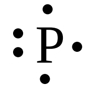
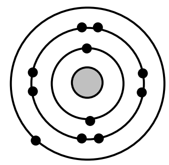
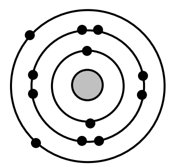
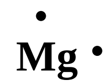
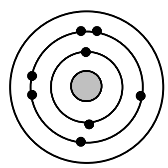
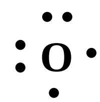
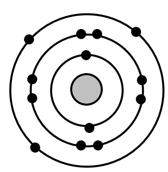
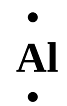
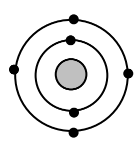
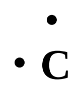
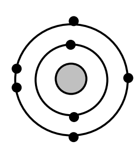
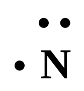
Electron Configurations, Rutherford-Bohr and Electron Dot Diagrams

Remember, when drawing electron dot diagrams:

- Write the symbol for the element and show only the outer (valence) electrons
- The number of valence electrons is equal to the Group Number (in Roman Numerals) for each element
- Follow the convention of only doubling up the electrons after all four "orbitals" have one electron each

eg. the electron dot diagram for phosphorus (Group V) would be 

Element	Atomic #	Electron Configuration	Rutherford-Bohr Diagram	# of Valence Electrons	Electron Dot Diagram
Na	**11**	$1s^2 2s^2 2p^6 3s^1$		**1**	
Mg	**12**	$1s^2 2s^2 2p^6 3s^2$		**2**	
O	**8**	$1s^2 2s^2 2p^4$		**6**	
Al	**13**	$1s^2 2s^2 2p^6 3s^2 3p^1$		**3**	
C	**6**	$1s^2 2s^2 2p^2$		**4**	
N	**7**	$1s^2 2s^2 2p^3$		**5**	

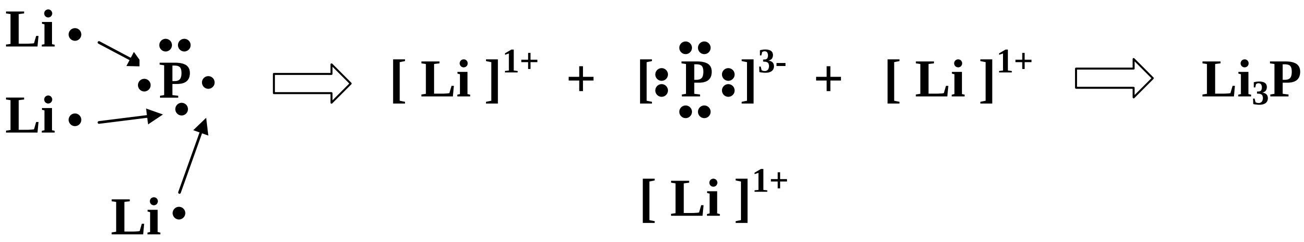
Homework:
After you have completed the above chart, draw the electron dot diagrams for atoms with atomic number 1, 9, 10, 14, 15, 16, 17, 18, 20, 34, 35, 36, 37, 38, 52, 53, 54, 55, 56 and 85

Atomic #1: hydrogen **H**	Atomic #9: fluorine **F**	Atomic #10: neon **Ne**	Atomic #14: silicon **Si**
Atomic #15: phosphorus **P**	Atomic #16: sulfur **S**	Atomic #17: chlorine **Cl**	Atomic #18: argon **Ar**
Atomic #20: calcium **Ca**	Atomic #34: selenium **Se**	Atomic #35: bromine **Br**	Atomic #36: krypton **Kr**
Atomic #37: rubidium **Rb**	Atomic #38: strontium **Sr**	Atomic #52: tellurium **Te**	Atomic #53: iodine **I**
Atomic #54: xenon **Xe**	Atomic #55: cesium **Cs**	Atomic #56: barium **Ba**	Atomic #85: astatine **At**

