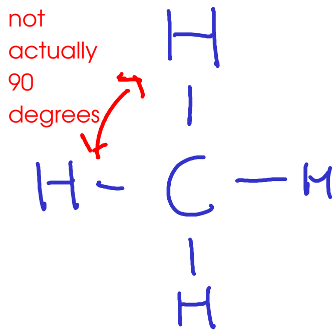
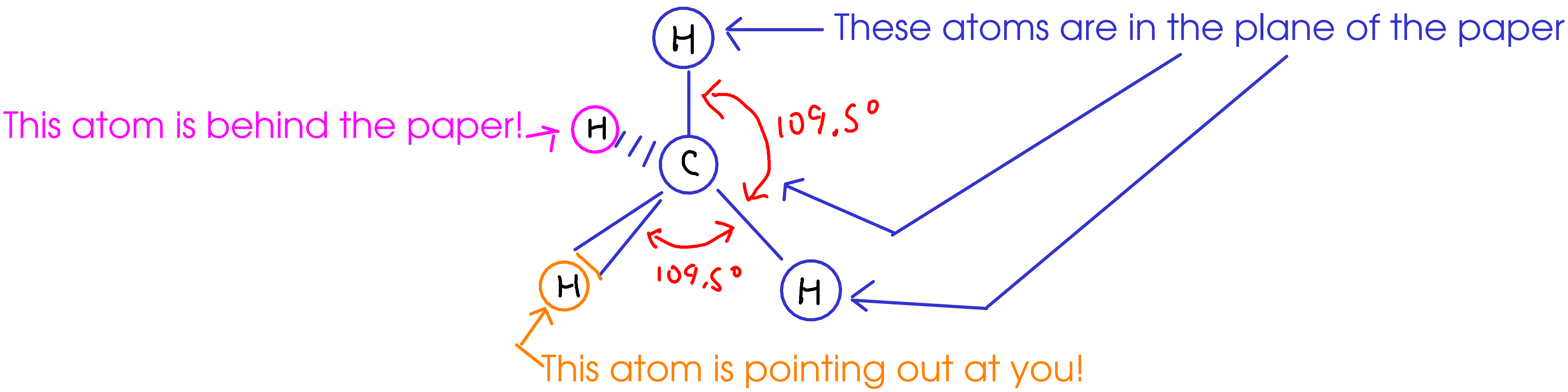


These hydrogen atoms might appear at first glance to be 90 degrees apart, but remember that molecules exist in THREE DIMENSIONS, not two!

Each hydrogen atom is actually 109.5 degrees apart, forming a TETRAHEDRON.



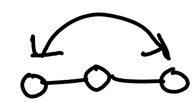
To see the tetrahedron in three dimensions WITHOUT buying a molecular model kit, just take four balloons, blow them up, and then tie them together. The knot will be the central atom, and the balloons will line themselves up to be 109.5 degrees apart.

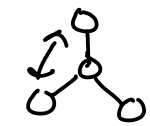
VSEPR shapes

* "Groups" can be either BONDS or LONE PAIRS!

VSEPR shapes:

Groups* around central atom	Shape	Bond angle(s) in degrees
2	linear	180
3	trigonal planar	120
4	tetrahedral / pyramidal / bent	109.5
5	trigonal bipyramidal (and derivatives)	90 and 120
6	octahedral (and derivatives)	90

