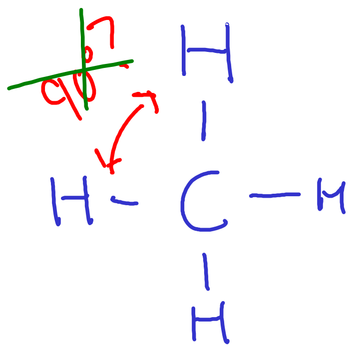
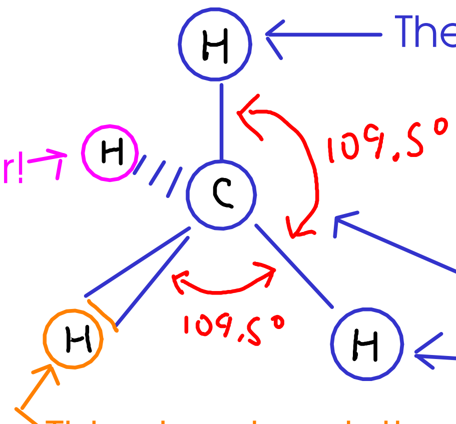


These hydrogen atoms might appear at first glance to be 90 degrees apart, but remember that molecules exist in THREE DIMENSIONS, not two!

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

These atoms are in the plane of the paper!

This atom is behind the paper!

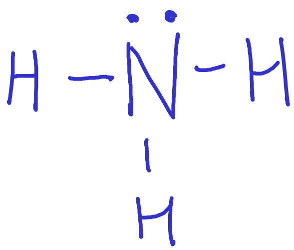


This atom is pointing out at you!

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.

DERIVATIVES OF THE TETRAHEDRON

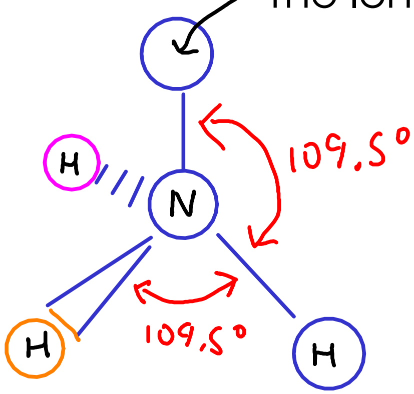
- What if there are lone pairs? The way the shape of a molecule is described depends on the ATOMS in the molecule, even though lone pairs play a role in the positions of the atoms.

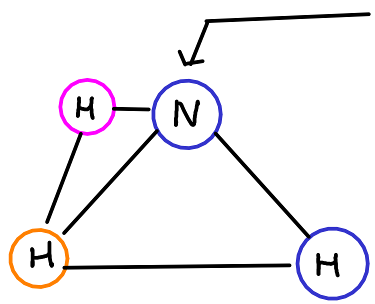


Since there are four "things" around the nitrogen atom, we would expect them to be approximately 109.5 degrees apart (in other words, TETRAHEDRAL). BUT ... only three of these things are atoms.

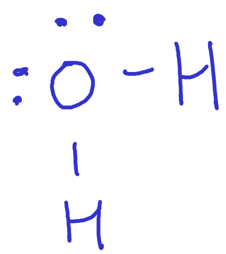
The atoms are arranged in a PYRAMID shape, so we call this molecule PYRAMIDAL!

The lone pair takes one position in the tetrahedron





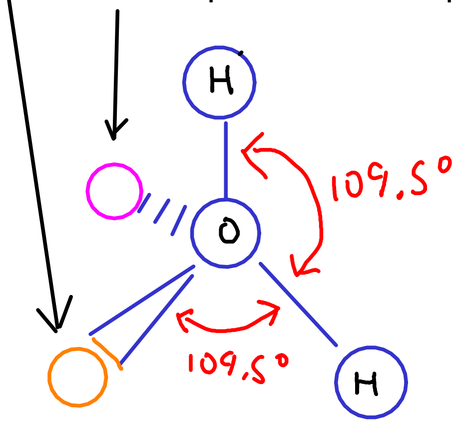
By just looking at the atoms, you can see the pyramid - with the central nitrogen atom as the top and the hydrogen atoms forming the base of the pyramid.



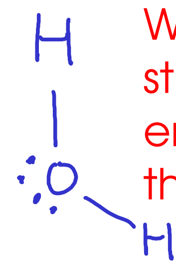
Since there are four "things" around the oxygen atom, we would expect them to be approximately 109.5 degrees apart (in other words, TETRAHEDRAL). BUT... only two of these things are atoms.

The atoms are all in a single plane, but they are not lined up in a straight line. We call this shape "BENT".