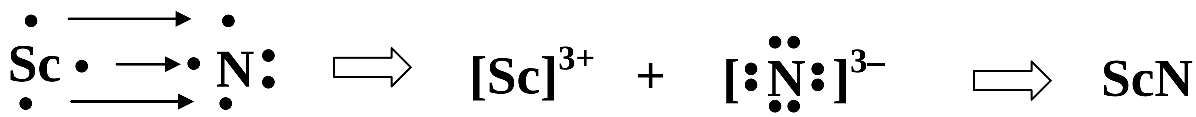
Answers to Homework: Ionic Bonding

1. Use EDDs to show the formation of the ionic compounds between:

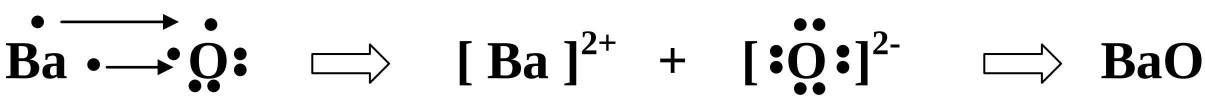
a) Li and P



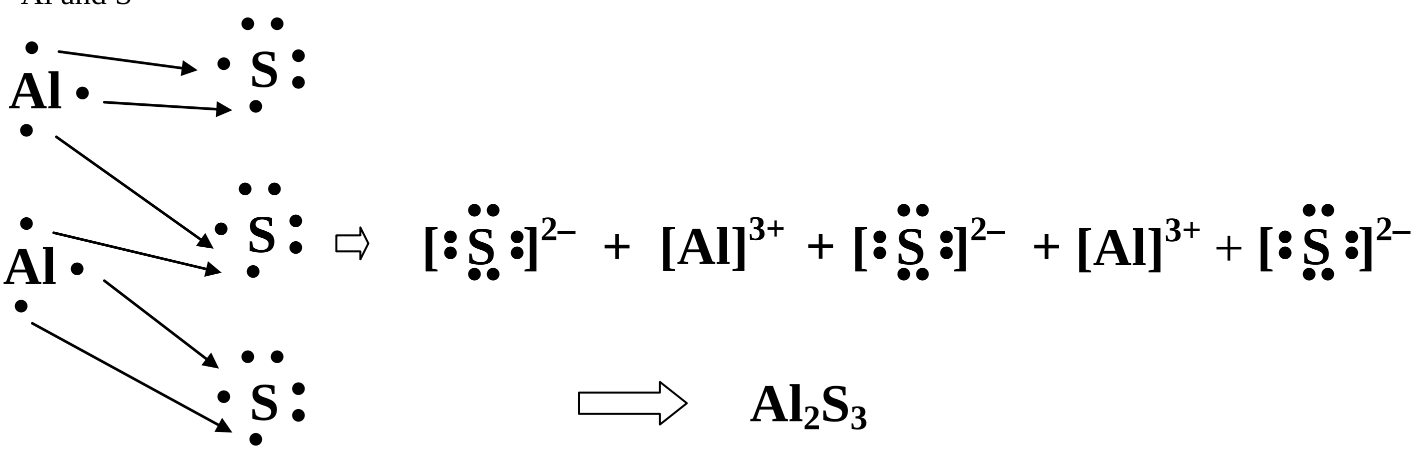
b) Sc and N



c) Ba and O



d) Al and S



Questions from pages 73 – 74 of text:

Q9. Follow steps as shown above

a) lithium iodide will have the chemical formula LiI

b) barium chloride will have the formula $BaC\ell_2$

c) potassium oxide will have the formula K_2O

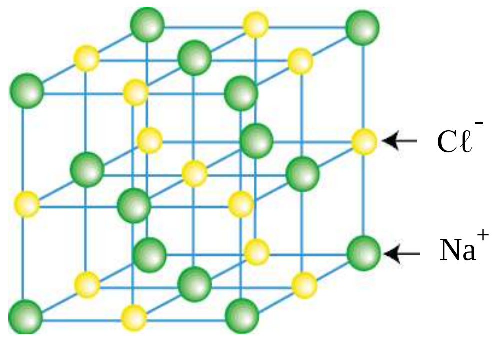
d) calcium fluoride will have the formula CaF_2

Q12. All five halogens will have seven valence electrons in their valence shell. Because all of these elements have the same number of valence electrons, they are part of a chemical family.

