

Chemical Bonds

Learning Outcomes

1. Name monoatomic and polyatomic ions.
2. Name binary ionic compounds and polyatomic ionic compounds (carbonate, hydroxide, nitrate, phosphate, ammonium, sulfate, and cyanide).
3. State the periodic trends for electronegativity.
4. Predict if two elements, based on their position in the periodic table, would form 1) polar covalent, 2) nonpolar covalent, or 3) ionic bonds.
- 5. Chemical Connections: Bone Chemistry.**
6. Name molecular compounds.
7. Classify elements as atomic or molecular and classify compounds as ionic or molecular.

Monoatomic Ions

Na^+ : Sodium cation

Cl^- : Chloride anion

TABLE 5.5 Some Common Anions

Nonmetal	Symbol for Ion	Base Name	Anion Name
fluorine	F^-	fluor-	fluoride
chlorine	Cl^-	chlor-	chloride
bromine	Br^-	brom-	bromide
iodine	I^-	iod-	iodide
oxygen	O^{2-}	ox-	oxide
sulfur	S^{2-}	sulf-	sulfide
nitrogen	N^{3-}	nit-	nitride

Common Polyatomic Ions

The names, formulas, and charges for the following polyatomic ions must be memorized for CHEM 60.

Common Polyatomic Ions			
Name	Formula	Name	Formula
carbonate	CO_3^{2-}	phosphate	PO_4^{3-}
hydroxide	OH^-	ammonium	NH_4^+
nitrate	NO_3^-	sulfate	SO_4^{2-}
		cyanide	CN^-

Naming Ionic Compounds: One Type of Cation

name of cation
(metal)

base name of anion
(nonmetal) + *-ide*

NaCl

Sodium Chloride

CaBr

Calcium Bromide

KBr

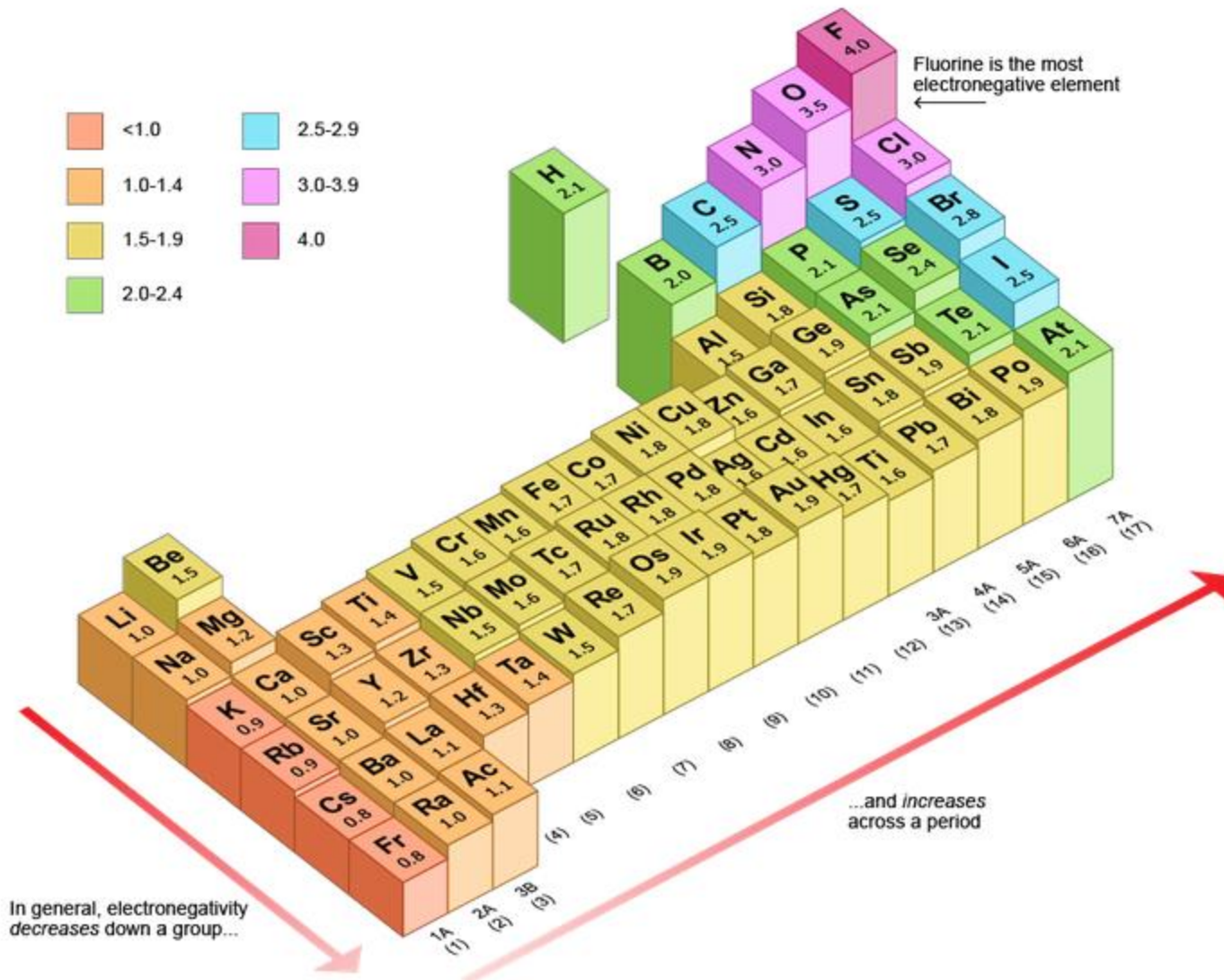
Potassium Bromide

Problem 1

Name the following ionic compounds.

- (a) MgO
- (b) MgCl_2
- (c) LiF
- (d) CaCl_2
- (e) CaO
- (f) CsCl
- (g) KCN
- (h) $(\text{NH}_4)_3\text{PO}_4$

Electronegativity Trends



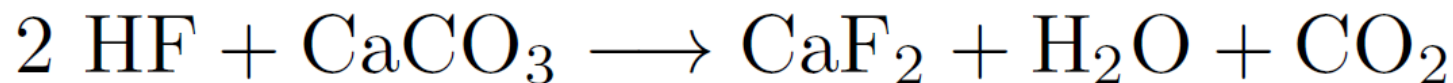
Chemistry of Bones

<https://www.youtube.com/watch?v=TzuCb8qgA8g>



Chemical Safety of HF and Bones

HF is a source of F^- . When exposed to the skin, F^- penetrates the skin and reacts with $CaCO_3$ to produce CaF_2 , H_2O , and CO_2 .



Naming Molecules



Prefix	Number
mono	1
di	2
tri	3
tetra	4
penta	5
hexa	6
hepta	7
octa	8
nona	9
deca	10

TABLE 5.5 Some Common Anions

Nonmetal	Symbol for Ion	Base Name	Anion Name
fluorine	F ⁻	fluor-	fluoride
chlorine	Cl ⁻	chlor-	chloride
bromine	Br ⁻	brom-	bromide
iodine	I ⁻	iod-	iodide
oxygen	O ²⁻	ox-	oxide
sulfur	S ²⁻	sulf-	sulfide
nitrogen	N ³⁻	nitr-	nitride

Naming Molecules



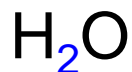
You omit the first element prefix if it is mono!



