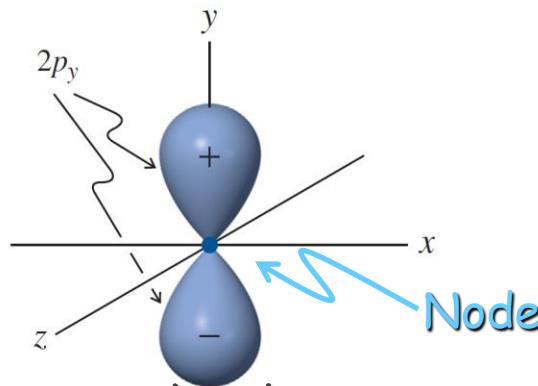
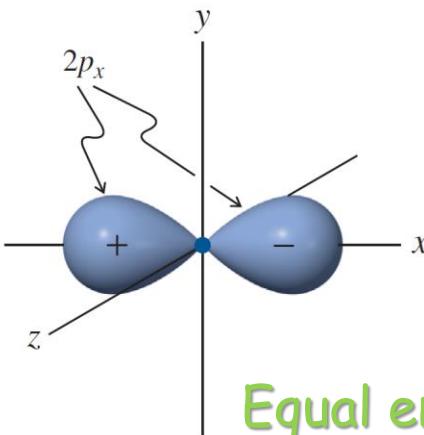
Node

x

z

1s

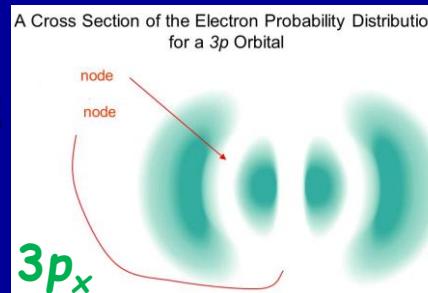
The Three 2P Orbitals



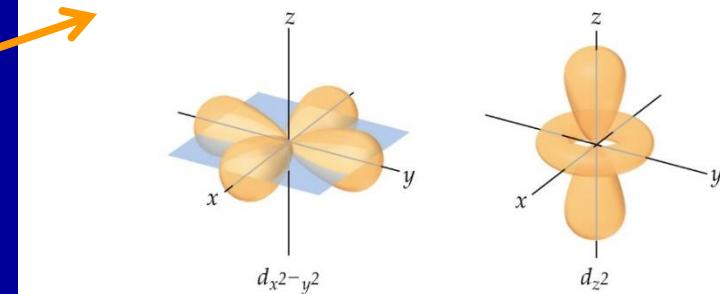
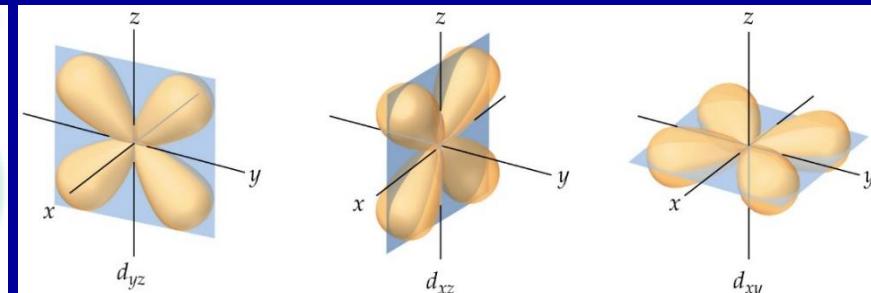
Equal energy (degenerate) solutions to wavefunction

2p

Then: next "shell":
 $3s, 3p_x, 3p_y, 3p_z,$
(2 nodes)



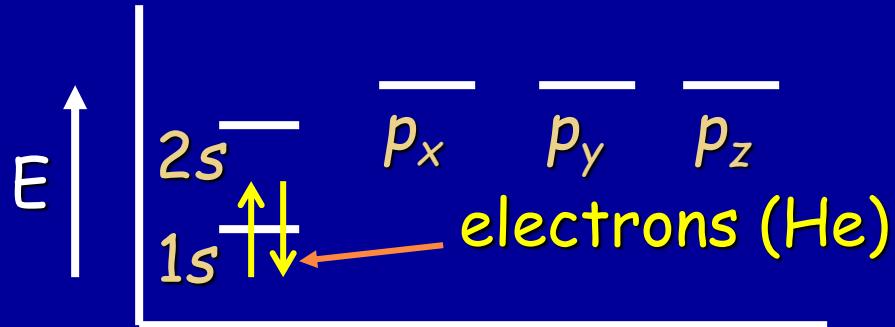
(then new solutions to the
wavefunctions: five d
orbitals, seven f orbitals)
(increasing energy)



Aufbau Principle

Or: To Which Orbital The Electrons Go With Increasing Count

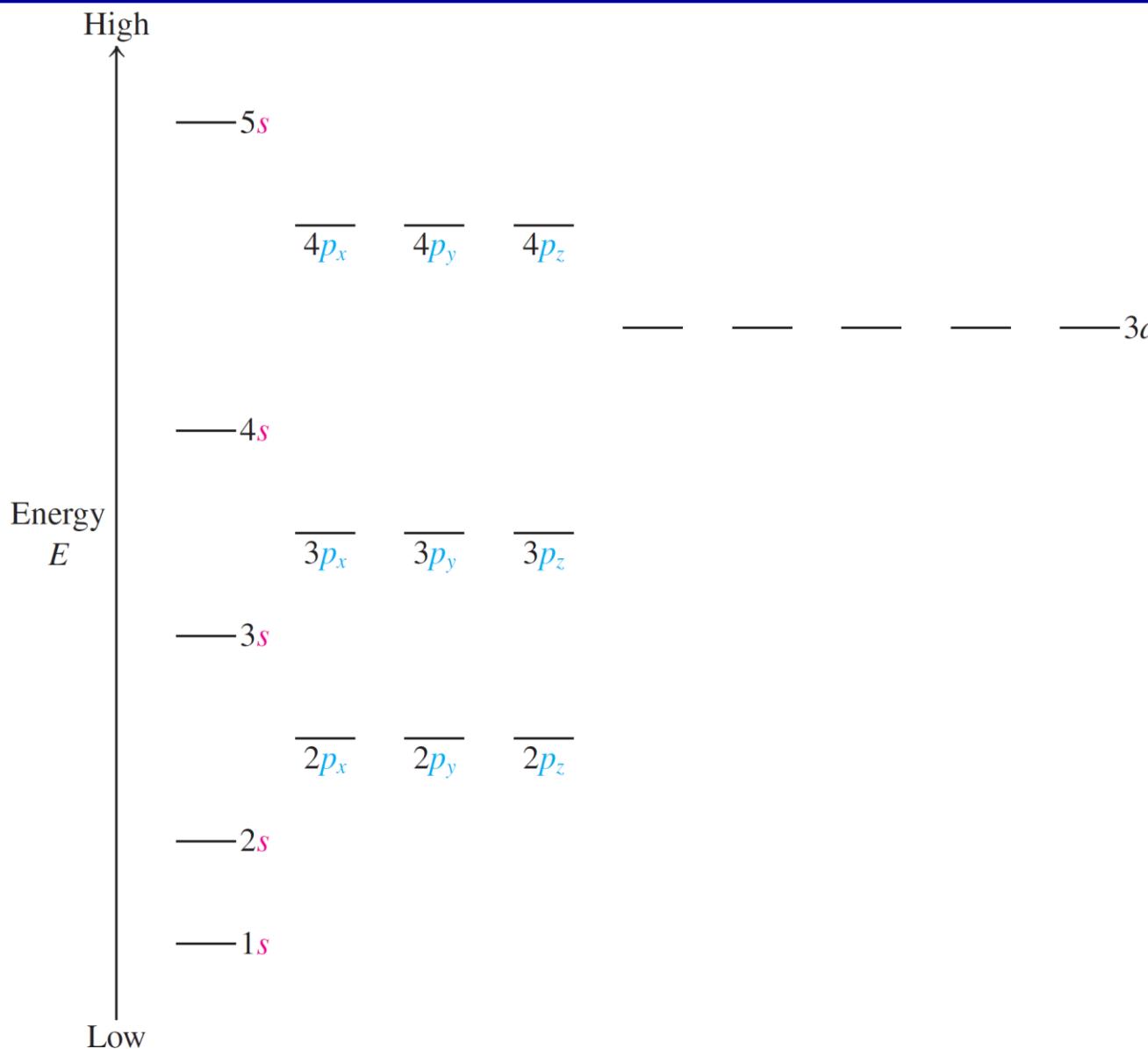
Energy diagram depicting solutions as energy "levels":