Q13. Follow steps as shown above

a) magnesium chloride: $MgC\ell_2$
b) sodium sulfide: Na_2S
c) aluminum oxide: Al_2O_3
d) barium chloride: $BaC\ell_2$
e) calcium fluoride: CaF_2
f) sodium iodide: NaI
g) potassium chloride: $KC\ell$

Sketch of a crystal lattice:



Answers to Homework: Covalent Bonding

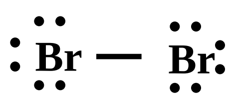
1. Define octet rule, covalent bond, bonding capacity, molecular formula. See notes.
2. Explain how a ***formula unit*** of an ionic compound is different from the ***molecular formula*** of a covalent compound.

   A formula unit is the lowest possible ratio in which the ions combine in an ionic compound. Because all of the negative ions are attracted to all of the positive ions in an ionic compound, the ions arrange themselves in a huge three-dimensional structure called a “crystal lattice”. There are many positive and negative ions in the crystal lattice, so the formula unit indicates the simplest ratio of positive to negative ions. For example, in calcium chloride ($CaCl_2$), there are two chloride ions for every one calcium ion.

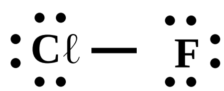
   A molecular formula of a covalent compound is the exact number of each type of atom present in one discrete molecule. For example, glucose has the molecular formula $C_6H_{12}O_6$ which tells us that there are 6 carbon atoms, 12 hydrogen atoms and 6 oxygen atoms all chemically bonded together to form one molecule. The molecular formula of a covalent compound can NOT be reduced to lower terms, because then it would no longer be the same substance.

3. Draw the Lewis structures (structural formulas) for the following molecules. Be sure to draw in all unshared electron pairs.