Carbon **D**ioxide



Carbon **Mono**oxide



Dihydrogen **Mono**oxide



Dihydrogen **Di**oxide

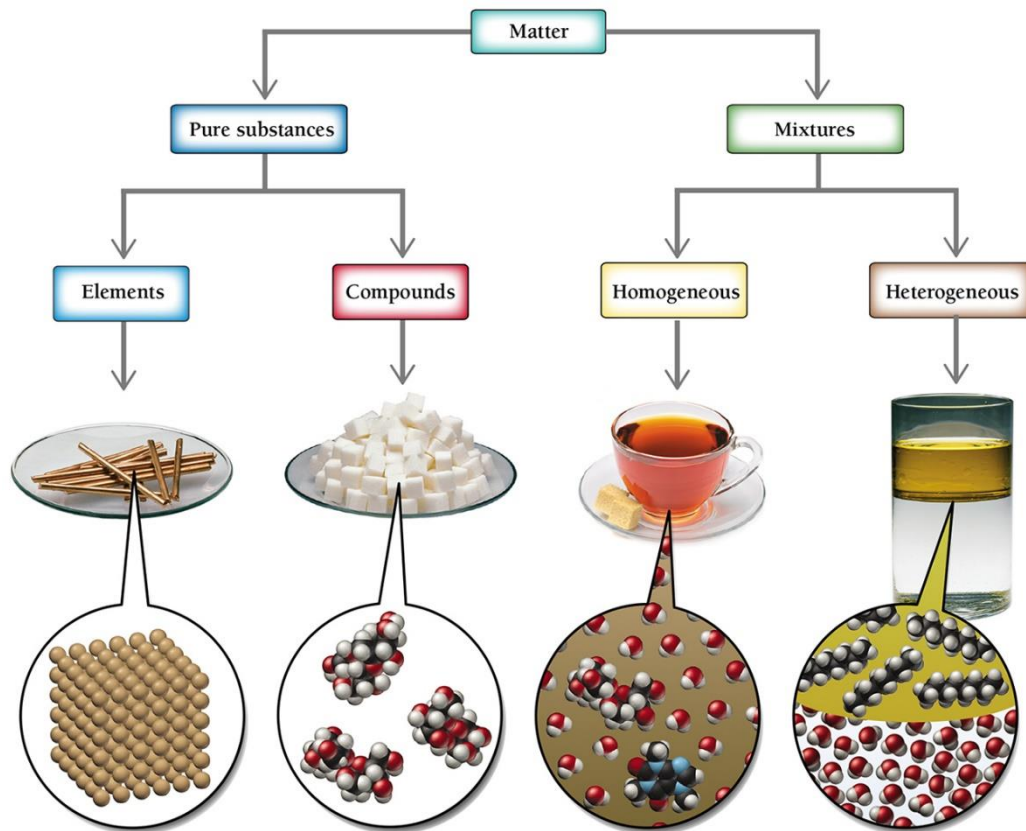


Carbon **Tetra**chloride

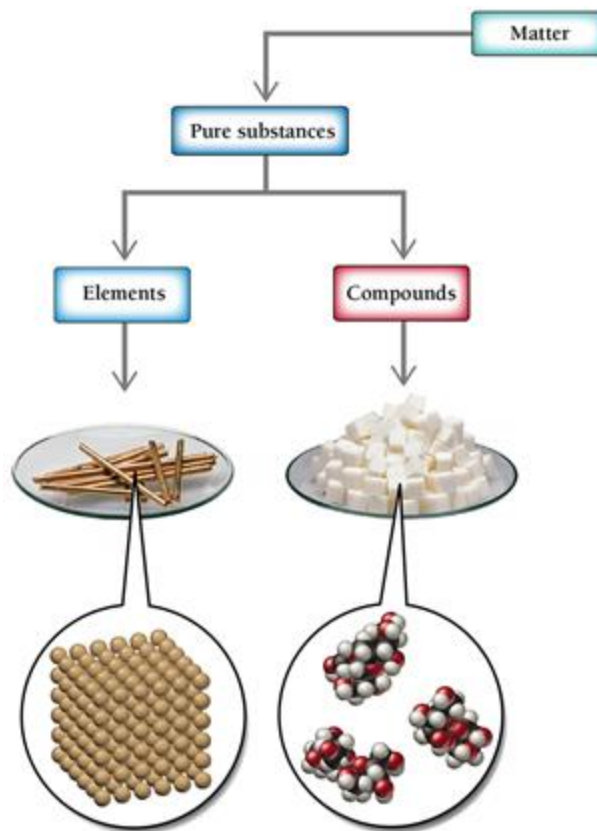


Carbon **Di**sulfide

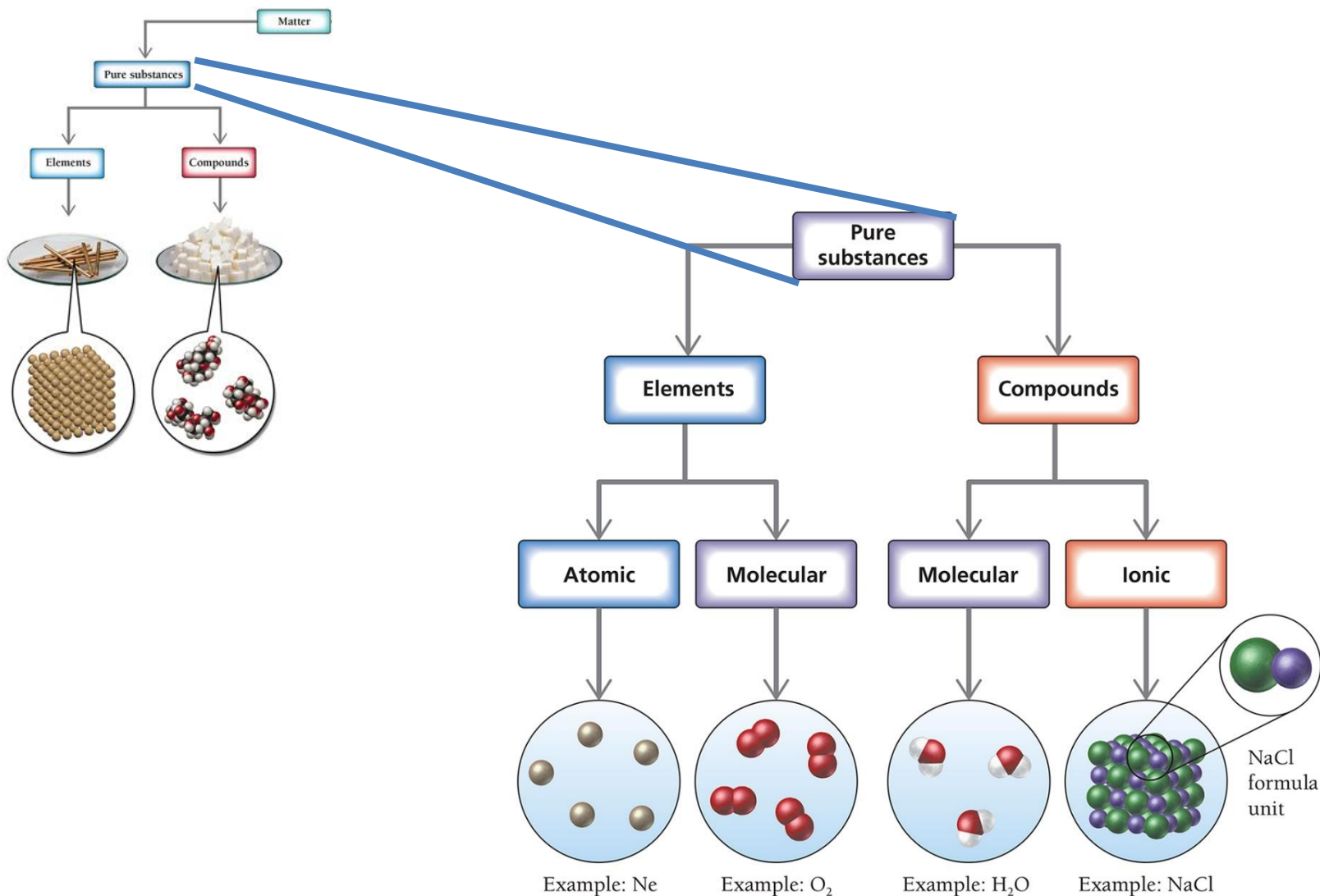
Review



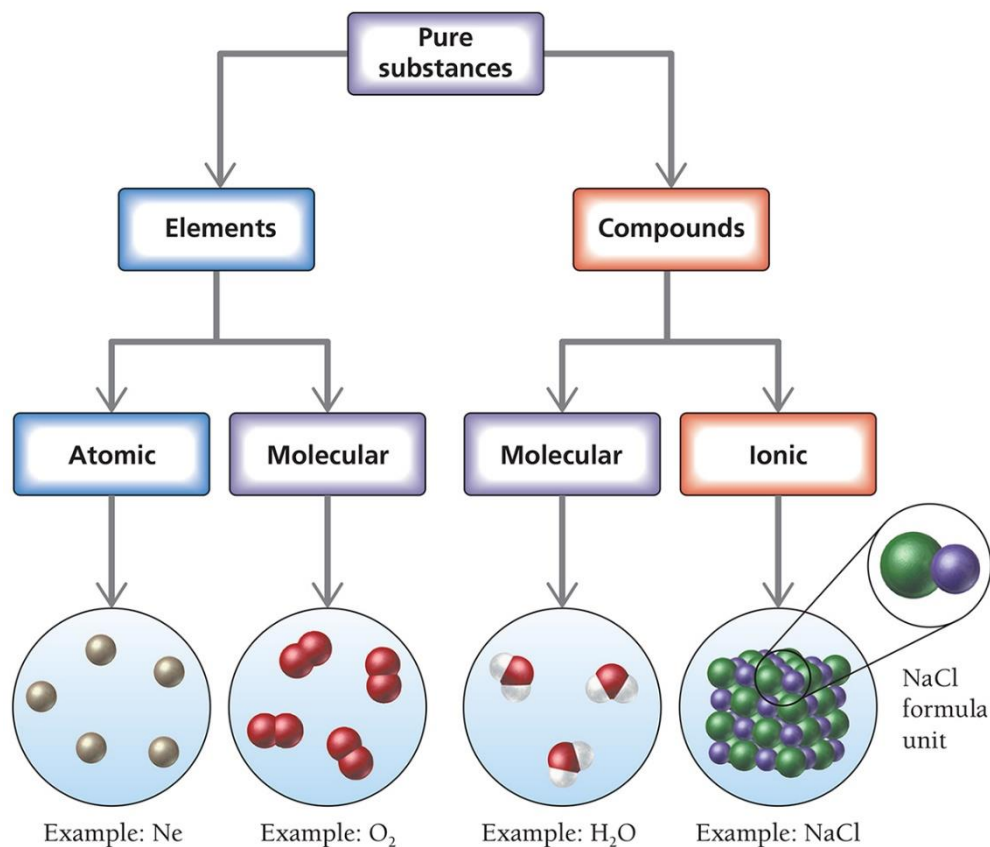
Review



Molecular and Ionic Compounds



Molecular and Ionic Compounds



Molecule: Molecular Formula
Ionic Compound: Formula Unit

Molecular Compound: Composed of two nonmetals
Ionic Compound: Composed of a metal and a nonmetal.

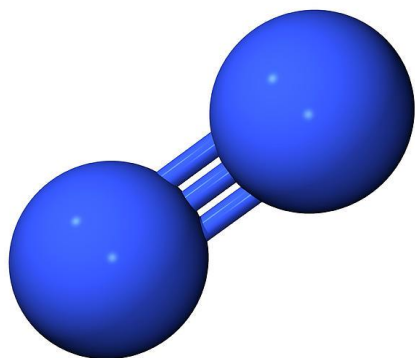
Problem 2

Does a molecule have to have more than one type of element?

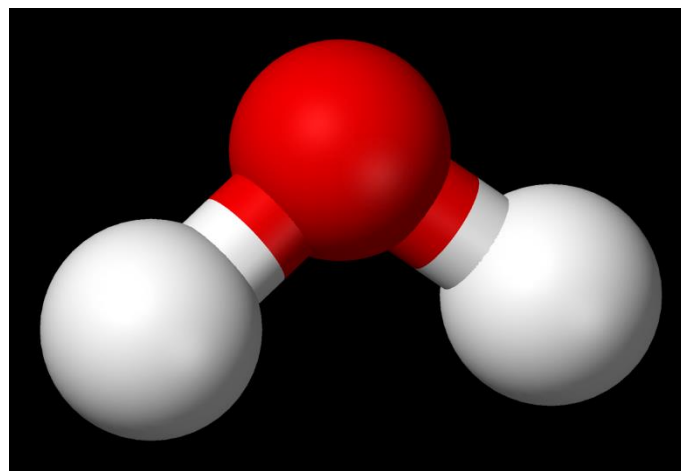
Problem 2 - Solution

A molecule does ***not*** have to have more than one type of element!

One oxygen atom



Molecular Nitrogen (N_2)



Two hydrogen atoms

Water Molecule (H_2O)

Problem 3

Identify each of the following as atomic or molecular elements?

- (a) Oxygen
- (b) Neon
- (c) Argon
- (d) Nitrogen
- (e) Helium
- (f) Krypton

Problem 4

Identify each of the following as ionic compound or a molecular compound.

- (a) CO_2
- (b) NaCl
- (c) LiF
- (d) BaCl_2
- (e) CS_2
- (f) NO_2

Learning Outcomes

1. Interpret a Lewis structure
2. Write simple Lewis structures
3. Determine whether a molecule is polar or nonpolar when **given** the molecular geometry.
 1. You will not be asked to predict the molecular geometry except for water (it is bent)

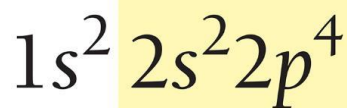
Review: The Periodic Table Tells Us

How Many Valence Electrons an Element Has (s and p Block Only)