There are rules for "filling up" levels with e

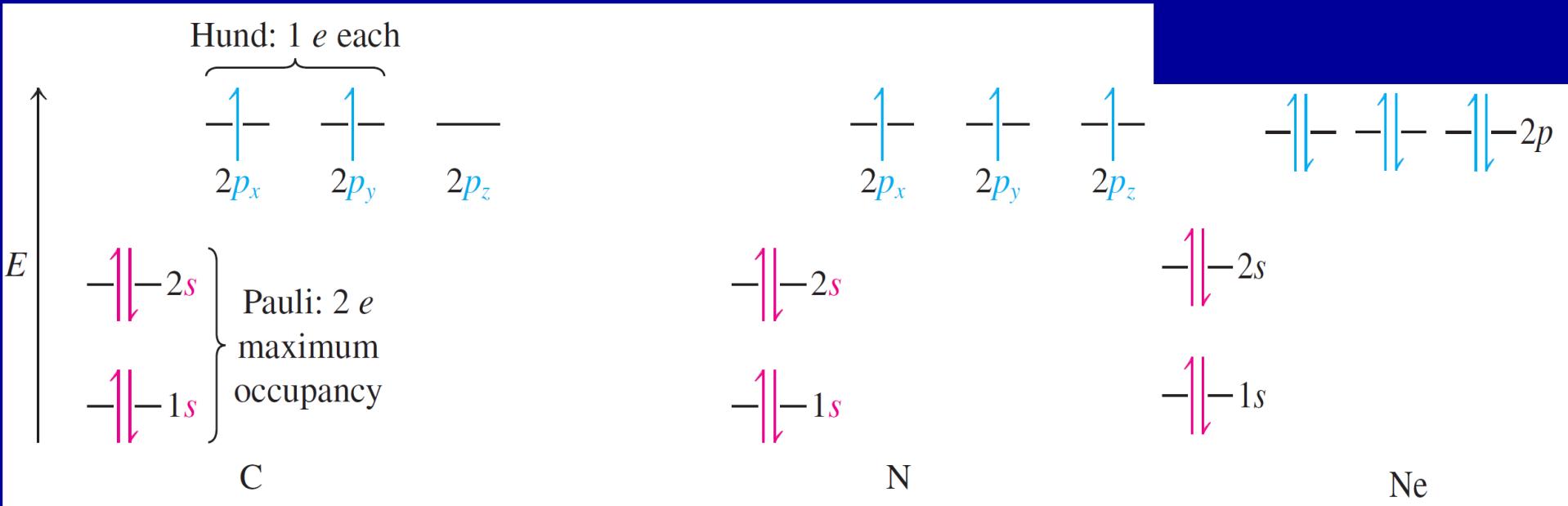
1. Lower energy orbitals filled first (**closed shell**)
2. Pauli **exclusion principle**: 2e max in each level
3. Hund's **rule**: equal energy orbitals (i.e. $p_{x,y,z}$) filled with one e each first

Approximate Energies Of Orbitals



Energies can be obtained from ionization potentials of electrons in these levels

Fill Them Up

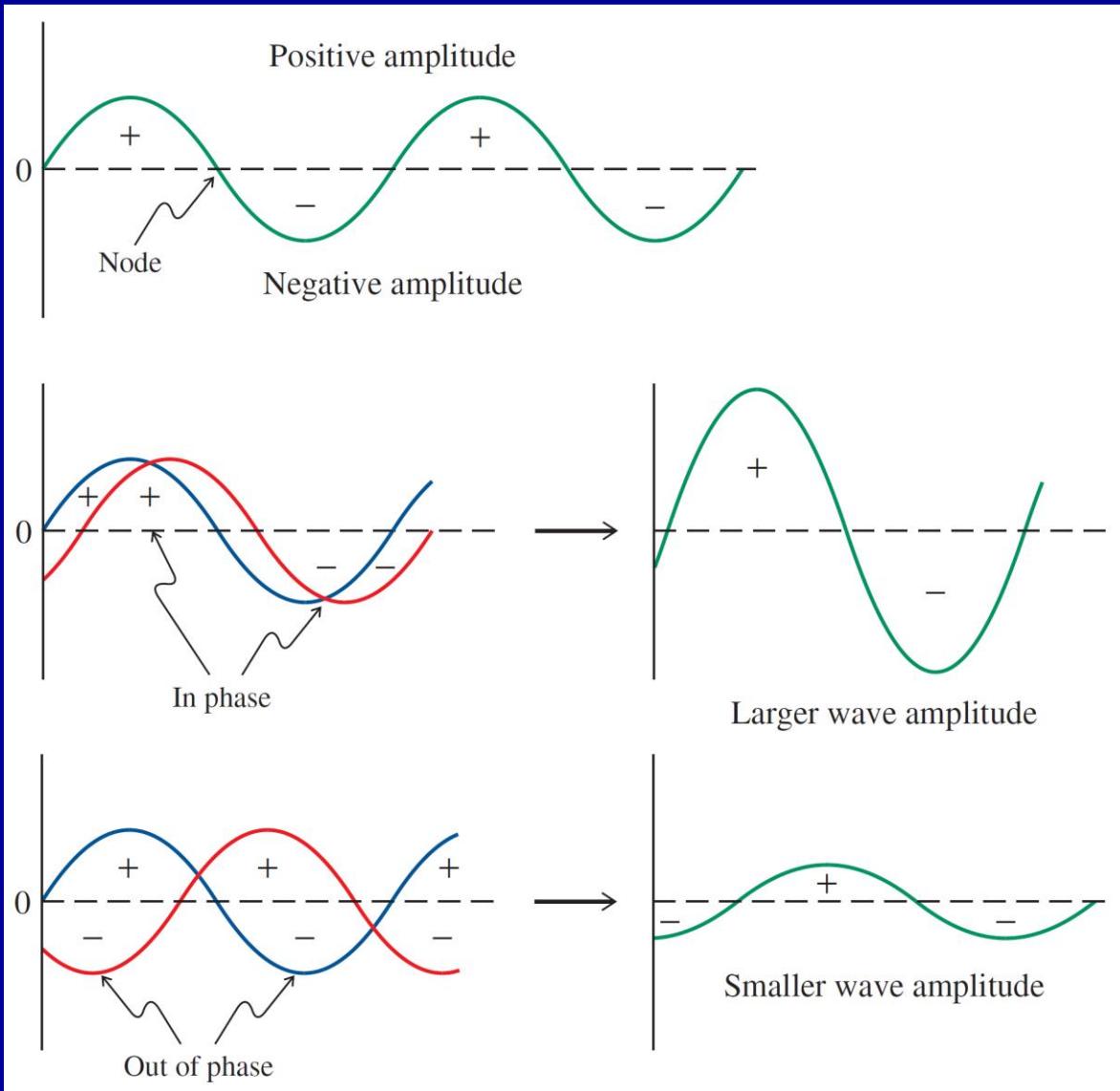


Therefore, description of electronic configurations:

$\text{H}(1s)^1$; $\text{He}(1s)^2$; $\text{Li}(1s)^2(2s)^1$; $\text{Be}(1s)^2(2s)^2$; $\text{B}(1s)^2(2s)^2(2p)^1$; $\text{C}(1s)^2(2s)^2(2p)^2$

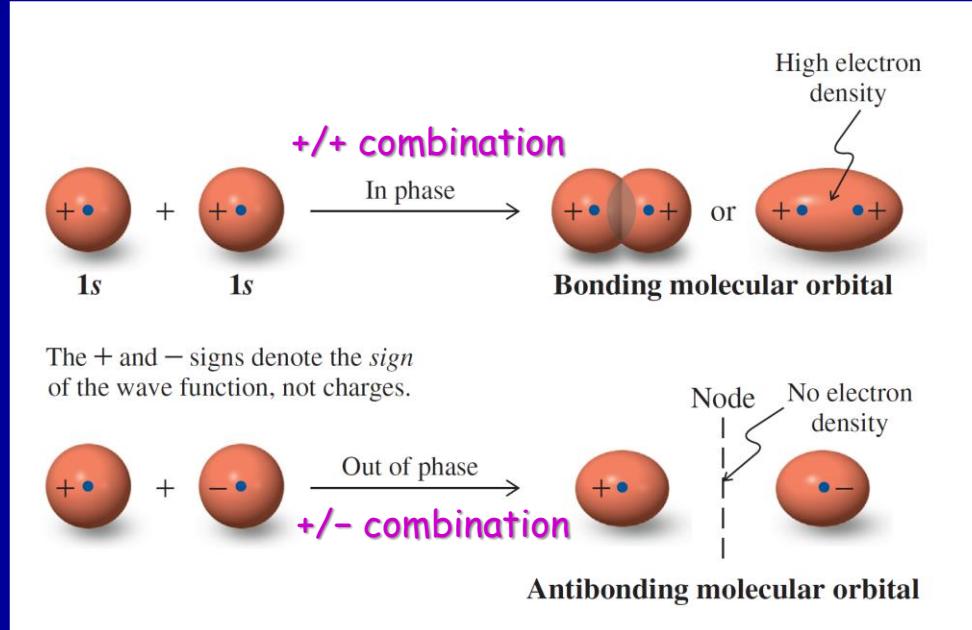
Bonding

Overlap of 2 atomic orbitals gives 2 molecular orbitals

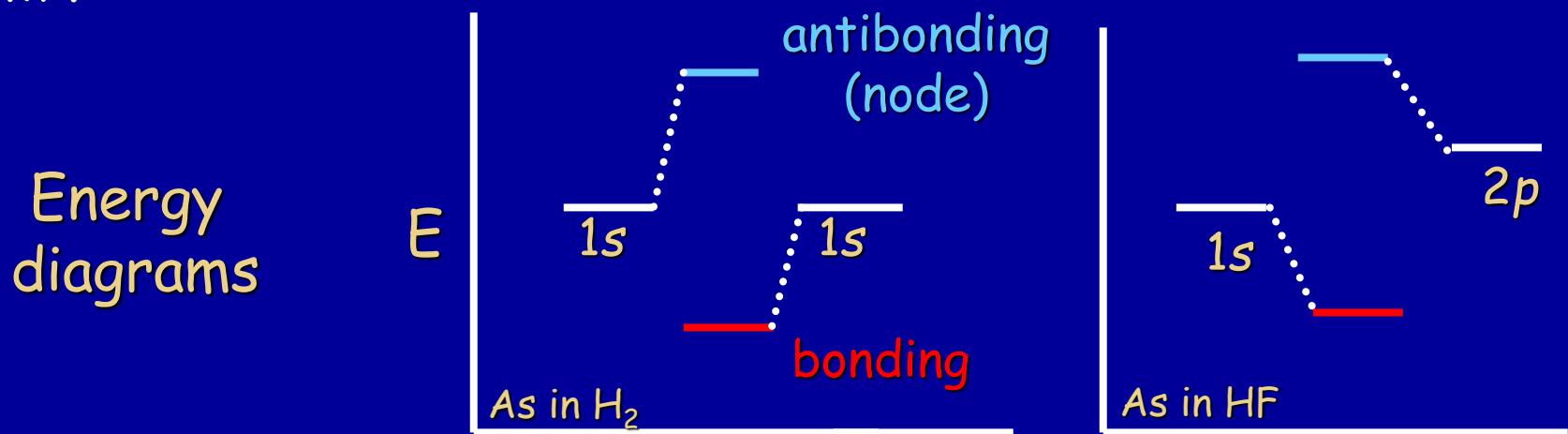


In phase overlap → bonding molecular orbital (lower E)

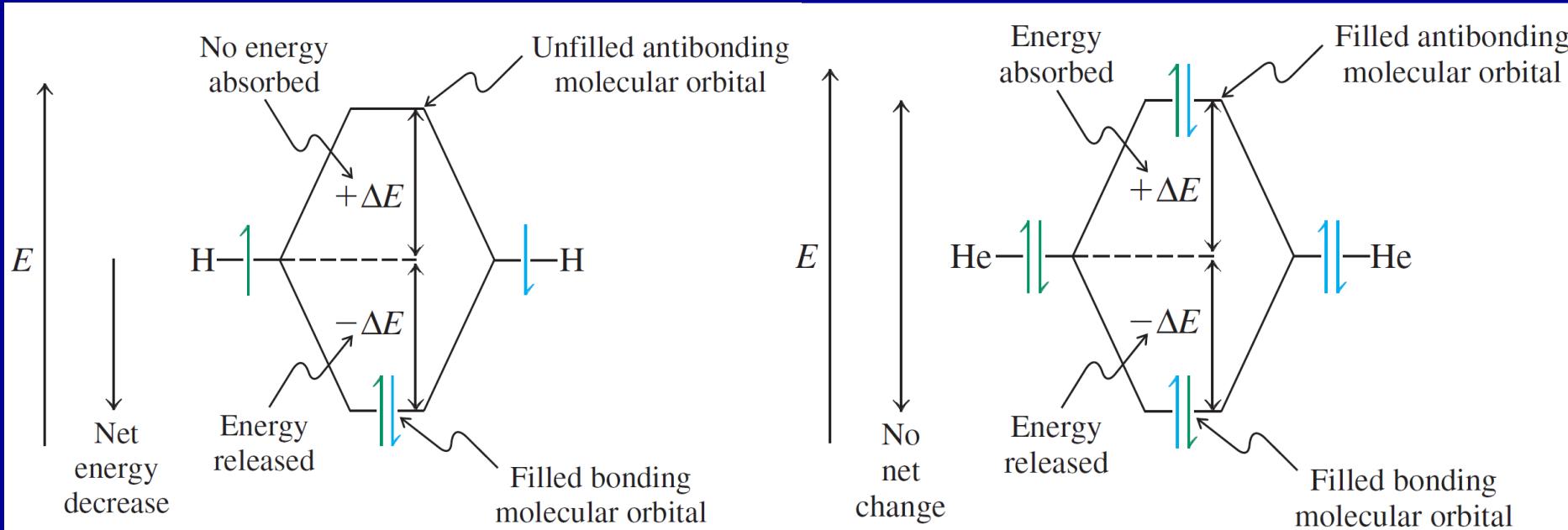
Out of phase overlap → antibonding molecular orbital (higher E)



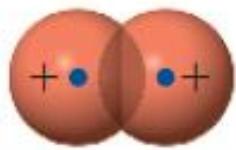
- Orbitals “split” energy levels when entering into **overlap**.
- The better the overlap [e.g. same type of orbital, same energy (shell)], the larger the splitting.
- For orbitals of unequal energy, the higher orbital “goes up”, the lower “down”.