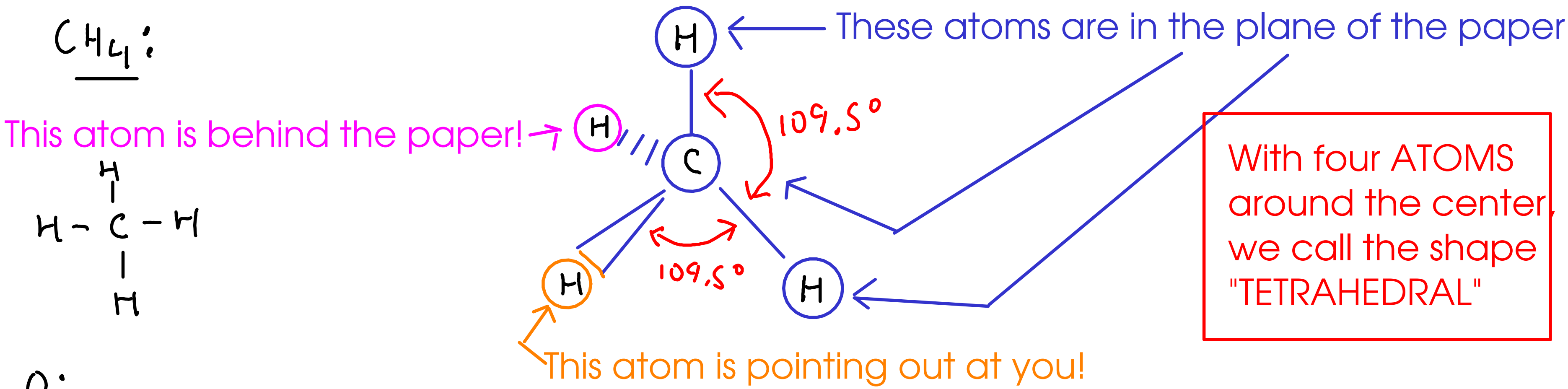




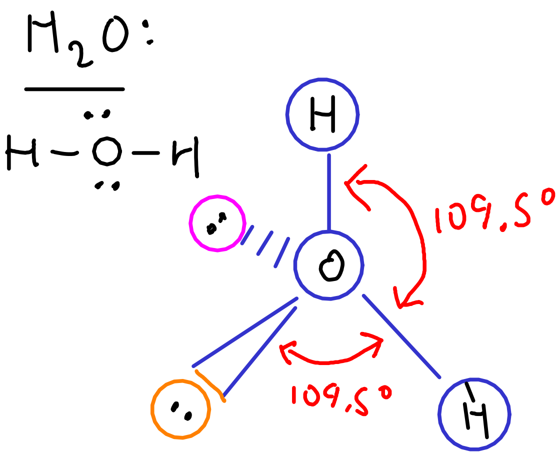
5 and 6 violate "octet rule"

More on "4 things around a central atom":

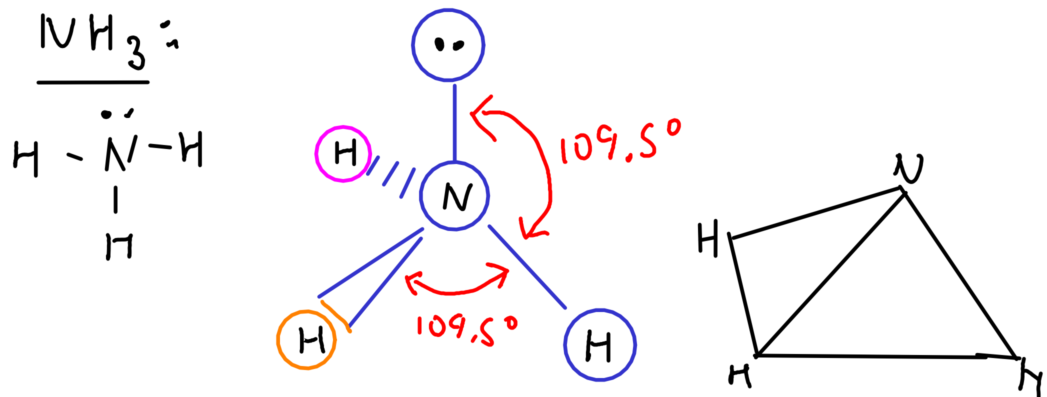
- A compound that obeys the octet rule can have a maximum of four groups around its central atom. But we describe the molecular shape based on how ATOMS are arrnaged around the center. What if some of those groups aren't atoms, but pairs of UNSHARED electrons?