<div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> <div>6</div> <div>7</div> <div>8</div>																	
<div>1 IA 1A</div> <div>2 IIA 2A</div> <div>3 IIIB 3B</div> <div>4 IVB 4B</div> <div>5 VB 5B</div> <div>6 VIB 6B</div> <div>7 VIIB 7B</div> <div>8 VIII 8</div> <div>9 VIII 8</div> <div>10 VIII 8</div> <div>11 IB 1B</div> <div>12 IIB 2B</div> <div>13 IIIA 3A</div> <div>14 IVA 4A</div> <div>15 VA 5A</div> <div>16 VIA 6A</div> <div>17 VIIA 7A</div> <div>18 VIIIA 8A</div>																	
<div>Atomic Number</div> <div>Atomic Mass</div> <div>Symbol</div> <div>Name</div> <div>Electron Configuration</div>																	
1 H Hydrogen 1s ¹	2 He Helium 1s ²	3 Li Lithium [He]2s ¹	4 Be Beryllium [He]2s ²	5 B Boron [He]2s ² 2p ¹	6 C Carbon [He]2s ² 2p ²	7 N Nitrogen [He]2s ² 2p ³	8 O Oxygen [He]2s ² 2p ⁴	9 F Fluorine [He]2s ² 2p ⁵	10 Ne Neon [He]2s ² 2p ⁶	11 Na Sodium [Ne]3s ¹	12 Mg Magnesium [Ne]3s ²	13 Al Aluminum [Ne]3s ² 3p ¹	14 Si Silicon [Ne]3s ² 3p ²	15 P Phosphorus [Ne]3s ² 3p ³	16 S Sulfur [Ne]3s ² 3p ⁴	17 Cl Chlorine [Ne]3s ² 3p ⁵	18 Ar Argon [Ne]3s ² 3p ⁶
19 K Potassium [Ar]4s ¹	20 Ca Calcium [Ar]4s ²	21 Sc Scandium [Ar]3d ¹ 4s ²	22 Ti Titanium [Ar]3d ² 4s ²	23 V Vanadium [Ar]3d ³ 4s ²	24 Cr Chromium [Ar]3d ⁵ 4s ¹	25 Mn Manganese [Ar]3d ⁵ 4s ²	26 Fe Iron [Ar]3d ⁶ 4s ²	27 Co Cobalt [Ar]3d ⁷ 4s ²	28 Ni Nickel [Ar]3d ⁸ 4s ²	29 Cu Copper [Ar]3d ¹⁰ 4s ¹	30 Zn Zinc [Ar]3d ¹⁰ 4s ²	31 Ga Gallium [Ar]3d ¹⁰ 4s ² 4p ¹	32 Ge Germanium [Ar]3d ¹⁰ 4s ² 4p ²	33 As Arsenic [Ar]3d ¹⁰ 4s ² 4p ³	34 Se Selenium [Ar]3d ¹⁰ 4s ² 4p ⁴	35 Br Bromine [Ar]3d ¹⁰ 4s ² 4p ⁵	36 Kr Krypton [Ar]3d ¹⁰ 4s ² 4p ⁶
37 Rb Rubidium [Kr]5s ¹	38 Sr Strontium [Kr]5s ²	39 Y Yttrium [Kr]4d ¹ 5s ²	40 Zr Zirconium [Kr]4d ² 5s ²	41 Nb Niobium [Kr]4d ⁴ 5s ¹	42 Mo Molybdenum [Kr]4d ⁵ 5s ¹	43 Tc Technetium [Kr]4d ⁵ 5s ²	44 Ru Ruthenium [Kr]4d ⁷ 5s ¹	45 Rh Rhodium [Kr]4d ⁸ 5s ¹	46 Pd Palladium [Kr]4d ¹⁰	47 Ag Silver [Kr]4d ¹⁰ 5s ¹	48 Cd Cadmium [Kr]4d ¹⁰ 5s ²	49 In Indium [Kr]4d ¹⁰ 5s ² 5p ¹	50 Sn Tin [Kr]4d ¹⁰ 5s ² 5p ²	51 Sb Antimony [Kr]4d ¹⁰ 5s ² 5p ³	52 Te Tellurium [Kr]4d ¹⁰ 5s ² 5p ⁴	53 I Iodine [Kr]4d ¹⁰ 5s ² 5p ⁵	54 Xe Xenon [Kr]4d ¹⁰ 5s ² 5p ⁶
55 Cs Cesium [Xe]6s ¹	56 Ba Barium [Xe]6s ²	57-71 Lanthanide Series	72 Hf Hafnium [Xe]4f ¹⁴ 5d ² 6s ²	73 Ta Tantalum [Xe]4f ¹⁴ 5d ³ 6s ²	74 W Tungsten [Xe]4f ¹⁴ 5d ⁴ 6s ²	75 Re Rhenium [Xe]4f ¹⁴ 5d ⁵ 6s ²	76 Os Osmium [Xe]4f ¹⁴ 5d ⁶ 6s ²	77 Ir Iridium [Xe]4f ¹⁴ 5d ⁷ 6s ²	78 Pt Platinum [Xe]4f ¹⁴ 5d ⁹ 6s ¹	79 Au Gold [Xe]4f ¹⁴ 5d ¹⁰ 6s ¹	80 Hg Mercury [Xe]4f ¹⁴ 5d ¹⁰ 6s ²	81 Tl Thallium [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ¹	82 Pb Lead [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ²	83 Bi Bismuth [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ³	84 Po Polonium [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁴	85 At Astatine [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁵	86 Rn Radon [Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁶
87 Fr Francium [Rn]7s ¹	88 Ra Radium [Rn]7s ²	89-103 Actinide Series	104 Rf Rutherfordium [Rn]5f ¹⁴ 6d ² 7s ²	105 Db Dubnium [Rn]5f ¹⁴ 6d ³ 7s ²	106 Sg Seaborgium [Rn]5f ¹⁴ 6d ⁴ 7s ²	107 Bh Bohrium [Rn]5f ¹⁴ 6d ⁵ 7s ²	108 Hs Hassium [Rn]5f ¹⁴ 6d ⁶ 7s ²	109 Mt Meitnerium [Rn]5f ¹⁴ 6d ⁷ 7s ²	110 Ds Darmstadtium [Rn]5f ¹⁴ 6d ⁸ 7s ²	111 Rg Roentgenium [Rn]5f ¹⁴ 6d ⁹ 7s ²	112 Cn Copernicium [Rn]5f ¹⁴ 6d ¹⁰ 7s ²	113 Uut Ununtrium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ¹	114 Fl Flerovium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ²	115 Uup Ununpentium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ³	116 Lv Livermorium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁴	117 Uus Ununseptium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁵	118 Uuo Ununoctium [Rn]5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁶
57 La Lanthanum [Xe]5d ¹ 6s ²	58 Ce Cerium [Xe]4f ¹ 5d ¹ 6s ²	59 Pr Praseodymium [Xe]4f ³ 6s ²	60 Nd Neodymium [Xe]4f ⁴ 6s ²	61 Pm Promethium [Xe]4f ⁵ 6s ²	62 Sm Samarium [Xe]4f ⁶ 6s ²	63 Eu Europium [Xe]4f ⁷ 6s ²	64 Gd Gadolinium [Xe]4f ⁷ 5d ¹ 6s ²	65 Tb Terbium [Xe]4f ⁹ 6s ²	66 Dy Dysprosium [Xe]4f ¹⁰ 6s ²	67 Ho Holmium [Xe]4f ¹¹ 6s ²	68 Er Erbium [Xe]4f ¹² 6s ²	69 Tm Thulium [Xe]4f ¹³ 6s ²	70 Yb Ytterbium [Xe]4f ¹⁴ 6s ²	71 Lu Lutetium [Xe]4f ¹⁴ 5d ¹ 6s ²			
89 Ac Actinium [Rn]6d ¹ 7s ²	90 Th Thorium [Rn]6d ² 7s ²	91 Pa Protactinium [Rn]5f ² 6d ¹ 7s ²	92 U Uranium [Rn]5f ³ 6d ¹ 7s ²	93 Np Neptunium [Rn]5f ⁴ 6d ¹ 7s ²	94 Pu Plutonium [Rn]5f ⁶ 7s ²	95 Am Americium [Rn]5f ⁷ 7s ²	96 Cm Curium [Rn]5f ⁸ 7s ²	97 Bk Berkelium [Rn]5f ⁹ 7s ²	98 Cf Californium [Rn]5f ¹⁰ 7s ²	99 Es Einsteinium [Rn]5f ¹¹ 7s ²	100 Fm Fermium [Rn]5f ¹² 7s ²	101 Md Mendelevium [Rn]5f ¹³ 7s ²	102 No Nobelium [Rn]5f ¹⁴ 7s ²	103 Lr Lawrencium [Rn]5f ¹⁴ 6d ¹ 7s ²			

Lewis Structures: Valence Electrons Are Represented With Dots

Oxygen



6 valence
electrons



6 dots representing
valence electrons

Problem 5

Write the Lewis structure for the following elements

(a) Li

(b) Be

(c) C

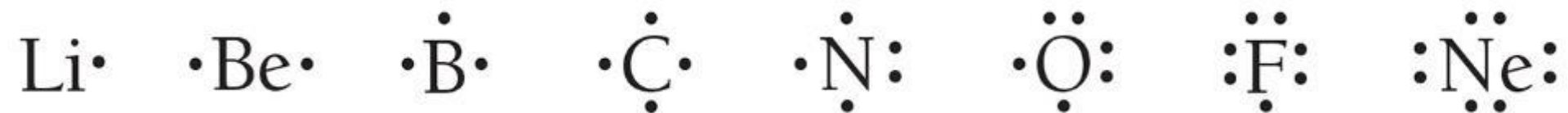
(d) N

(e) O

(f) F

(g) Ne

Problem 5 - Solution



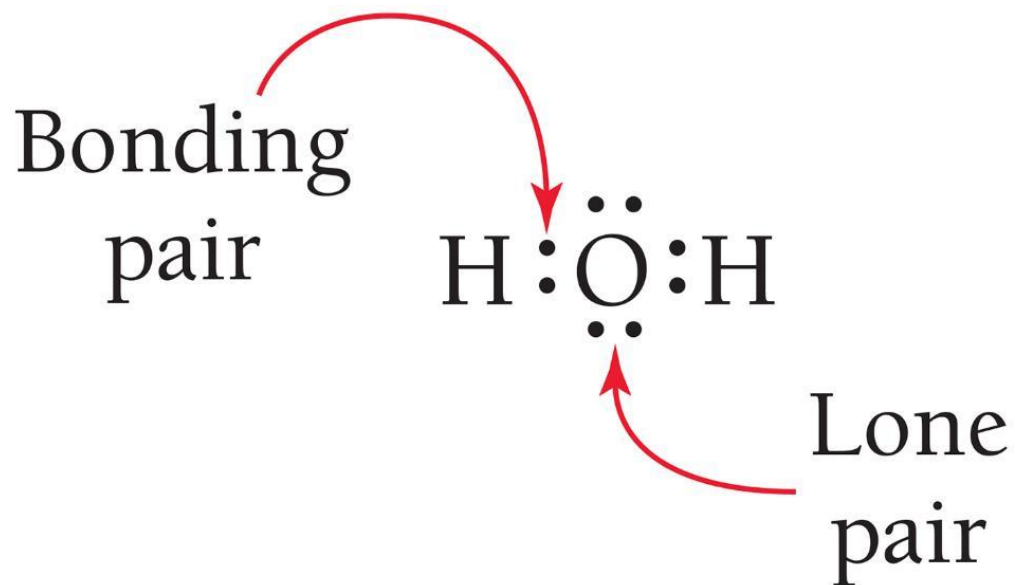
Problem 6

Draw the Lewis structure for H_2O .