Energy Diagram of Bonding In H_2 And He_2

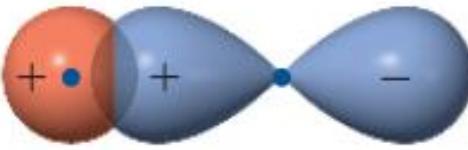


The Types Of Orbital Overlap



1s 1s
 σ bond,
as in H–H

A



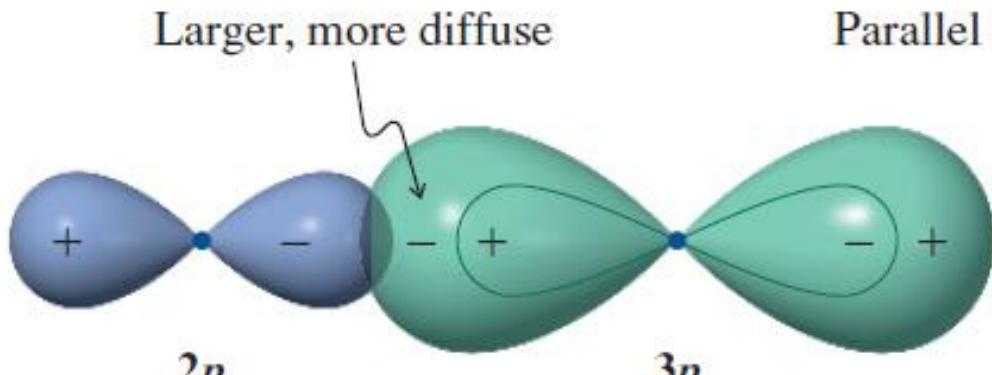
1s 2p
 σ bond,
as in H–F

B



2p 2p
 σ bond,
as in F–F

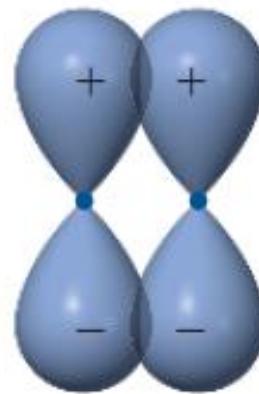
C



2p 3p
 σ bond,
as in F–Cl

D

Parallel orientation



2p 2p
 π bond,
as in $\text{H}_2\text{C}=\text{CH}_2$

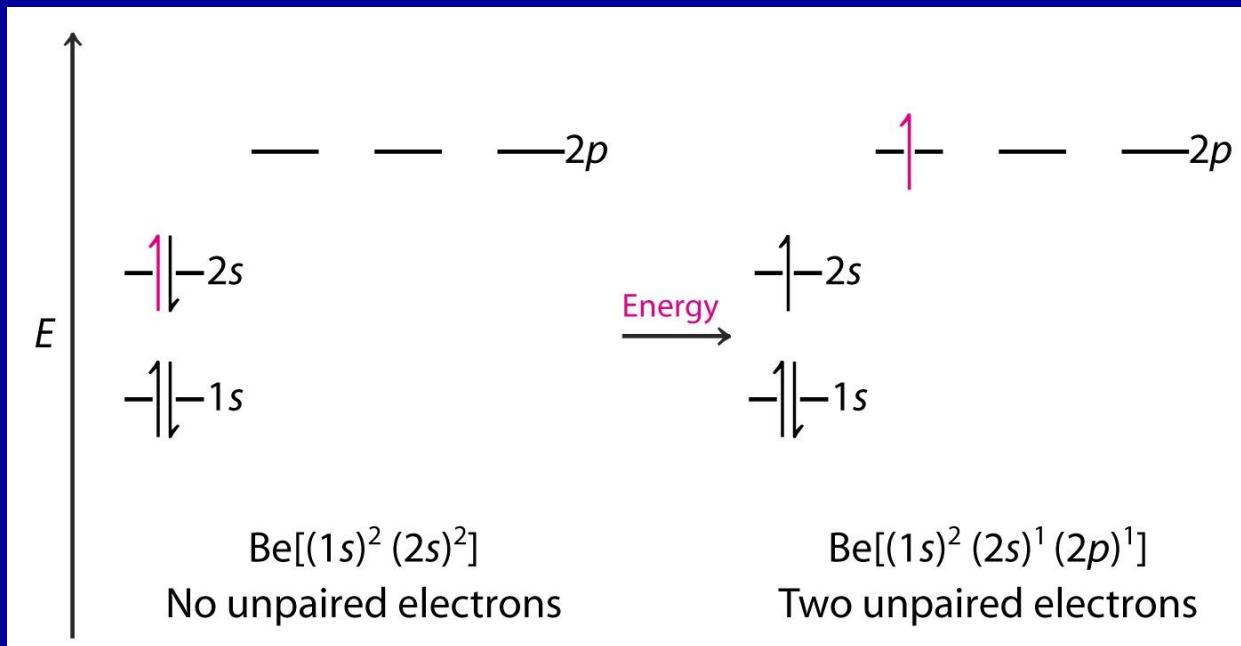
E

Hybridization And Geometry

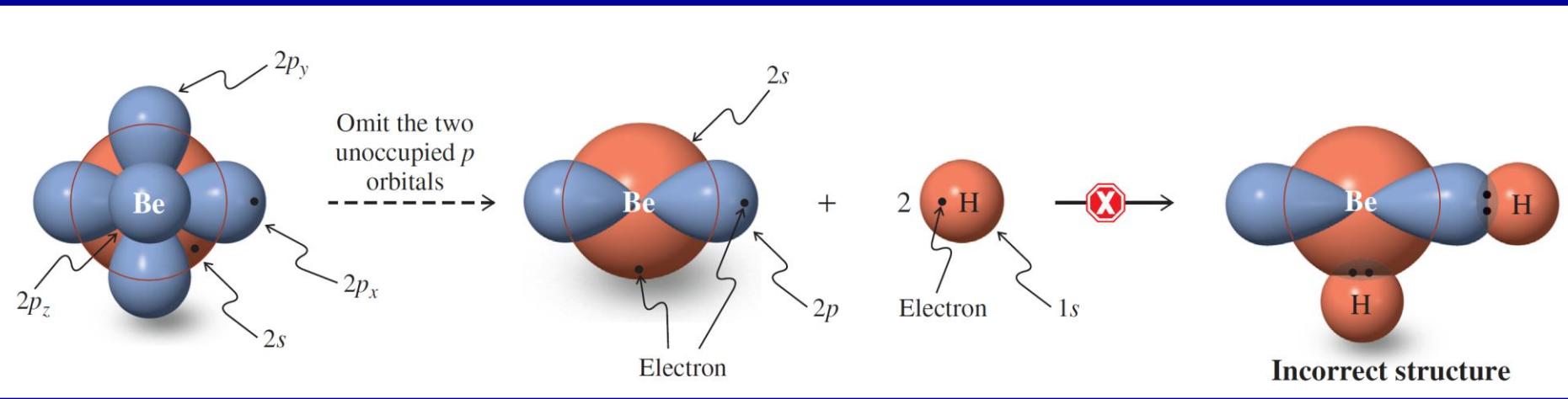
Li:H $2s + 1s$. No shape "issues"

δ^- H : Be : H δ^{++} (linear); but Be atom has filled shells $(1s)^2(2s)^2$.