With four ATOMS around the center, we call the shape "TETRAHEDRAL"



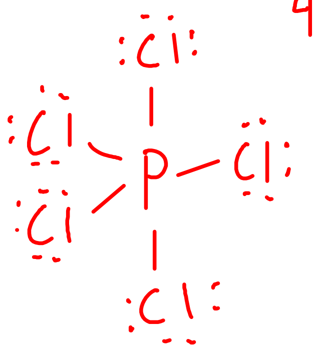
With two ATOMS and two LONE PAIRS, we call the shape "BENT"



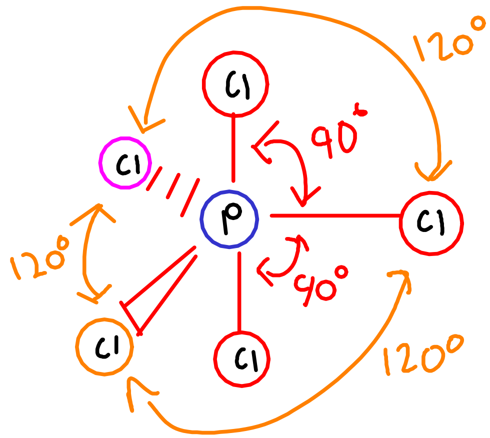
With three ATOMS and one LONE PAIR, we call the shape "PYRAMIDAL"

6 SHAPES OF EXPANDED VALENCE MOLECULES

PCl_5: P : 5
Cl : 7 × 5
40

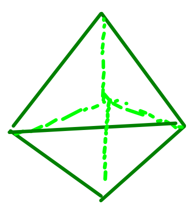


There are five atoms bonded to the central phosphorus atom, and they will attempt to get as far apart as possible from one another!



The top and bottom atoms are 90 degrees apart from the atoms around the center.

The atoms around the center are 120 degrees apart from each other.

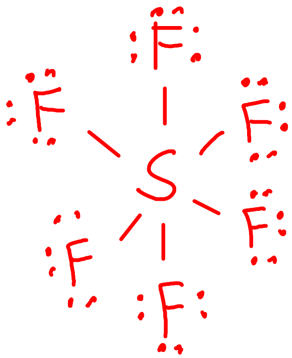


There are acually two DIFFERENT bond angles in this structure. It's called TRIGONAL BIPYRAMIDAL.

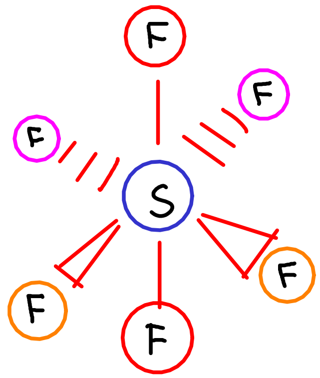
There are several derivatives of the trigonal bipyramidal shape (like the tetrahedral shape) - depending on how many things around the central atom are atoms!

SF_6:

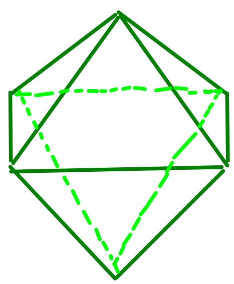
S : 6
F : 7x6
48



There are six atoms bonded to the central sulfur atom, and they will attempt to get as far apart as possible from one another!



All bond angles in this arrangement are 90 degrees!



This shape is called OCTAHEDRAL, since it has eight sides.

Like the tetrahedral and trigonal bipyramidal arrangements, there are several derivatives of the octahedron - depending on how many of the six things around the center are atoms!

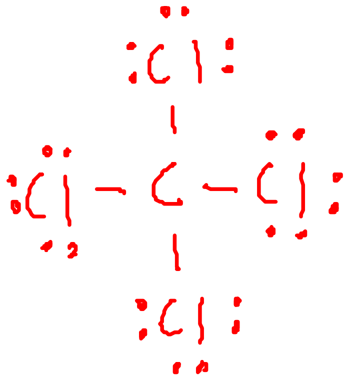
Examples:

CCl_4

$C: 1 \times 4$

$Cl: 4 \times 7$

$32\ e^-$



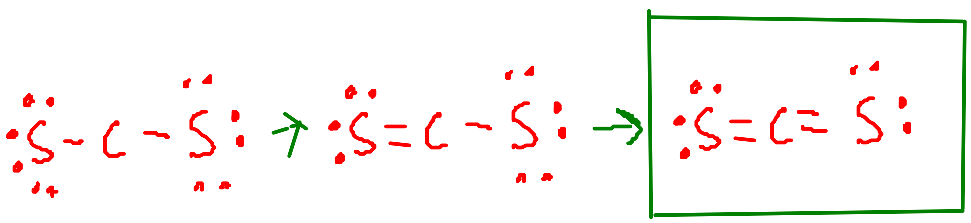
Shape? 4 groups around central atom, so tetrahedral geometry. All four are atoms, so TETRAHEDRAL shape.