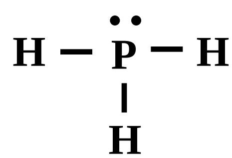
a) Br_2



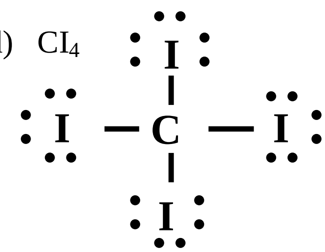
b) $C\ell F$



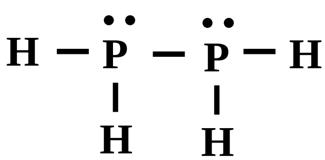
c) PH_3



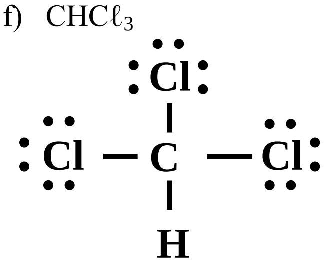
d) CI_4



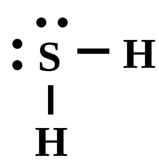
e) P_2H_4



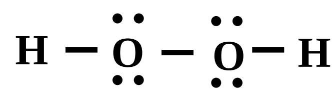
f) $CHC\ell_3$



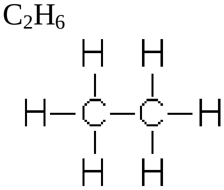
g) H_2S



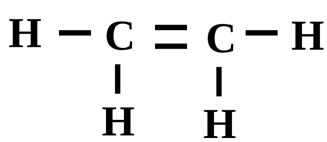
h) H_2O_2



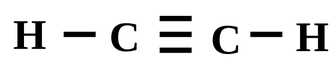
i) C_2H_6



j) C_2H_4

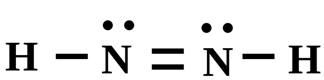


k) C_2H_2



l) CO_2

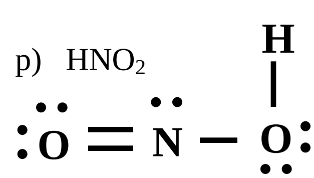
m) N_2H_2



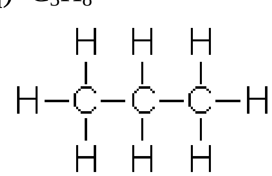
n) N_2

o) SiO_2

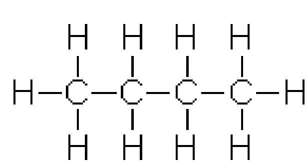
p) HNO_2



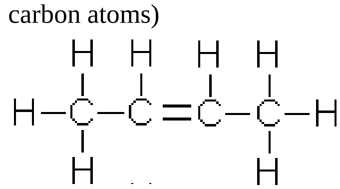
q) C_3H_8



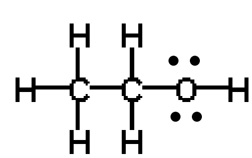
r) C_4H_{10}



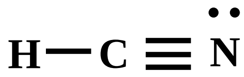
s) C_4H_8 (the double bond can be between any two carbon atoms)



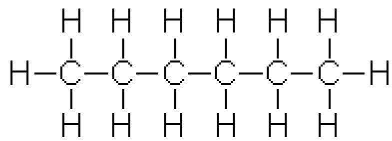
t) C_2H_5OH



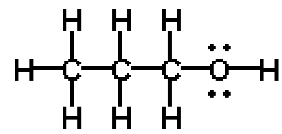
u) HCN



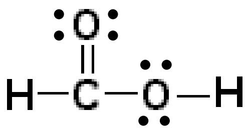
v) C_6H_{14}



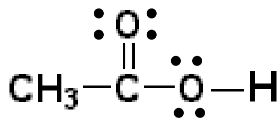
w) C_3H_7OH



x) HCOOH

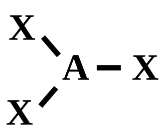
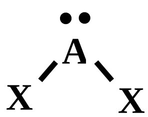
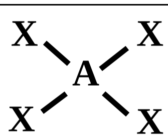
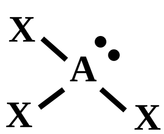
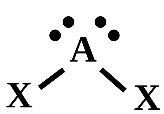


y) CH_3COOH



Homework: The Shapes of Molecules

1. Complete the chart below using AXE notation (AXnEm) to show the number of bonded electron groups on the central atom (n), number of lone electron pairs (LP) on the central atom (m), the total number of electron groups on the central atom (n+m) and the name of the shape of the molecule.

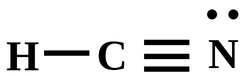
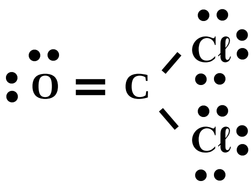
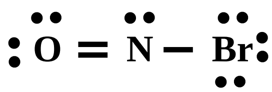
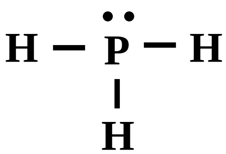
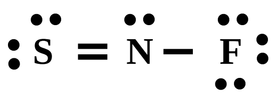
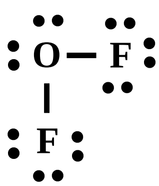
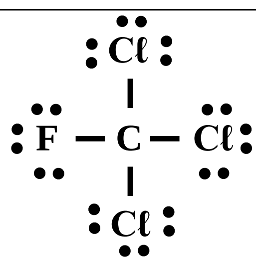
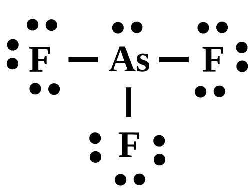
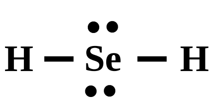
Drawing of Molecule	**AXE Notation (AXnEm)**	**# of bonded electron groups on the central atom (n)**	**# of lone pairs on the central atom (m)**	**total # of electron groups on central atom (n + m)**	**Name of the Shape of the Molecule**
	AX_2E_0	2	0	2	linear
	AX_3E_0	3	0	3	trigonal planar
	AX_2E_1	2	1	3	V-shaped (bent)
	AX_4E_0	4	0	4	tetrahedral
	AX_3E_1	3	1	4	trigonal pyramidal
	AX_2E_2	2	2	4	V-shaped (bent)