Lone pairs take up two positions in the tetrahedron

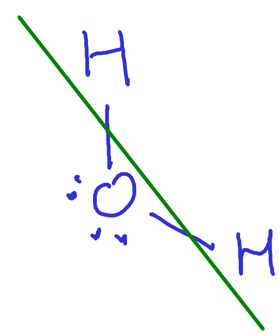


* These atoms are in the same plane, like carbon dioxide. But they are not arranged linearly!



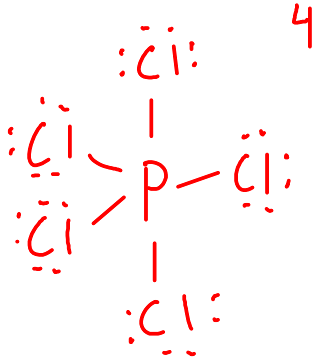
We sometimes draw the Lewis structure of water this way to emphasize the "bent" nature of the molecule!

Notice that this molecule has two "sides", one with the oxygen atom and one with hydrogen atoms.

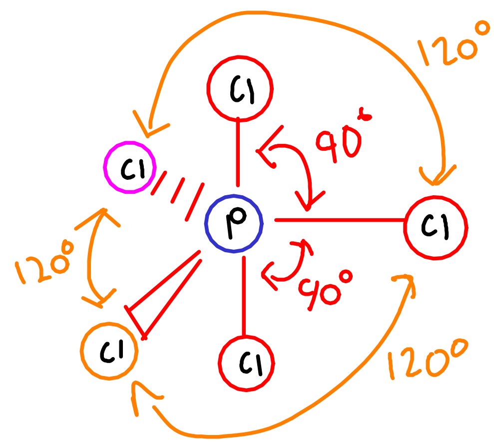


SHAPES OF EXPANDED VALENCE MOLECULES

PCl_5: P : 5
Cl : 7x5
40

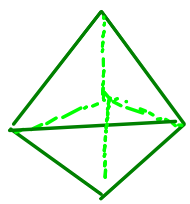


There are five atoms bonded to the central phosphorus atom, and they will attempt to get as far apart as possible from one another!



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.

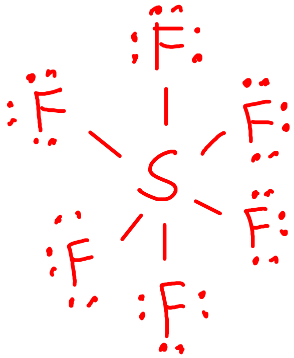


There are acually two DIFFERENT bond angles in this structure. It's called TRIGONAL BIPYRAMIDAL.

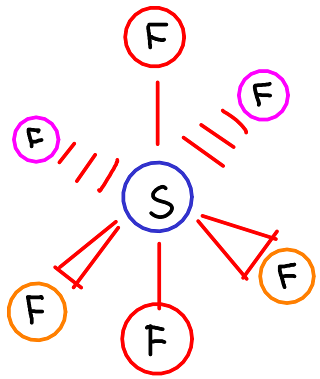
There are several derivatives of the trigonal bipyramidal shape (like the tetrahedral shape) - depending on how many things around the central atom are atoms!

SF_6:

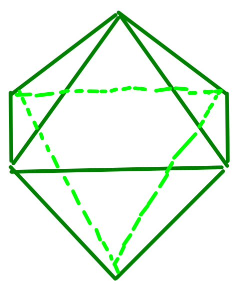
S: 6
F: 7x6
48



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!

POLARITY

- When atoms share electrons, the electrons might not be EVENLY shared. Shared electrons may spend more time around one atomic nucleus than the other.

- When electrons are shared UNEVENLY, this results in a POLAR BOND.

... 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!

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

ELECTRONEGATIVITY TRENDS (AGAIN!)

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

INCREASING ELECTRO-NEGATIVITY

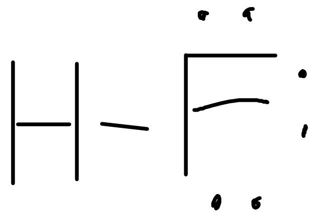
	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA
2	Li	Be											B	C	N	O	F
3	Na	Mg											Al	Si	P	S	Cl
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I
6	Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At
7	Fr	Ra	Ac*	Rf	Db	Sg	Bh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

*"inner" transition metals go here

Notes:

1. - FLUORINE is the most electronegative 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

ELECTRONEGATIVITY EXAMPLE

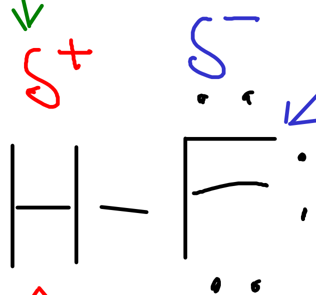


2.1 4.0 – Electronegativity values

Difference = 1.9

Fluorine is much more electronegative than hydrogen. This is a POLAR BOND, and the shared electrons will be held more closely to FLUORINE!