CS_2

$C: 1 \times 4$

$S: 2 \times 6$

$16\ e^-$



skeletal structure

final structure

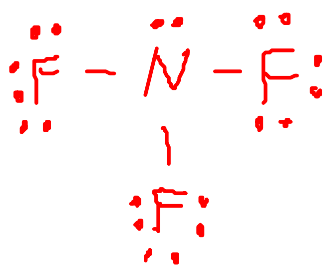
Shape? Two groups around central atom, so linear geometry. Both atoms, so linear shape.

NF_3

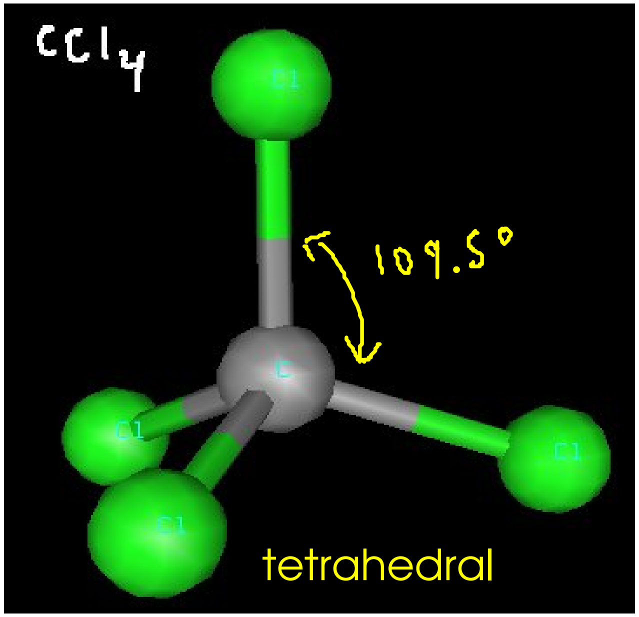
$N: 1 \times 5$

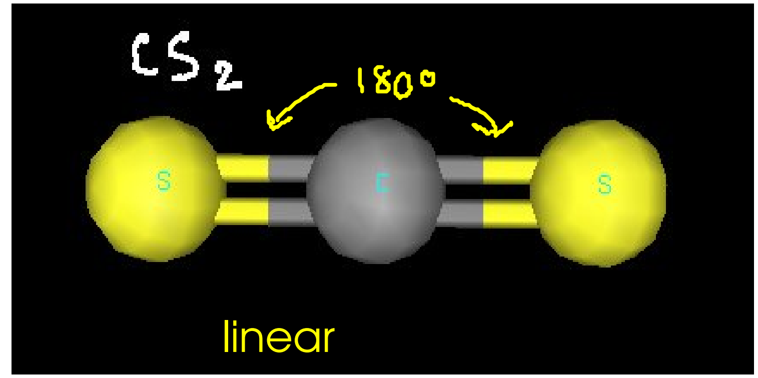
$F: 3 \times 7 = 21$

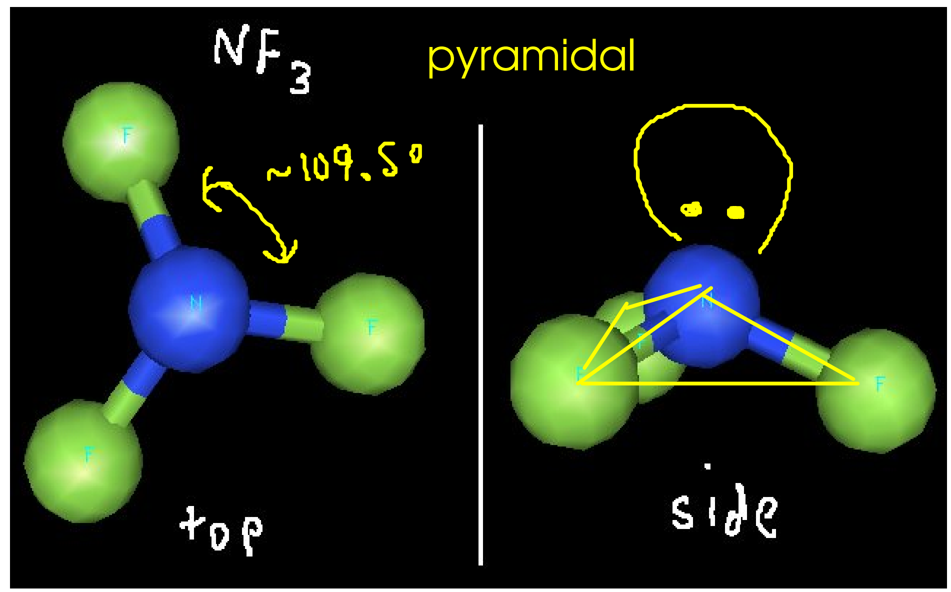
$26\ e^-$



Shape? Four groups around central atom, so tetrahedral geometry. Three atoms and one lone pair, so PYRAMIDAL shape.


CCl4
109.5°
Cl
C
tetrahedral


CS2
180°
S
C
linear