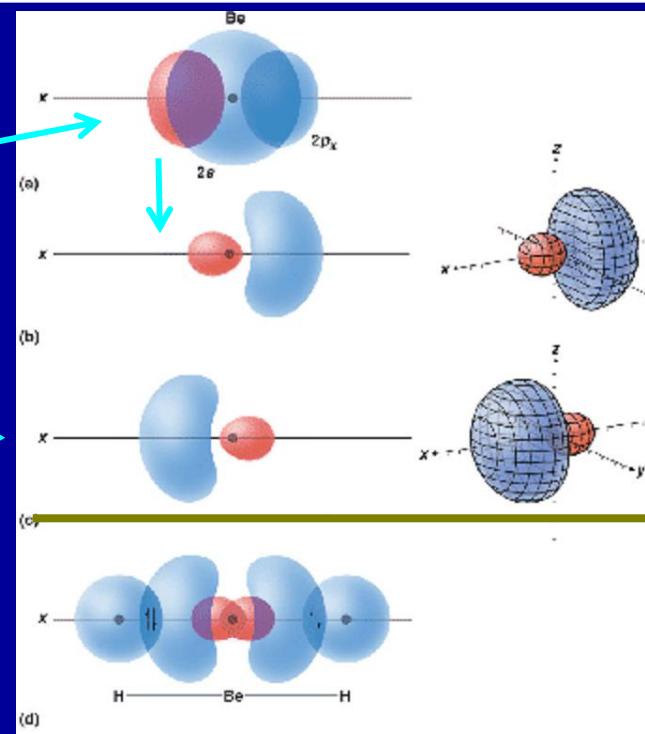
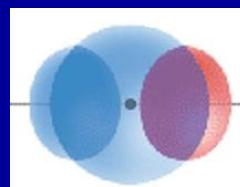
How does it bond? Use an empty p orbital:



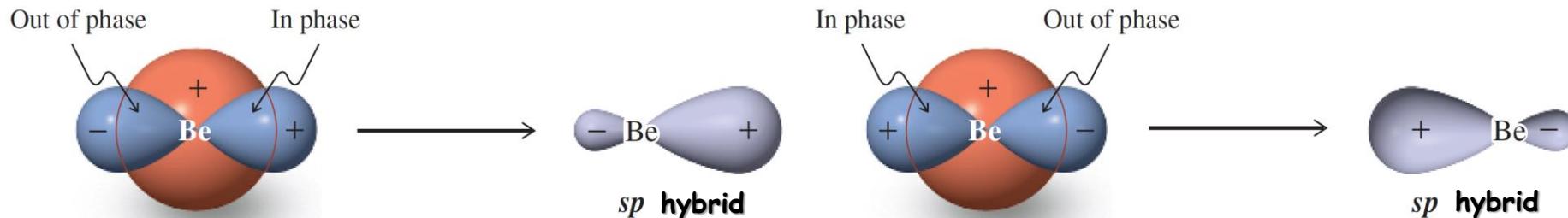
This allows for bonds by overlap of the H 1s with the Be 2s and 2p orbitals, but gives wrong structure:



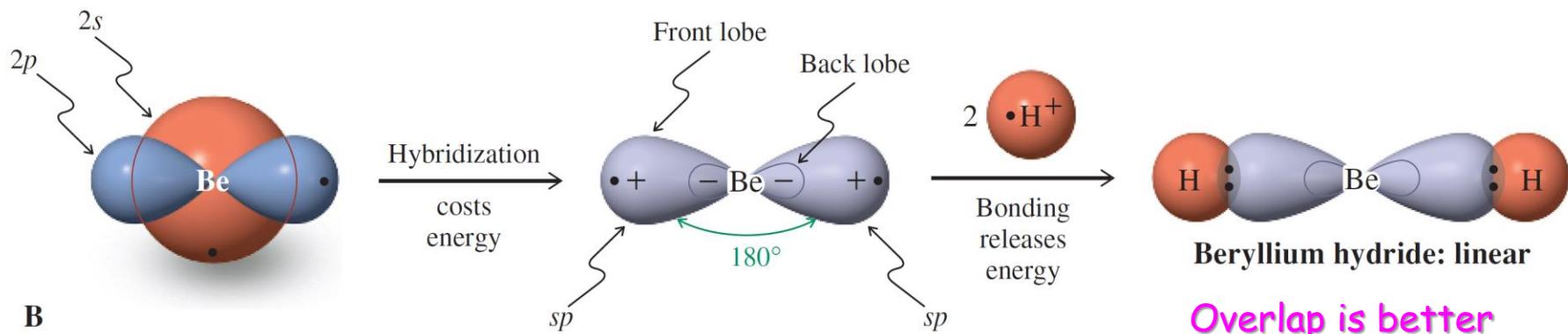
Better: "Hybridization" of the two orbitals = Intraatomic overlap ("in phase" and "out of phase") to generate two new hybrid molecular orbitals: $s + p \rightarrow$ two *sp* hybrids, with linear arrangement for BeH_2