δ means "small" here



This end of the molecule will have a slight NEGATIVE charge, since the shared electrons are closer to FLUORINE!

This end of the molecule will have a slight POSITIVE charge, since the shared electrons are pulled away from HYDROGEN!

POLARITY OF MOLECULES

So what can a molecule's LEWIS STRUCTURE, SHAPE, and the POLARITY of its bonds tell us?

... the POLARITY of the overall molecule, which will tell us (among other things) what a given molecule will mix with or dissolve in!

POLAR MOLECULES

- Will dissolve in or dissolve other polar molecules
- Will dissolve some ionic compounds
- Will NOT easily dissolve nonpolar molecules

Example: WATER

NONPOLAR MOLECULES

- Will dissolve in or dissolve other nonpolar molecules
- Will NOT easily dissolve polar molecules or ionic compounds

Example: OILS

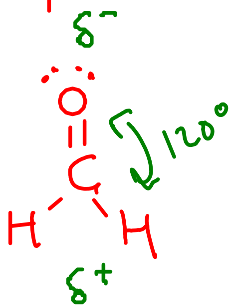
For a molecule to be polar, it must ...

1. Have polar bonds! (Any molecule that contains no polar bonds must be nonpolar!)
2. Have polar bonds arranged in such a way that they don't balance each other out! (This is why you need to know the structure and shape of the molecule)

Examples:

H_2CO

H : 1x2
C : 4
O : 6
| 12

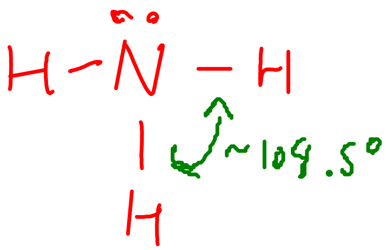


What about shape? TRIGONAL PLANAR. There are THREE THINGS (=O, -H, -H) around the central carbon.

Is the molecule polar? POLAR, because the C=O bond is polar and not "canceled" out by any other equivalent bonds.

NH_3

N : 5
H : 1x3
8

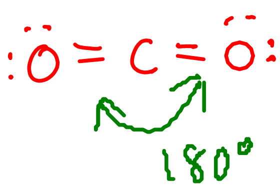


Shape? PYRAMIDAL There are four things around the central nitrogen atom, but only three of them are atoms. So the angles are tetrahedral (109.5 degrees), but we describe the shape as pyramidal.

Polar? Nitrogen-hydrogen bonds are polar, and the nitrogen is at the "top" of the pyramid, we expect that the nitrogen end of the molecule would have a slight negative charge. POLAR

CO_2

C : 4
O : 6x2
16



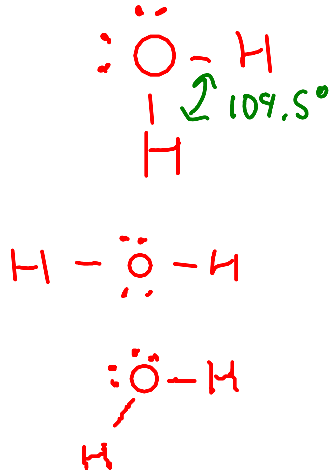
Shape? LINEAR, since there are only two things around the central atom.

Polar? We expect C=O bonds to be polar, BUT they are arranged symmetrically in this molecule. They "cancel" each other out, and the overall molecule is NONPOLAR.

EXAMPLES

Water, H_2O

H: 2x1
O: 6
8

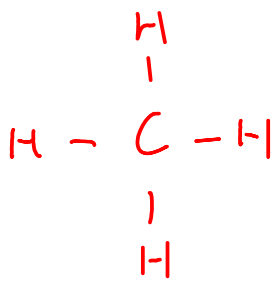


Shape? Even though there are four "things" around the central oxygen, only two of them are atoms. So we describe this as "BENT".

Polarity? POLAR. O-H bonds are polar, and we would expect that the oxygen side of this molecule would have a slight negative charge, while the hydrogen side would be positive.

methane, CH_4

C: 4
H: 4x1
8

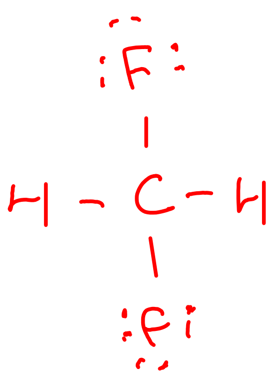


Shape? TETRAHEDRAL. Four hydrogen atoms around the carbon center.