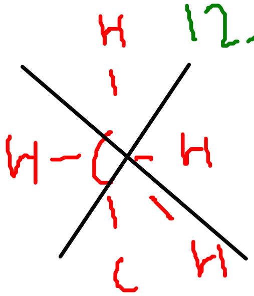

NF3
pyramidal
~109.5°
F
N
top
side

C_2H_4

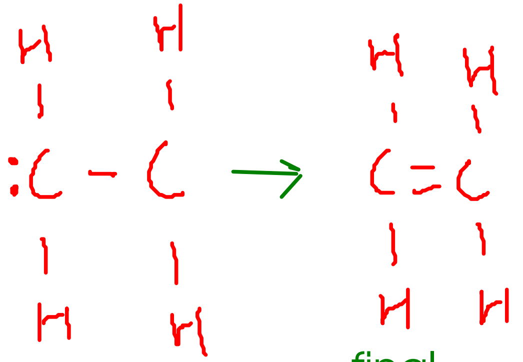
$C: 2 \times 4$

$H: 4 \times 1$

$12e^-$



Structure tip: Multiple carbon atoms mean multiple "central atoms"

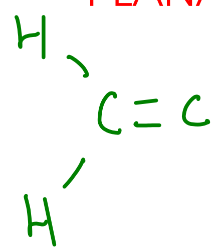


skeletal structure

final structure

Shape? For larger molecules with more than one center, describe the shape around each central atom.

Each carbon atom has three groups attached to it, and all three are atoms. So, the geometry and shape around each carbon center is TRIGONAL PLANAR.