2. For the following molecules:

a) draw the molecule following the octet rule

b) determine the AXE notation for the shape of the molecule

c) name the shape of the molecule

Drawing of Molecule	**AXE Notation (AXnEm)**	**Name of Shape**
	AX_2E_0	linear
	AX_2E_0	linear
	AX_3E_0	trigonal planar
	AX_2E_1	V-shaped (bent)
	AX_3E_1	trigonal pyramidal
	AX_2E_1	V-shaped (bent)
	AX_2E_2	V-shaped (bent)
	AX_4E_0	tetrahedral
	AX_3E_1	trigonal pyramidal
	AX_2E_2	V-shaped (bent)

Answers to Homework: Classifying Bonds and the Bonding Continuum

1. Read over this note very carefully.

2. For the following bonds:

a) calculate the difference in electronegativity (ΔEN) between the bonding atoms

b) determine the type of bonding that will occur: non-polar, polar or ionic

- if the bond is non-polar, it is uncharged so do not draw in any charged regions
- if the bond is polar, label the appropriate atoms with partial positive (δ+) and partial negative (δ–) charges
- if the bond is ionic, label the appropriate atoms with full positive (+) and full negative (–) charges

$^{\delta+}$ H – O $^{\delta-}$ ΔEN= 3.44 – 2.20 = 1.24 polar bond, so draw in partial charges	$^{+}$ Na – Br^{-} ΔEN= 2.96 – 0.93 = 2.03 ionic bond, so draw in full + and – charges	$^{+}$ Mg – O^{-} ΔEN= 3.44 – 1.31 = 2.13 ionic bond, so draw in full + and – charges	$^{\delta+}$ C – F $^{\delta-}$ ΔEN= 3.98 – 2.55 = 1.43 polar bond, so draw in partial charges
H – S ΔEN= 2.58 – 2.20 = 0.38 non-polar covalent bond, do not draw any charges	N – O ΔEN= 3.44 – 3.04 = 0.40 non-polar covalent bond, do not draw any charges	P – H ΔEN= 2.20 – 2.19 = 0.01 non-polar covalent bond, do not draw any charges	$^{\delta+}$ B – Cl $^{\delta-}$ ΔEN= 3.16 – 2.04 = 1.12 polar covalent bond, so draw in partial charges
$^{+}$ K – Cl $^{-}$ ΔEN= 3.16 – 0.82 = 2.34 ionic bond, so draw in full + and – charges	C – H ΔEN= 2.55 – 2.20 = 0.35 non-polar covalent bond, do not draw any charges	$^{\delta-}$ F – Se $^{\delta+}$ ΔEN= 3.98 – 2.55 = 1.43 polar covalent bond, so draw in partial charges	S – C ΔEN= 2.58 – 2.55 = 0.03 non-polar covalent bond, do not draw any charges

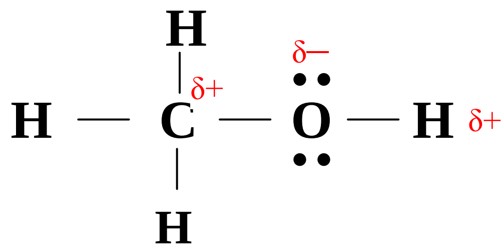
3. Give three examples of bonds for which ΔEN = 0.0.