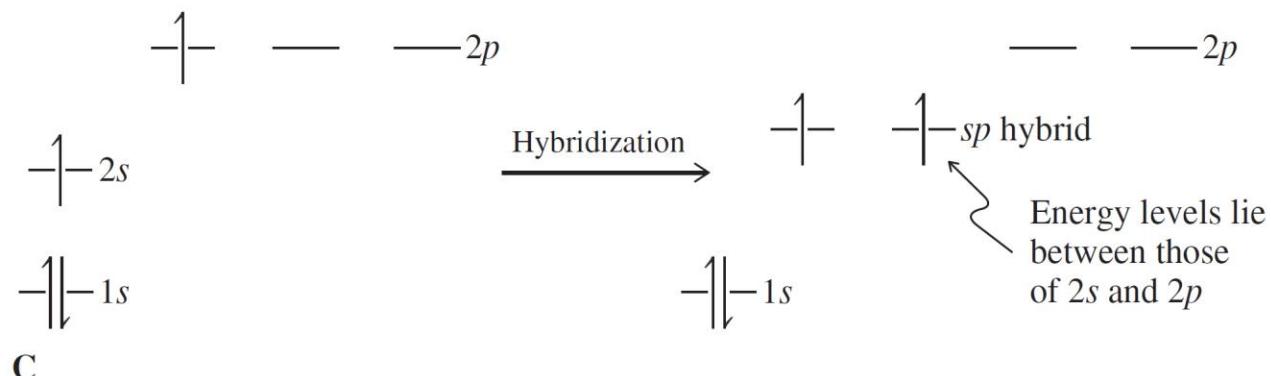
Bonding In BeH_2



A



Overlap is better
and there is
minimal e-repulsion



Sp

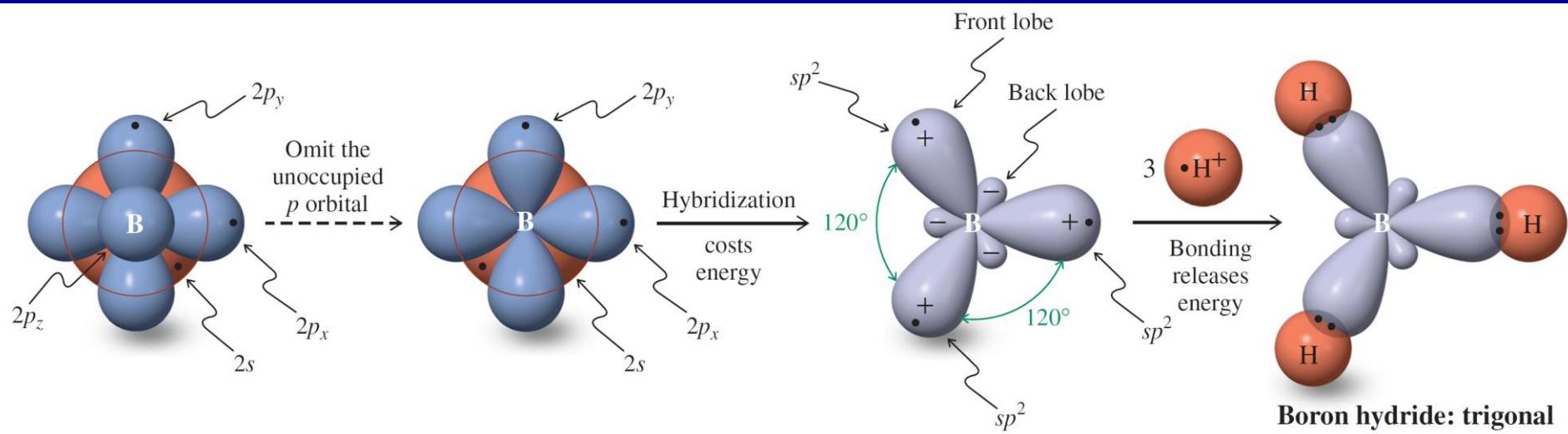
We shall see next that other combinations of intraatomic overlap (hybridization) are possible:

$s + p + p \rightarrow 3 sp^2$ with trigonal shape

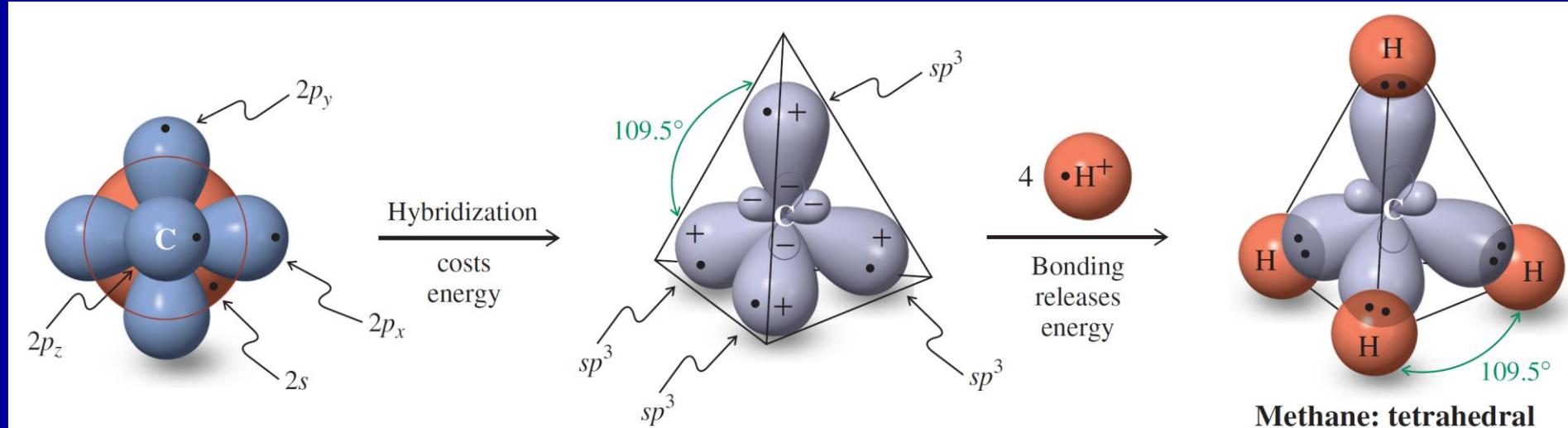
$s + p + p + p \rightarrow 4 sp^3$ with tetrahedral shape

Note: n atomic orbitals $\rightarrow n$ new orbitals

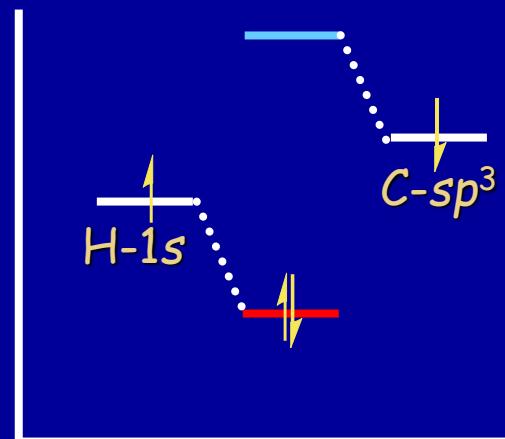
Example: Bonding In BH_3 . Hybridization To Trigonal



Bonding In Methane: Hybridization To Tetrahedral

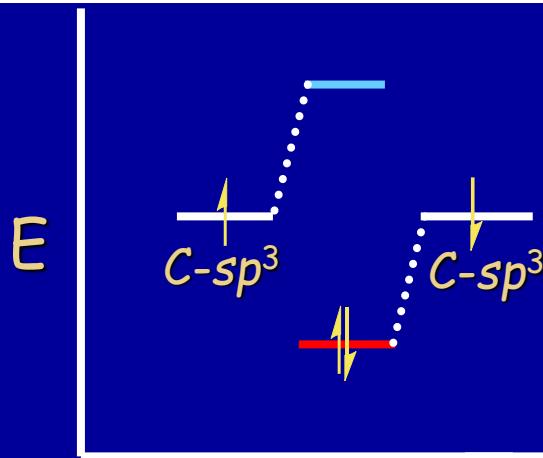
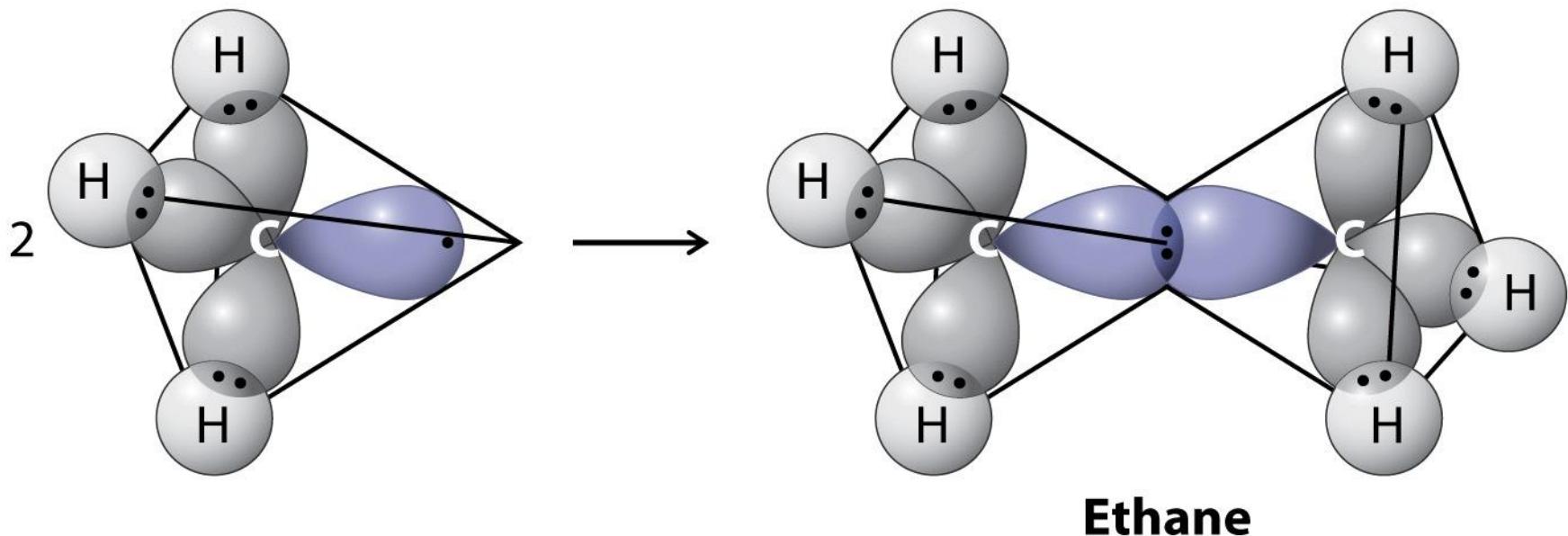