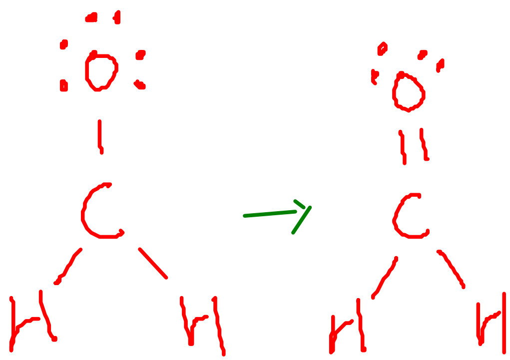
H_2CO

$H: 2 \times 1$

$C: 1 \times 4$

$O: 1 \times 6$

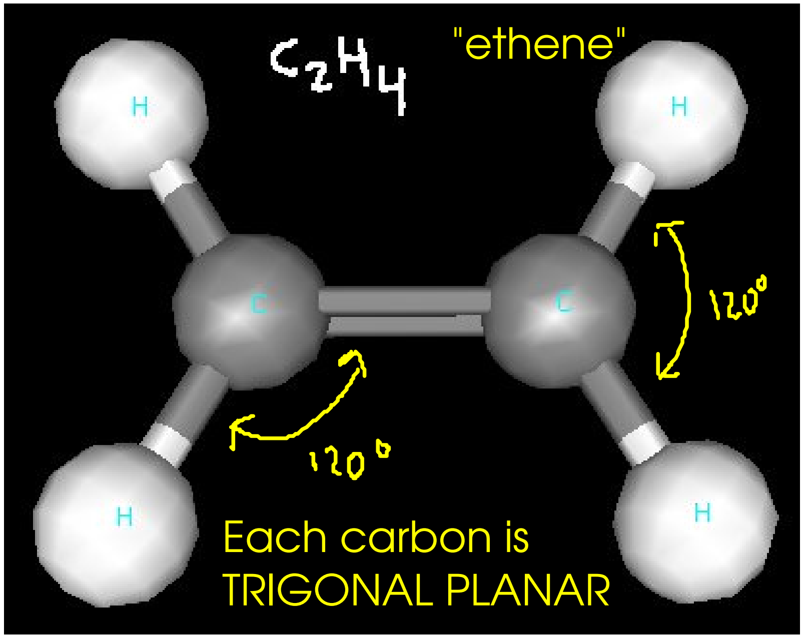
$12e^-$

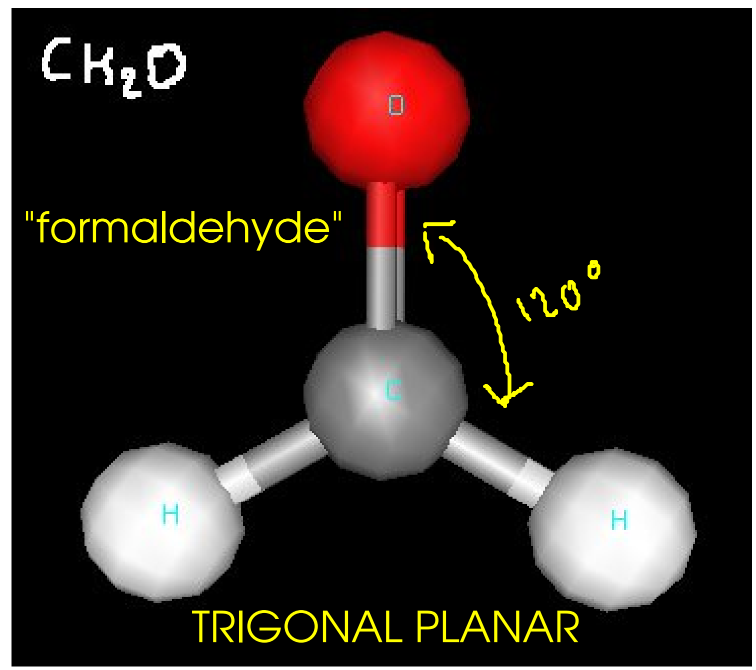


skeletal structure

final structure

Shape? There are three groups around the central atom and all three are other atoms, so both geometry and shape are TRIGONAL PLANAR.


C_2H_4
"ethene"
H
H
C
C
120°
120°
H
H
Each carbon is
TRIGONAL PLANAR

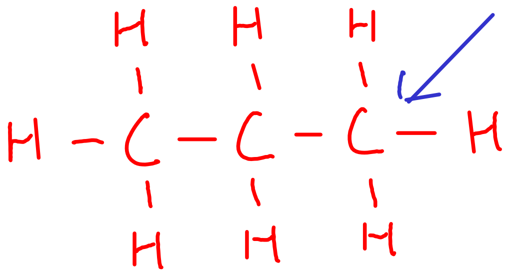

CH_2O
O
"formaldehyde"
120°
C
H
H
TRIGONAL PLANAR

VSEPR and large molecules

- Large molecules have more than one "center" atom

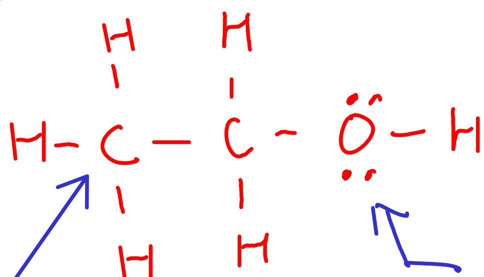
- Describe the molecule by describing the shape around each "center".