Any bond between atoms of the same element will have ΔEN = 0.0, for example, O – O , H – H , Br – Br , and any of the other HOBrFINCl elements, or C – C bonds etc. Do not use metal – metal as your example, because two metal atoms do not bond in this way.

4. For the following molecules, determine the type of bond(s) and label any partial or full charges.

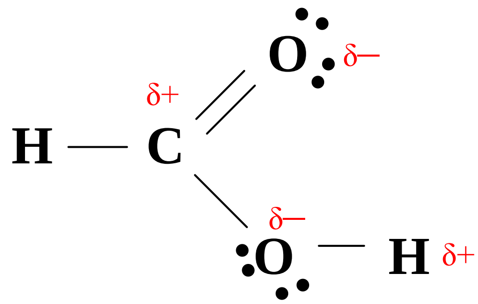
Hydrogen cyanide (a poisonous gas) HCN	**Dihydrogen Monoxide (water) H_2O**
H — C ≡ N: ΔEN_{C-H} = 2.55 – 2.20 = 0.35 ∴ non-polar bond ΔEN_{C-N} = 3.04 – 2.55 = 0.49 ∴ non-polar bond no polar bonds, so do not draw in any charges	δ+ **H — Ö — H** δ+ δ– ΔEN= 3.44 – 2.20 = 1.24 ∴ polar bond, so draw in partial charges

Methanol (a poisonous alcohol) CH_3OH



$\Delta EN_{C-H} = 2.55 - 2.20$
$= 0.35 \therefore$ non-polar, no charges
$\Delta EN_{C-O} = 3.44 - 2.55$
$= 0.89 \therefore$ polar, partial charges
$\Delta EN_{O-H} = 3.44 - 2.20$
$= 1.24 \therefore$ polar, partial charges

Formic Acid (in red ant stings) HCOOH



$\Delta EN_{C-H} = 2.55 - 2.20$
$= 0.35 \therefore$ non-polar, no charges
$\Delta EN_{C-O} = 3.44 - 2.55$
$= 0.89 \therefore$ polar, partial charges
$\Delta EN_{O-H} = 3.44 - 2.20$
$= 1.24 \therefore$ polar, partial charges

Practice Determining the Polarity of Molecules

CO_2

AXE notation: AX_2E_0

Name of Shape: linear

Symmetry of Shape: symmetrical

Symmetry of Atoms: symmetrical

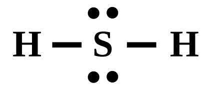
$\Delta EN_{C-O} = |2.55 - 3.44|$

$= 0.89$ ∴ polar bonds

Polarity of Molecule: it is symmetrical ∴ non-polar

Charges? No charges, they cancel out.

H_2S



AXE notation: AX_2E_2

Name of Shape: bent or V-shaped

Symmetry of Shape: asymmetrical

Symmetry of Atoms: symmetrical

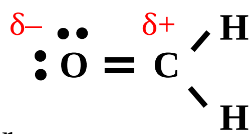
$\Delta EN_{S-H} = |2.58 - 2.20|$

$= 0.38$ ∴ non-polar bonds

Polarity of Molecule: asymmetrical with no polar bonds ∴ slightly polar

Charges? very slight charges, do not label them

CH_2O



AXE notation: AX_3E_0

Name of Shape: trigonal planar

Symmetry of Shape: symmetrical

Symmetry of Atoms: asymmetrical

$\Delta EN_{C-O} = |2.55 - 3.44|$

$= 0.89$ ∴ polar bonds

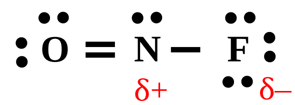
$\Delta EN_{C-H} = |2.55 - 2.20|$

$= 0.35$ ∴ non-polar bonds

Polarity of Molecule: asymmetrical with at least one polar bond ∴ very polar.