Energy splitting diagram of the C–H bond:

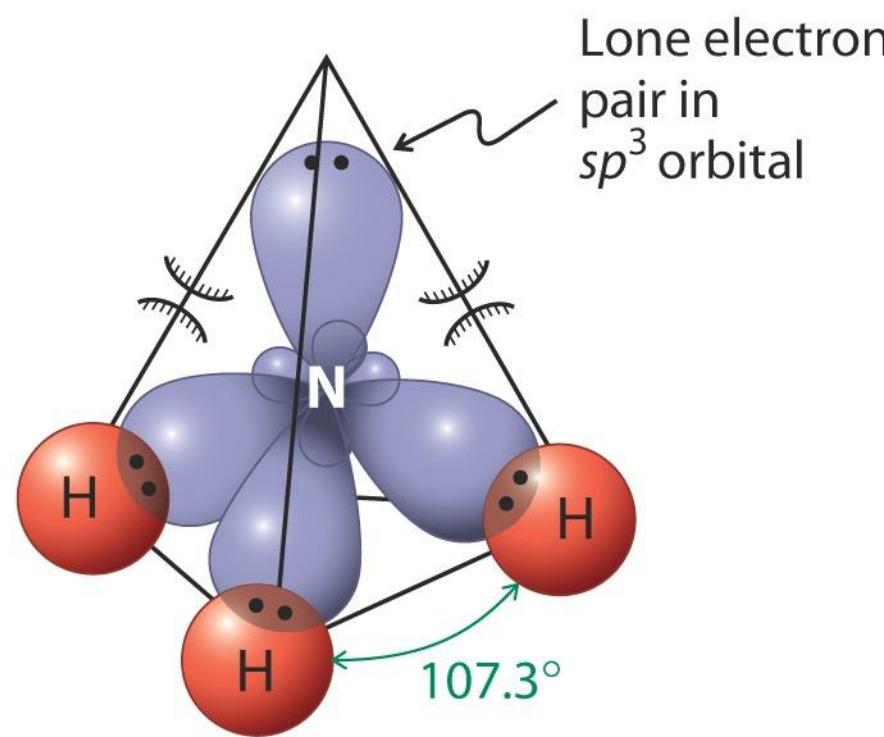


sp³

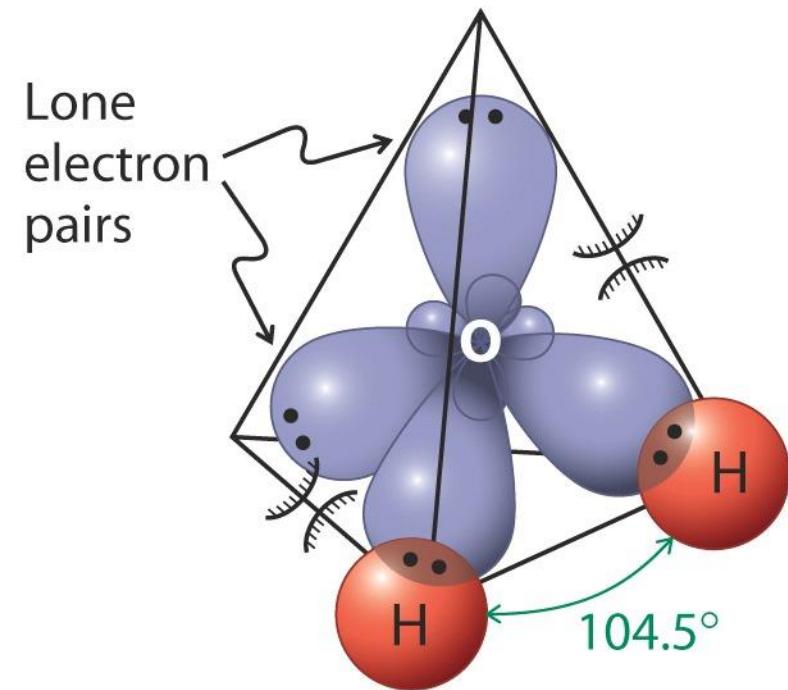
Bonding In Ethane: Overlap Of Two sp^3 Hybrid Orbitals