C_3H_8:



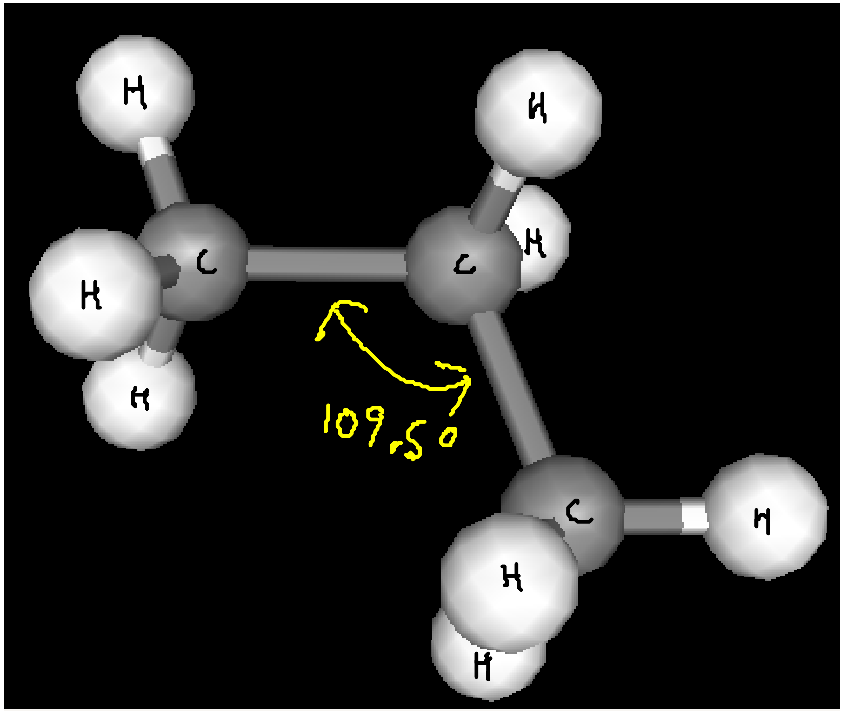
Each of the three carbon centers is TETRAHEDRAL, since each are surrounded by four groups.

CH_3CH_2OH:



The shape around this oxygen atom is BENT.

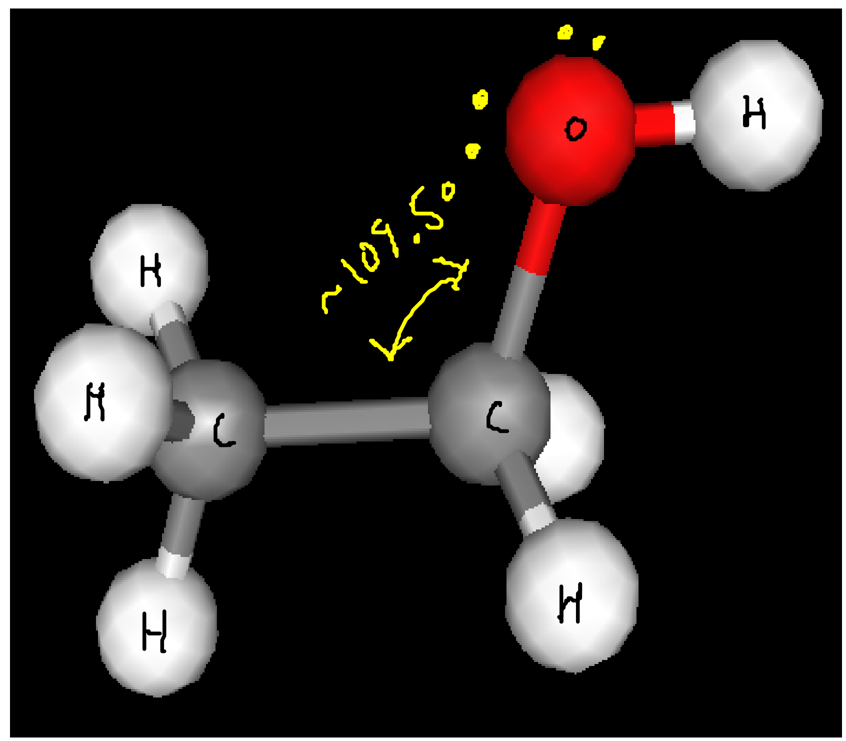
These carbon atoms have TETRAHEDRAL geometry.