Charges? Yes...label only the polar bond

NOF



AXE notation: AX_2E_1

Name of Shape: bent or V-shaped

Symmetry of Shape: asymmetrical

Symmetry of Atoms: asymmetrical

$\Delta EN_{N-O} = |3.04 - 3.44|$

$= 0.40$ ∴ non-polar bond

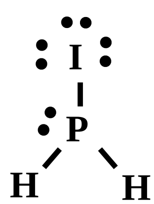
$\Delta EN_{N-F} = |3.04 - 3.98|$

$= 0.94$ ∴ polar bond

Polarity of Molecule: asymmetrical with at least one polar bond ∴ very polar.

Charges? Yes...label only the polar bond.

PH_2I



AXE notation: AX_3E_1

Shape: trigonal pyramidal

Symmetry of Shape: asymmetrical

Symmetry of Atoms: asymmetrical

$\Delta EN_{P-I} = |2.19 - 2.66|$

$= 0.47$ ∴ non-polar bond

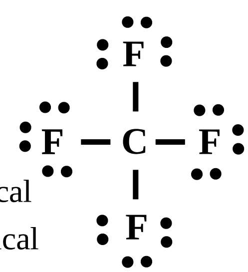
$\Delta EN_{P-H} = |2.19 - 2.20|$

$= 0.01$ ∴ non-polar bonds

Polarity of Molecule: asymmetrical with no polar bonds ∴ slightly polar

Charges? Very slight charges, do not label them

CF_4



AXE notation: AX_4E_0

Shape: tetrahedral

Symmetry of Shape: symmetrical

Symmetry of Atoms: symmetrical

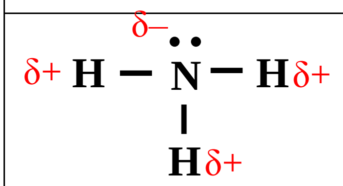
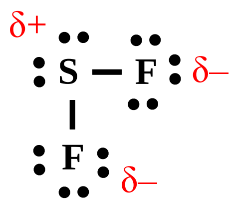
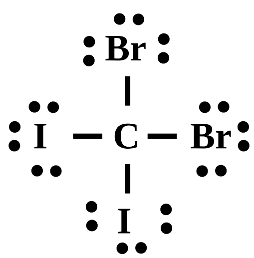
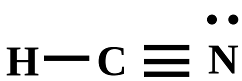
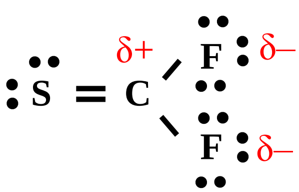
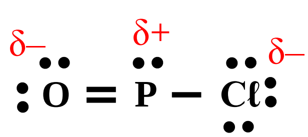
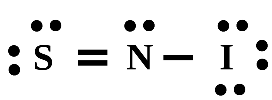
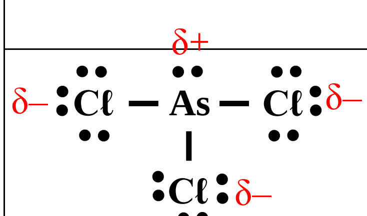
$\Delta EN_{C-F} = |2.55 - 3.98|$

$= 1.43$ ∴ polar bonds

Polarity of Molecule: it is symmetrical ∴ non-polar

Charges? No charges, they cancel out.

Homework: Draw stick diagrams for the compounds below. Determine the overall polarity of each molecule. Label any charges. NH_3 SF_2 CBr_2I_2 HCN CSF_2 PCℓO CS_2 NSI AsCℓ$_3$