More sp^3 Hybrids: NH_3 And H_2O

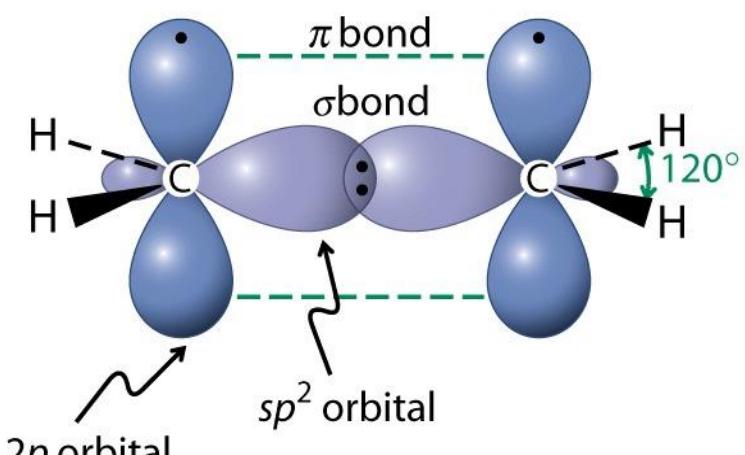


Ammonia

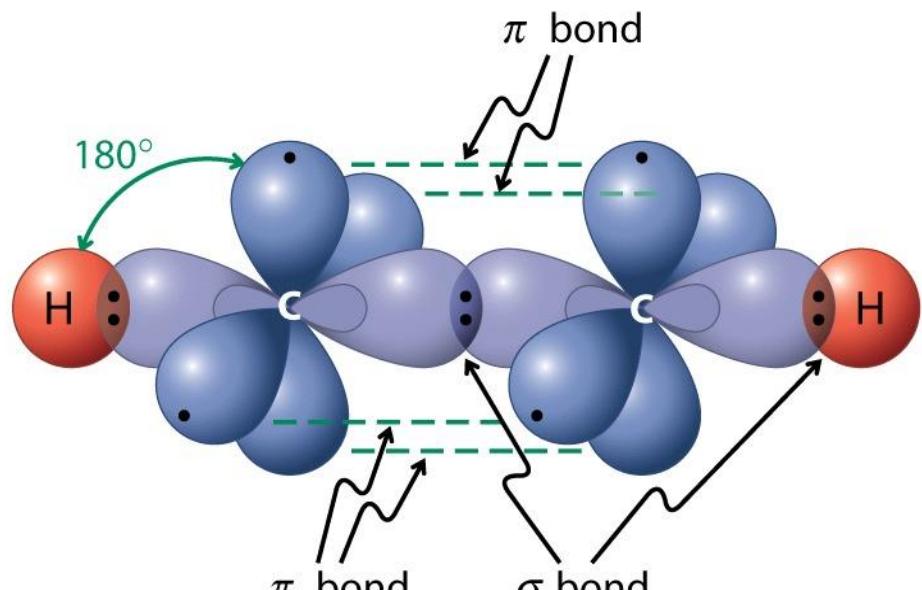


Water

Double And Triple Bonds: A Preview



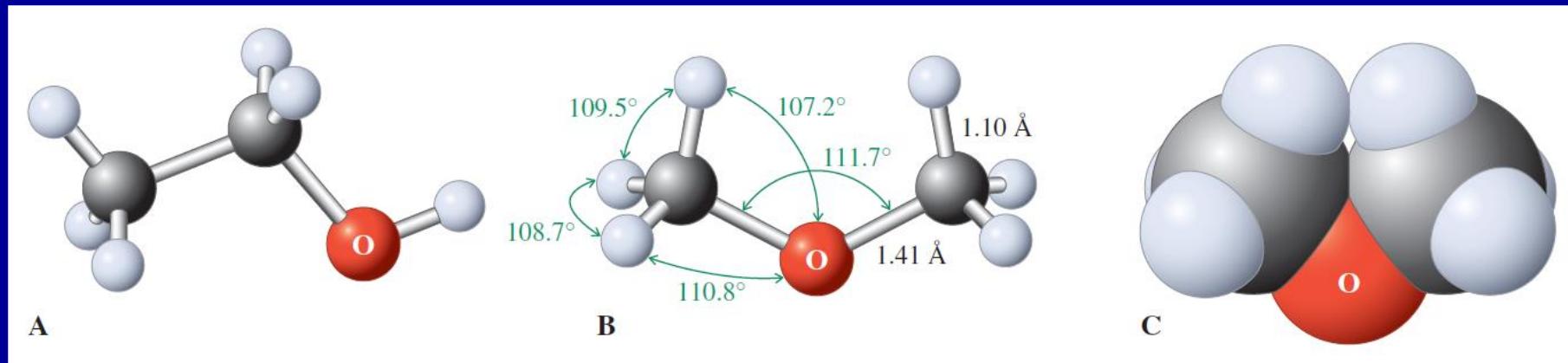
Ethene



Ethyne

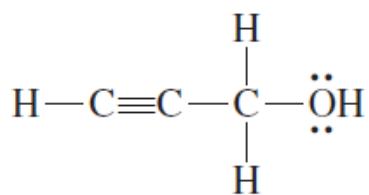
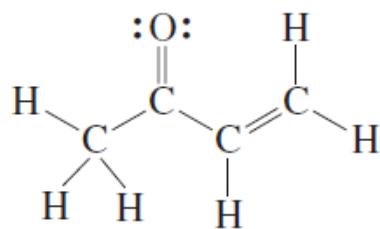
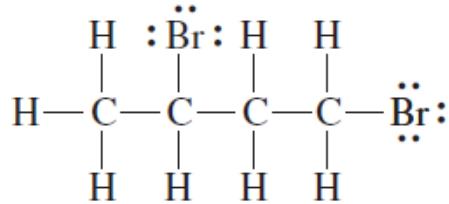
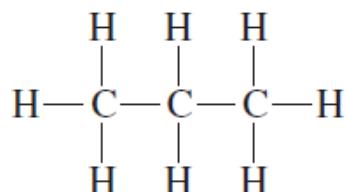
Molecular Models:

Use Them!!!

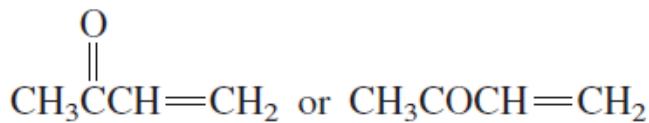
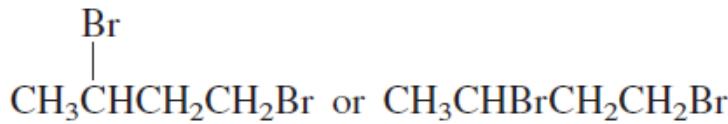


Drawing Molecules

Kekulé

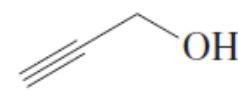
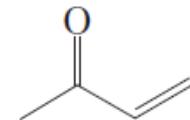
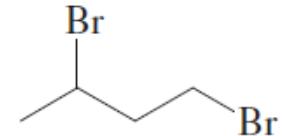


Condensed

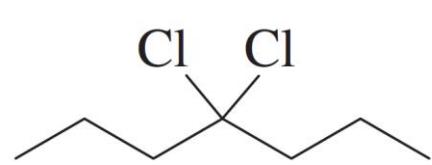
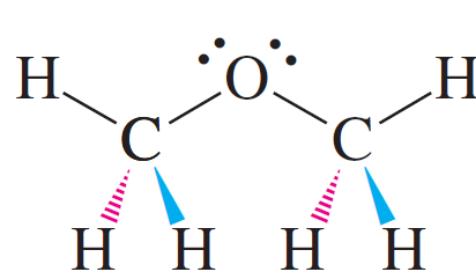
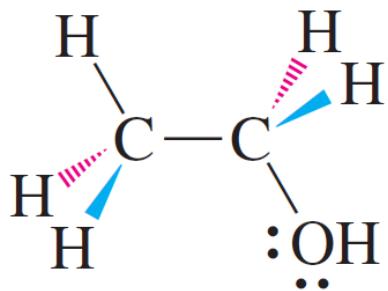
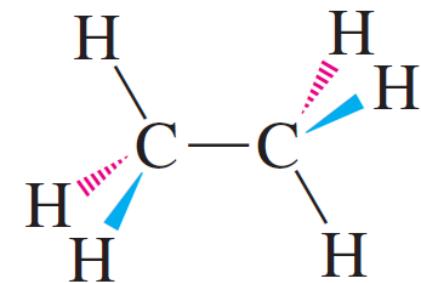
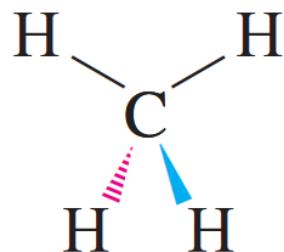
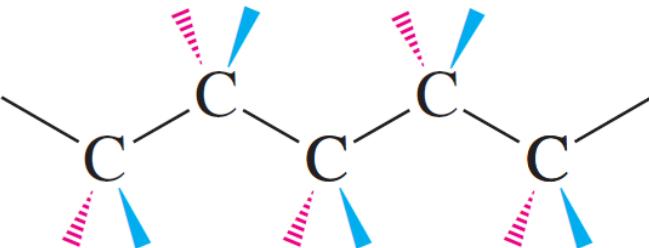


Bond-Line Formulas

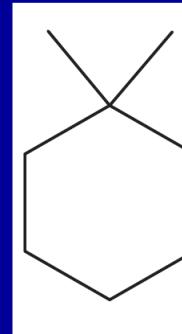
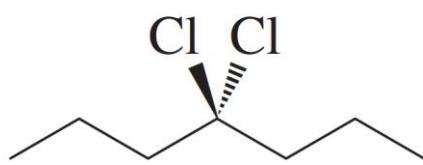
(all carbons are assumed to be "capped off" with hydrogens)



The Hashed-Wedged Line Notation



is really



is really