Covalent Lewis Structures

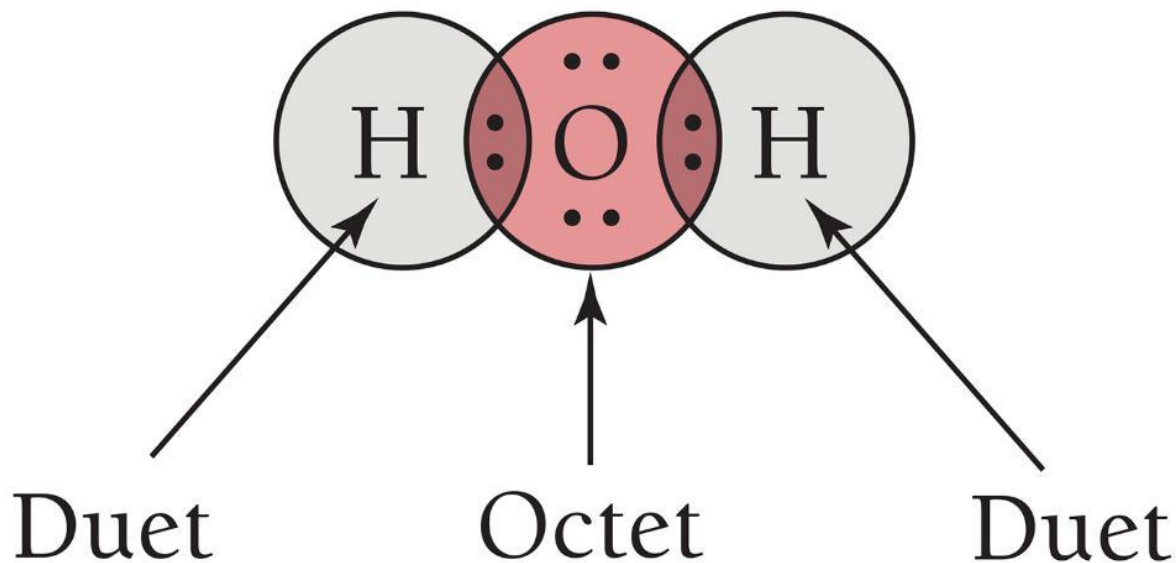
Two ***shared*** electrons represents a bond.

Nonbonding electrons are called a lone pair.



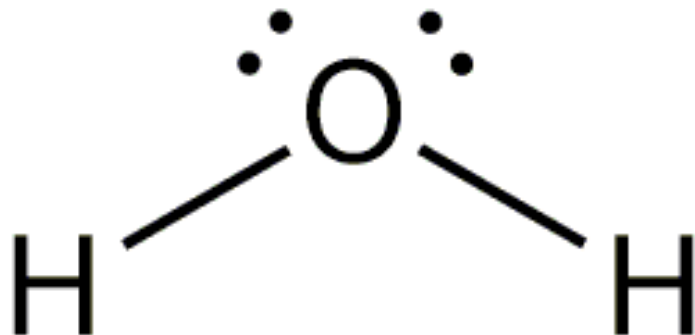
Octet “Rule”

In CHEM 60, hydrogen will have a ***duet*** and all other atoms will have an ***octet***.



Note that in future classes there will be atom that can have more than 10 electrons!

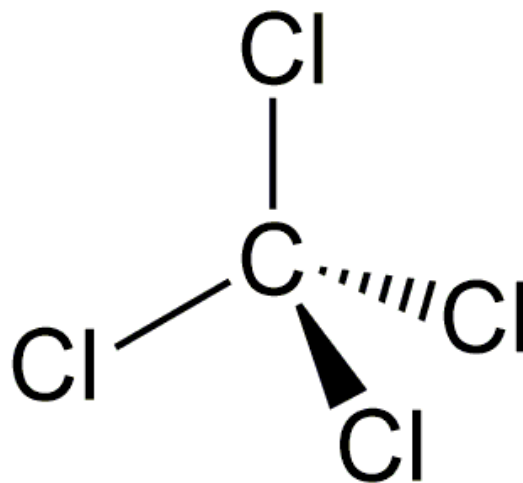
Problem 6 - Solution



Problem 7

Write the Lewis structure for CCl_4 .

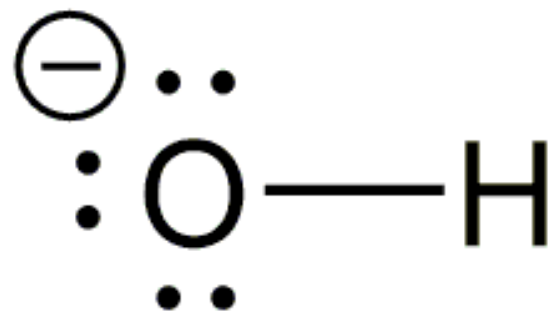
Problem 7 - Solution



Problem 8

Write the Lewis structure for OH^-

Problem 8 - Solution



Problem 9

Write the Lewis structure for HCN.

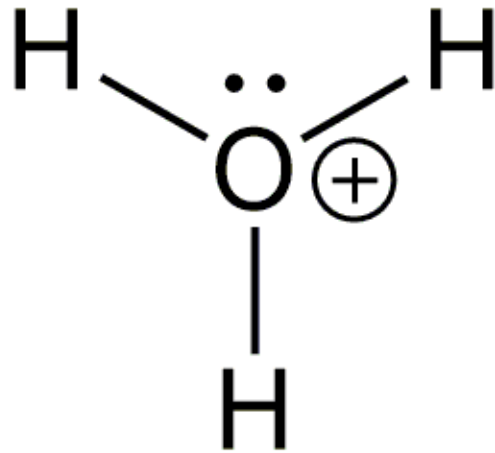
Problem 9 - Solution



Problem 10

Write the Lewis structure for H_3O^+ .

Problem 10 - Solution

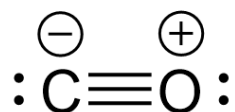


Evaluating Structures

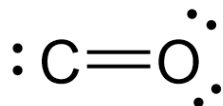
1. Atoms that have octets should have octets
2. Minimize the magnitude of formal charge on an atom (this will be listed for you!)
3. Minimize the number of atoms with formal charge

Problem 11

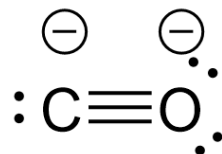
Which of the following Lewis structures for carbon monoxide is the best Lewis structure?