Drawing of Molecule	AXE Notation and Name of Shape	Polarity of Molecule
	AX_3E_1 trigonal pyramidal	• asymmetrical shape • polar bonds (△EN = 0.84) ∴ **very polar molecule**
	AX_2E_2 V-shaped (bent)	• asymmetrical shape • polar bonds (△EN = 1.40) ∴ **very polar molecule**
	AX_4E_0 tetrahedral	• symmetrical shape • asymmetrical atoms • non-polar bonds (△EN = 0.41, 0.11) ∴ **slightly polar molecule (don't draw charges)**
	AX_2E_0 linear	• symmetrical shape • asymmetrical atoms • non-polar bonds (△EN = 0.35, 0.49) ∴ **slightly polar molecule (don't draw charges)**
	AX_3E_0 trigonal planar	• symmetrical shape • asymmetrical atoms • polar bonds (△EN = 0.03, 1.43) ∴ **very polar molecule**
	AX_2E_1 V-shaped (bent)	• asymmetrical shape • asymmetrical atoms • polar bonds (△EN = 1.25, 0.97) ∴ **very polar molecule**
	AX_2E_0 linear	• symmetrical shape • symmetrical atoms • non-polar bonds (△EN = 0.03) ∴ **non-polar molecule**
	AX_2E_1 V-shaped (bent)	• asymmetrical shape • asymmetrical atoms • non-polar bonds (△EN = 0.46, 0.38) ∴ **slightly polar molecule (don't draw charges)**
	AX_3E_1 trigonal pyramidal	• asymmetrical shape • polar bonds (△EN = 1.00) ∴ **very polar molecule**

Answers to Homework:
Using Polarity of Molecules to Predict Physical Properties of Substances

This chart summarizes the strength of intermolecular attraction and resulting physical properties for the compounds from the Unit 03 Handouts to Print: Practice Determining the Polarity of Molecules.

Compound	Description of Molecule	Polarity of Molecules	Description of Charges	Strength of IMFs	Predicted State at SATP	Predicted Melting and Boiling Points	Predicted Solubility in Water
CO_2	Symmetrical	Non-polar	No charges	Very Weak	Gas	Very low	Insoluble
H_2S	Asymmetrical with no polar bonds	Slightly polar	Slight partial charges (do not label)	Weak	Gas	Low	Slightly soluble
CH_2O	Asymmetrical with at least one polar bond	Very polar	Partial charges (label δ– & δ+ on polar bonds)	Medium	Liquid	Low/medium	Soluble
NOF	Asymmetrical with at least one polar bond	Very polar	Partial charges (label δ– & δ+ on polar bonds)	Medium	Liquid	Low/medium	Soluble
PH_2I	Asymmetrical with no polar bonds	Slightly polar	Slight partial charges (do not label)	Weak	Gas	Low	Slightly soluble
CF_4	Symmetrical	Non-polar	No charges	Very Weak	Gas	Very low	Insoluble
NH_3	Asymmetrical with at least one N-H, O-H or F-H bond	Very polar + hydrogen bonding	Strong partial charges (label on polar bonds)	Strong	Gas/Liquid -because NH_3 weighs very little, it is a gas	Medium	Completely Soluble
SF_2	Asymmetrical with at least one polar bond	Very polar	Partial charges (label δ– & δ+ on polar bonds)	Medium	Liquid	Low/medium	Soluble
CBr_2I_2	Asymmetrical with no polar bonds	Slightly polar	Slight partial charges (do not label)	Weak	Gas	Low	Slightly soluble
HCN	Asymmetrical with no polar bonds	Slightly polar	Slight partial charges (do not label)	Weak	Gas	Low	Slightly soluble
CSF_2	Asymmetrical with at least one polar bond	Very polar	Partial charges (label δ– & δ+ on polar bonds)	Medium	Liquid	Low/medium	Soluble
PCℓO	Asymmetrical with at least one polar bond	Very polar	Partial charges (label δ– & δ+ on polar bonds)	Medium	Liquid	Low/medium	Soluble
CS_2	Symmetrical	Non-polar	No charges	Very Weak	Gas	Very low	Insoluble
NSI	Asymmetrical with no polar bonds	Slightly polar	Slight partial charges (do not label)	Weak	Gas	Low	Slightly soluble
$AsC\ell_3$	Asymmetrical with at least one polar bond	Very polar	Partial charges (label δ– & δ+ on polar bonds)	Medium	Liquid	Low/medium	Soluble

* Make sure you know why NOF, CH_2O and HCN molecules are NOT able to hydrogen bond to each other