← C_3H_8

All bond angles in the propane molecule are 109.5 degrees

CH_3CH_2OH →



Like propane, the bond angles in ethanol are also close to 109.5 degrees.

14 POLARITY and shape:

- A polar molecule has an uneven distribution of electron density, making it have ends (poles) that are slightly charged.

POLARITY influences several easily observable properties.

- Melting point. (Polar substances have higher melting points than nonpolar substances of similar molecular weight.)
- Boiling point. (Polar substances have higher boiling points than nonpolar substances of similar molecular weight.)
- Solubility. (Polar substances tend to dissolve in other polar substances, while being insoluble in nonpolar substances. Nonpolar substances dissove other nonpolar substances, and generally have poor solubility in polar solvents.)

- Polar molecules contain POLAR BONDS arranged in such a way that they do not cancel each other out.

... but how can we tell whether or not a bond will be POLAR? Use experimental data on ELECTRONEGATIVITY!

ELECTRONEGATIVITY:
-A measure of how closely to itself an atom will hold shared electrons

- A bond where there is a LARGE electronegativity difference between atoms will be either POLAR or (for very large differences) IONIC! (chart, p 352)

- A bond with little or no electronegativity difference between atoms will be NONPOLAR

ELECTRONEGATIVITY TRENDS

- You may look up elecronegativity data in tables, but it helps to know trends!

INCREASING ELECTRO-NEGATIVITY

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	VIIIB	IB	IIB	IIIA	IVA	VA	VIA	VIIA
2	Li	Be											B	C	N	O	F
3	Na	Mg											Al	Si	P	S	Cl
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I
6	Cs	Ba	~~La~~*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At
7	Fr	Ra	~~Ac~~*	Rf	Db	Sg	Bh	Hs	Mt								

*"inner" transition metals go here

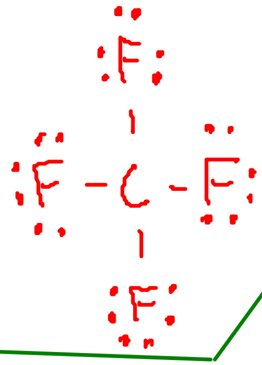
Notes:

1. - FLUORINE is the most elecronegative element, while FRANCIUM is the least!
2. - All the METALS have low electronegativity, and metal/nonmetal combinations form IONIC bonds
3. - HYDROGEN is similar in electronegativity to CARBON, so C-H bonds are considered NONPOLAR

Examples:

CF_4

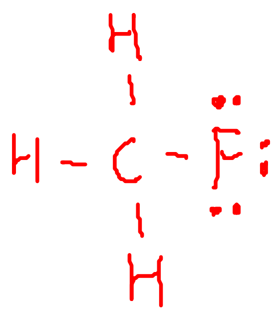
C: 1 x 4
F: 4 x 7
32 e^-



Polar?
1) POLAR BONDS? Yes. C-F bonds should be polar.
2) SHAPE? The C-F bonds are arranged in a tetrahedron. This makes the molecule symmetric and NONpolar, since the fluorines all pull against one another!

CH_3F

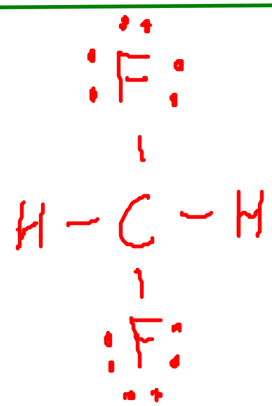
C: 1 x 4
H: 3 x 1
F: 1 x 7
14 e^-



Polar?
1) POLAR BONDS? Yes. C-F bond is polar.
2) SHAPE? The bonds are arranged in a tetrahedron. But the molecule has a H side and an F side, so the molecule is POLAR.

CH_2F_2

C: 1 x 4
H: 2 x 1
F: 2 x 7
20 e^-



Polar?
1) POLAR BONDS? Yes. C-F bonds should be polar.
2) SHAPE? The bonds are arranged in a tetrahedron. IN THREE DIMENSIONS, the molecule is not symmetric ... since the fluorine atoms are on one side and the hydrogens are on the other. This molecule is POLAR.

CO_2

C: 1 x 4
O: 2 x 6
16 e^-