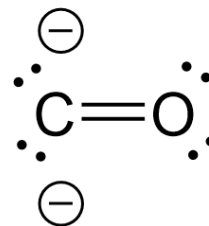
A



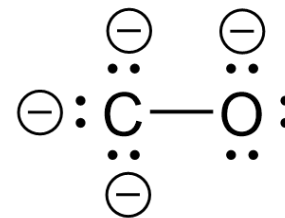
B



C

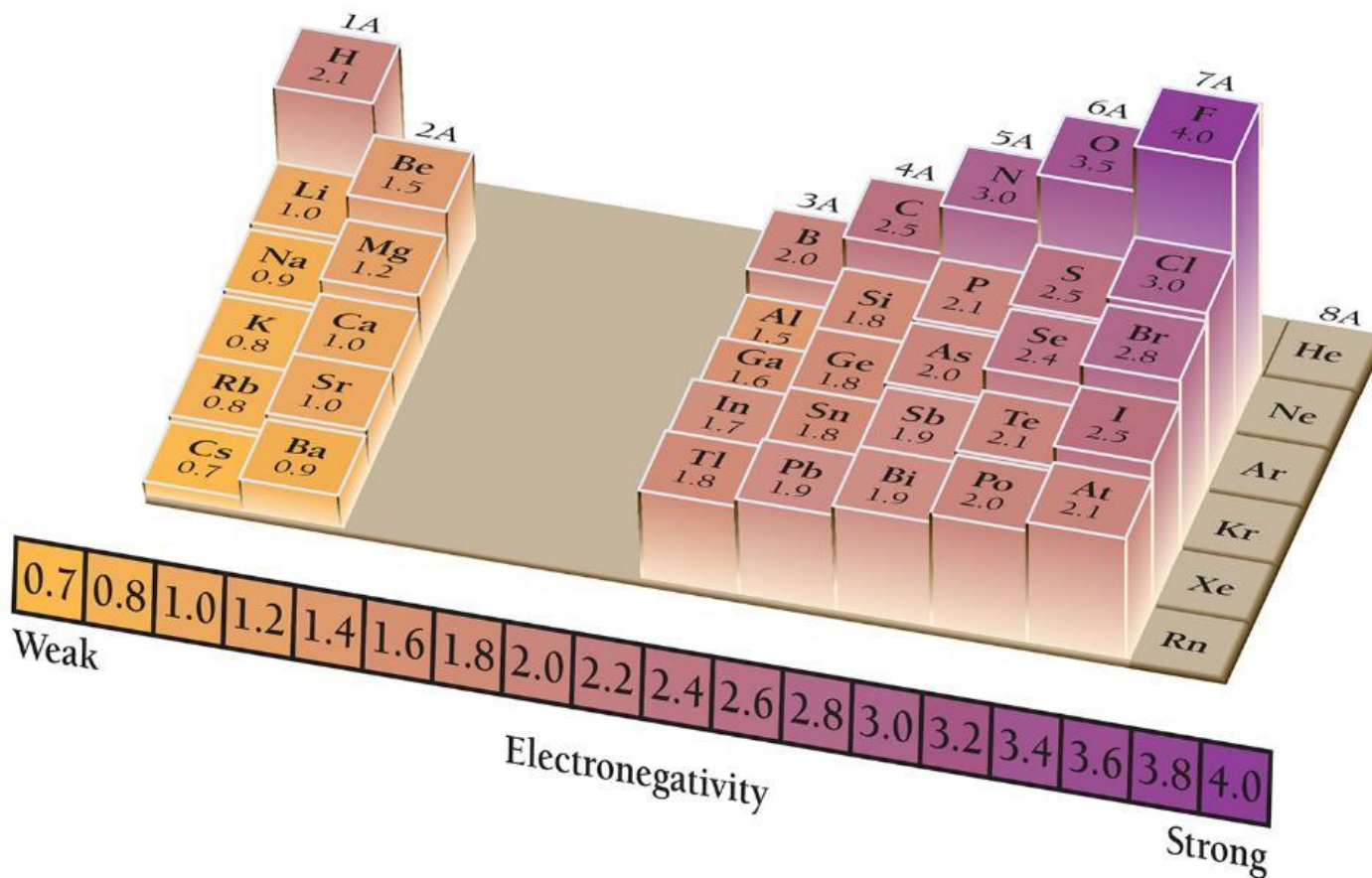


D



E

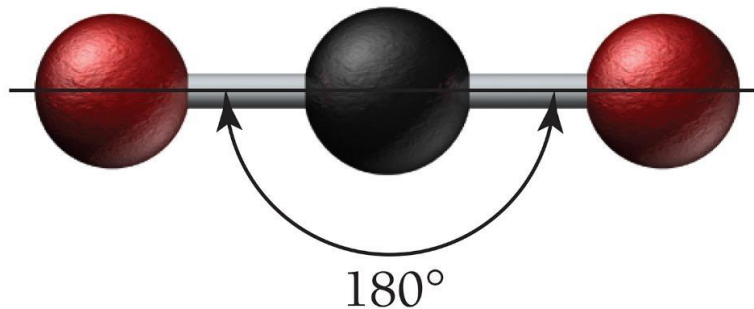
Electronegativity



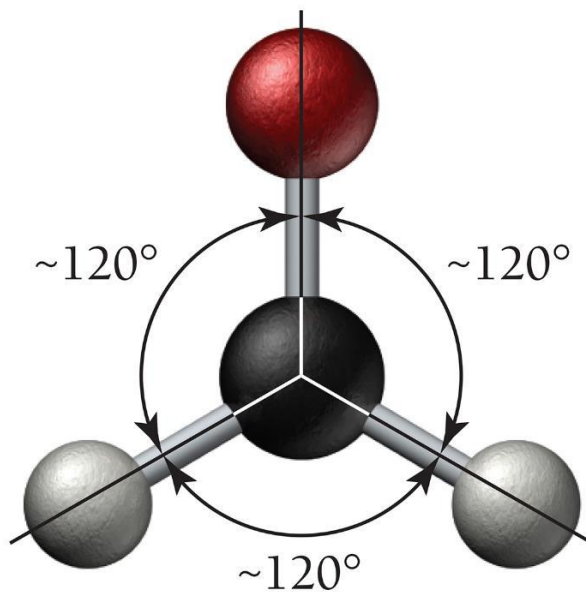
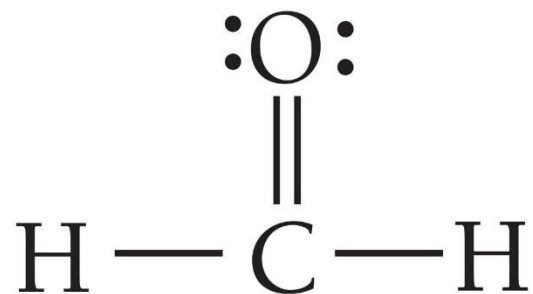
Molecular Geometry

The shape of a molecule is important because it plays a key role in the reactivity and physical properties of the molecule.

Molecular Geometry









Molecular Geometry



Molecular Geometry Table

This table DOES NOT NEED TO BE memorized.

Electron Groups*	Bonding Groups	Lone Pairs	Electron Geometry	Angle between Electron Groups**	Molecular Geometry	Example
2	2	0	linear	180°	linear	$\text{:}\ddot{\text{O}}=\text{C}=\ddot{\text{O}}\text{:}$ 
3	3	0	trigonal planar	120°	trigonal planar	$\begin{array}{c} \ddot{\text{O}}\text{:} \\ \\ \text{H}-\text{C}-\text{H} \end{array}$ 
3	2	1	trigonal planar	120°	bent	$\text{:}\ddot{\text{O}}=\ddot{\text{S}}-\ddot{\text{O}}\text{:}$ 
4	4	0	tetrahedral	109.5°	tetrahedral	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{H} \\ \\ \text{H} \end{array}$ 
4	3	1	tetrahedral	109.5°	trigonal pyramidal	$\begin{array}{c} \text{H}-\ddot{\text{N}}-\text{H} \\ \\ \text{H} \end{array}$ 
4	2	2	tetrahedral	109.5°	bent	$\text{H}-\ddot{\text{O}}-\text{H}$ 

* Count only electron groups around the *central* atom. Each of the following is considered one electron group: a lone pair, a single bond, a double bond, and a triple bond.

** Angles listed here are idealized. Actual angles in specific molecules may vary by several degrees. For example, the bond angles in ammonia are 107° and the bond angle in water is 104.5°.