Polar? NONPOLAR. All the bonds in this molecule (C-H) are nonpolar

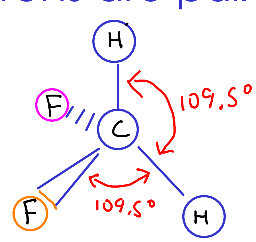
CH_2F_2

C : 4
H : 2x1 = 2
F : 2x7 = 14
20



Shape? TETRAHEDRAL like methane

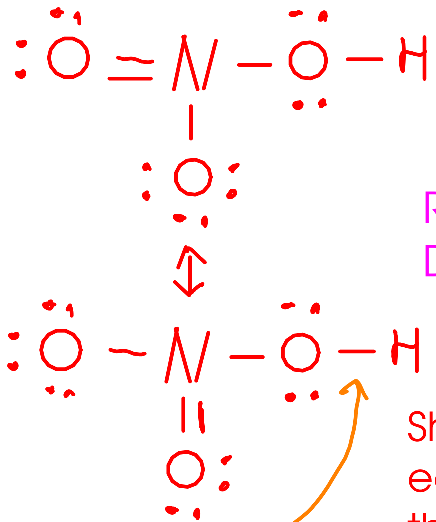
Polar? POLAR. In three dimensions, we can clearly see that this molecule has two distinct sides: one with the hydrogen atoms, and one with the fluorine atoms. Electrons are pulled towards the fluorine side



HNO_3

H : 1
N : 5
O : 6 x 3
24

Start drawing skeleton by recognizing that this compound is an OXYACID .... hydrogen attached to a polyatomic ion.



Resonance structures. The oxygen bonded to the nitrogen have a DELOCALIZED bond.

Shape? The molecule has TWO centers, so we describe the shape around each center. Around the NITROGEN, the shape is TRIGONAL PLANAR, since there are three atoms surrounding N and no lone pairs. Around the OXYGEN atom (on the right), the shape is BENT (two atoms and two lone pairs).

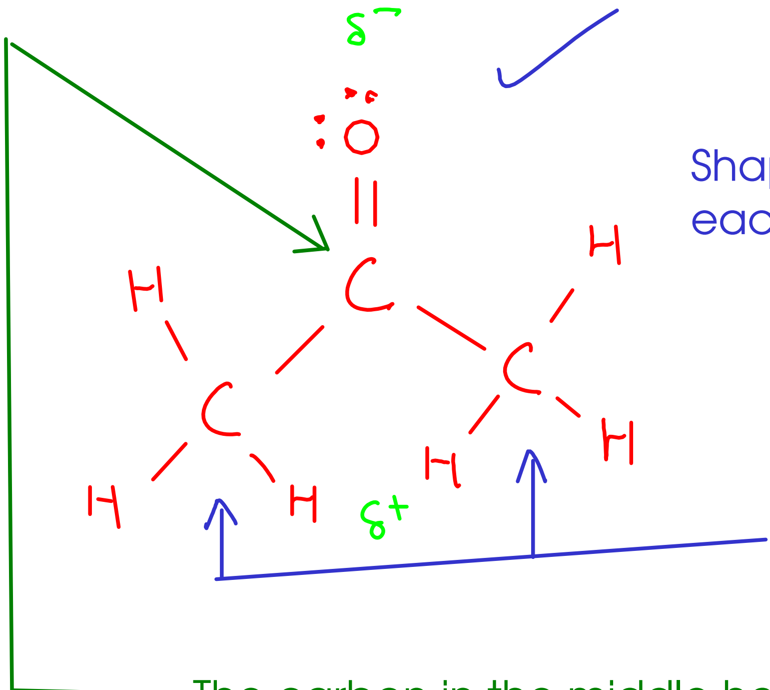
Polar? We expect the molecule to be POLAR. Electron desnity is pulled away from the acidic hydrogen by the oxgen atom it's bonded to.

In water, the acidic hydrogen can lose its electrons entirely to the oxygen atoms - forming H+ ion and nitrate ion.

CH_3COCH_3 (acetone)

C: 4 x 3
H: 1 x 6
O: 6
———
24

The formula provides a clue to the skeletal structure of the molecule. There are three carbon centers in this molecule!



Shape? We need to describe the shape of the molecule around each one of its centers.

These two carbon atoms are TETRAHEDRAL, since each of these carbons is surrounded by four other atoms.

The carbon in the middle has a TRIGONAL PLANAR shape, since it's surrounded by only three atoms (and no lone pairs).

Polarity? C-H bonds are nonpolar, but C=O is polar. Electrons are pulled towards the oxygen end of the bond, making the overall molecule POLAR.

Experimentally, we observe that acetone dissolves very well in water (another polar molecule).

POLARITY AND MOLECULAR PROPERTIES

- POLAR MOLECULES have
  - higher boilng points and melting points that comparably sized nonpolar molecules.
  - higher solubility in polar solvents like water than nonpolar molecules

"LIKE DISSOLVES LIKE"

- NONPOLAR MOLECULES have
  - lower boilng points and melting points that comparably sized polar molecules.
  - higher solubility in nonpolar solvents like carbon tetrachloride or oils