Polarity

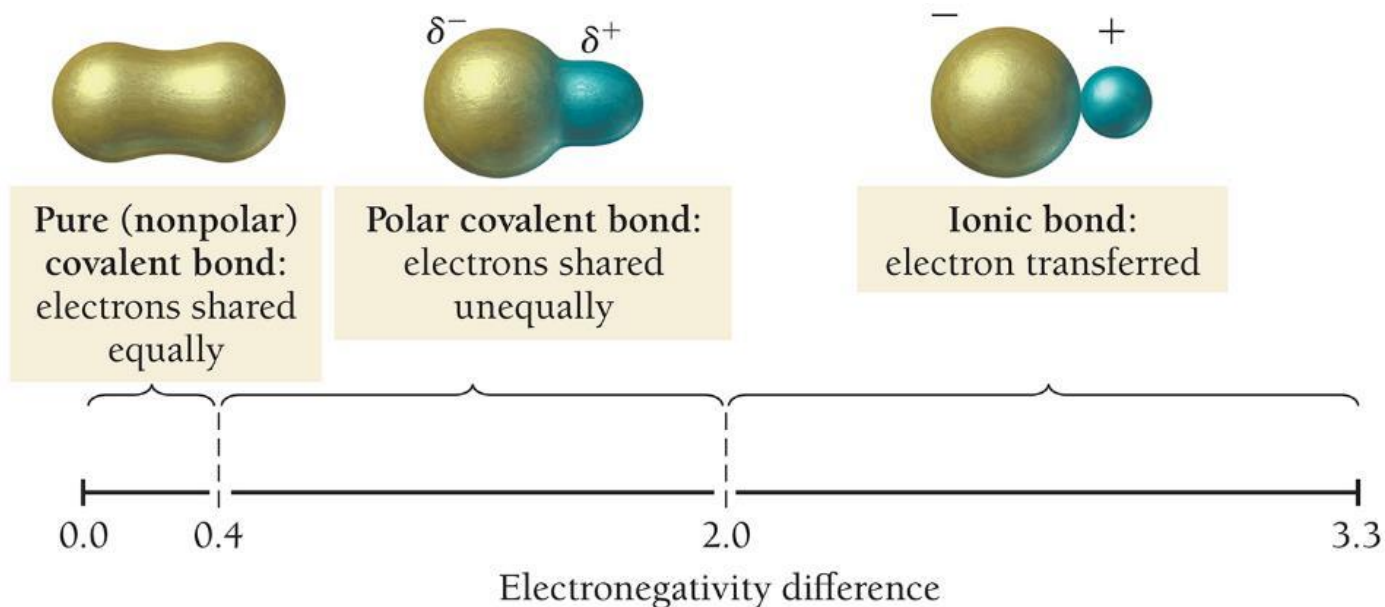


TABLE 10.2 The Effect of Electronegativity Difference on Bond Type

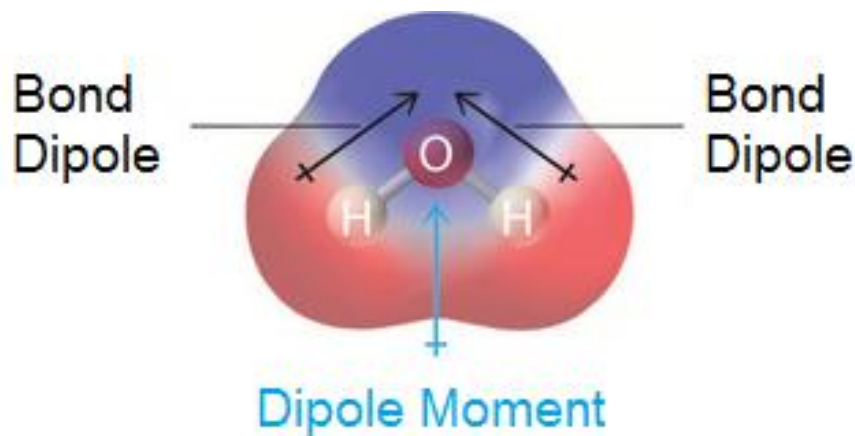
Electronegativity Difference (ΔEN)	Bond Type	Example
zero (0–0.4)	pure covalent	Cl_2
intermediate (0.4–2.0)	polar covalent	HF
large (2.0+)	ionic	NaCl

Bond Dipole vs. Dipole Moment

A dipole moment is the vector (arrow) sum of the different bond dipoles

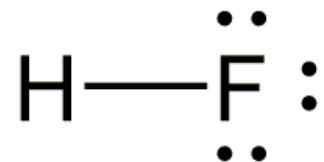
CHEM 60 Definition of Polar: If a molecule has a dipole moment it is polar.

CHEM Definition of Nonpolar: If a molecule has no dipole moment
(bond dipoles cancel out) it is nonpolar.

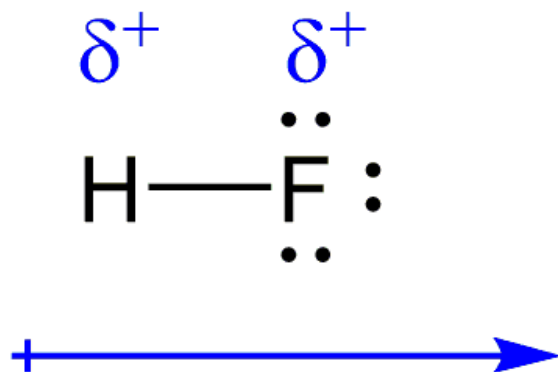


Problem 12

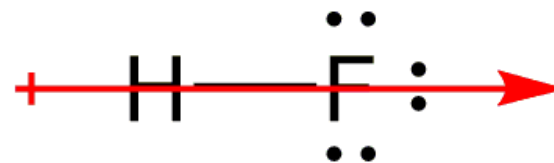
Is HF polar?



Problem 12 - Solution



Bond Dipole



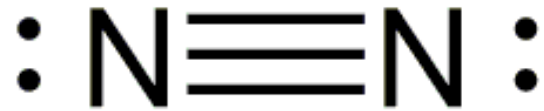
Dipole Moment

Problem 13

Is N_2 polar?

Problem 13 - Solution

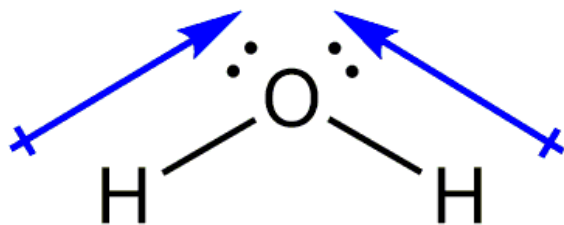
No Dipole Moment



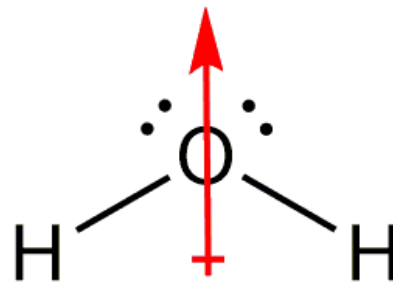
Problem 14

Is H_2O polar?

Problem 14 - Solution



Bond Dipoles



Dipole Moment

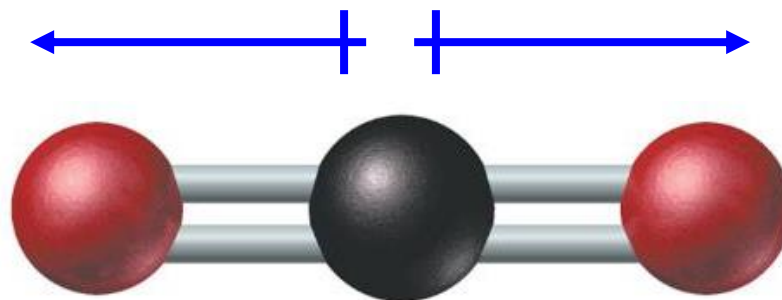
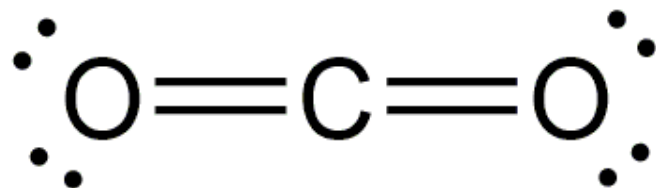
Problem 15

Is CO_2 polar?



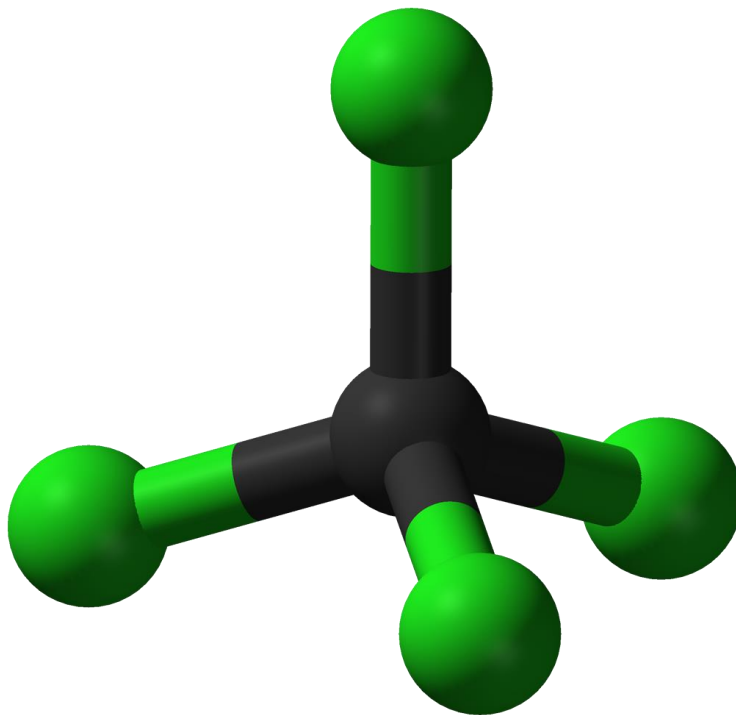
Problem 15 - Solution

No Dipole Moment



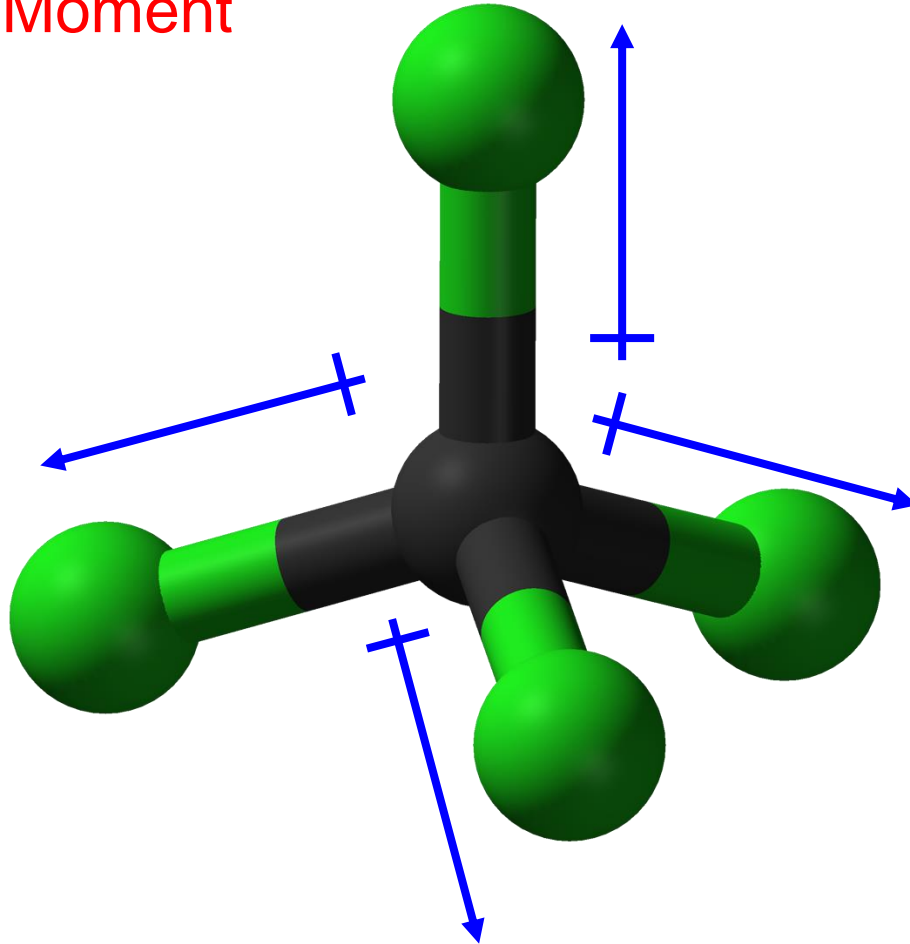
Problem 16

Is CCl_4 polar?



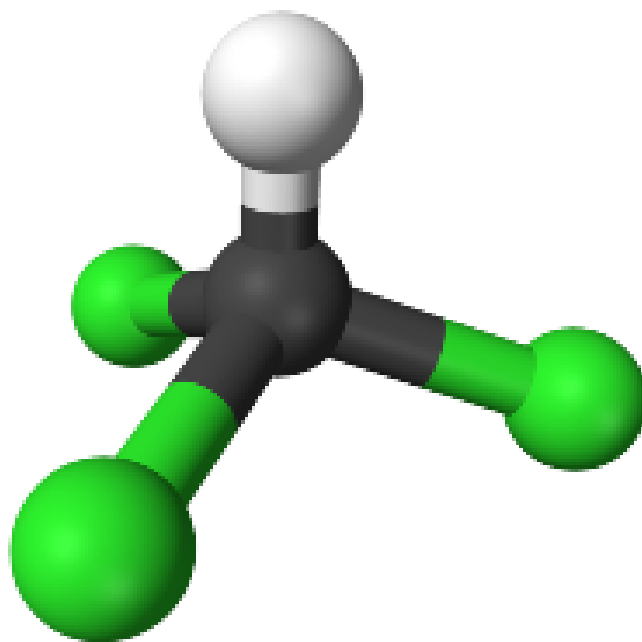
Problem 16 - Solution

No Dipole Moment

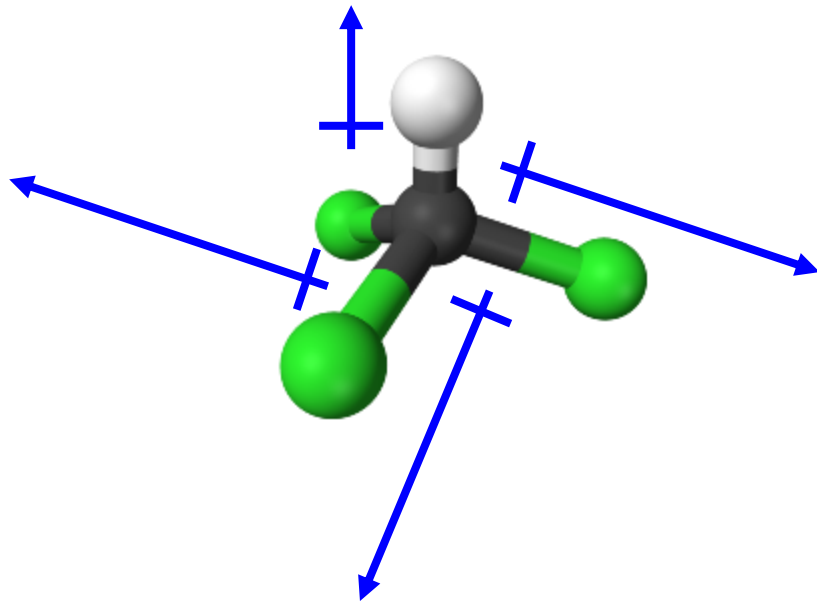


Problem 17

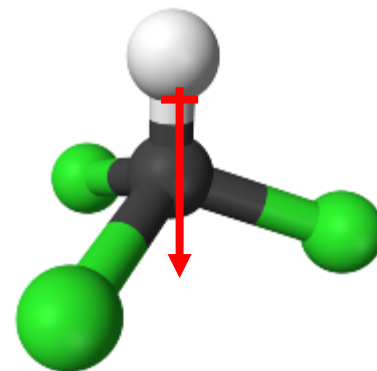
Is CHCl_4 polar?



Problem 17 - Solution



Bond Dipoles



Dipole Moment