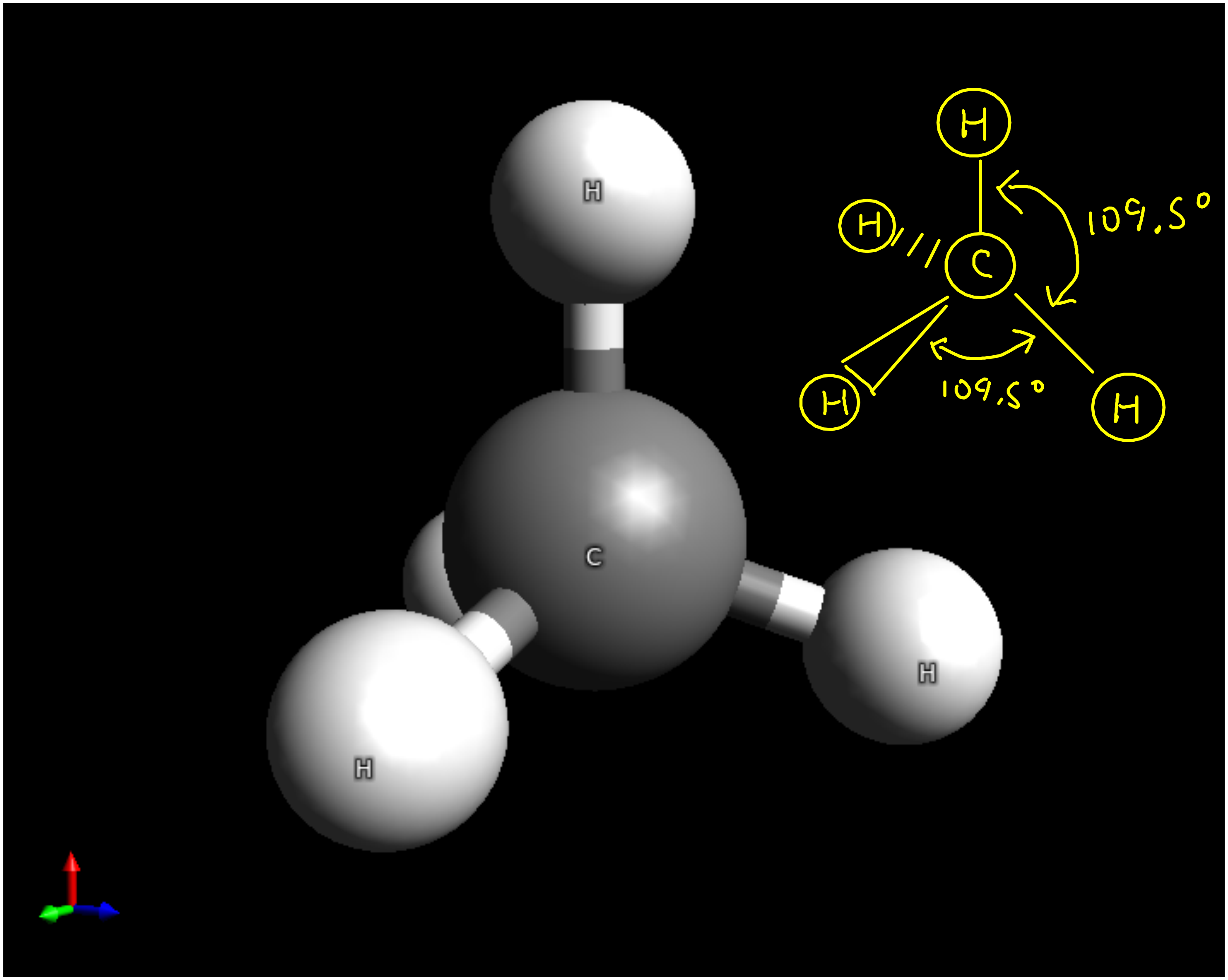
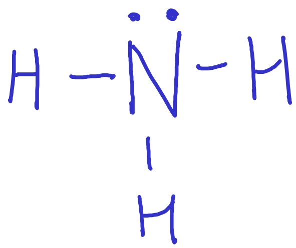
Here's a computer ball-and-stick rendering of the methane molecule.



DERIVATIVES OF THE TETRAHEDRON

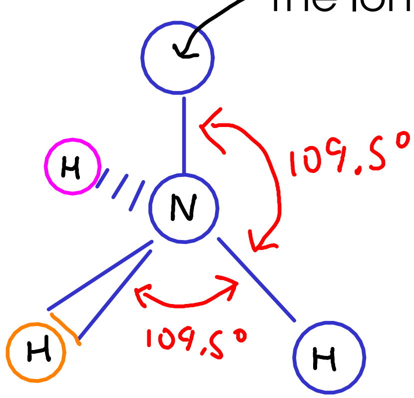
- What if there are lone pairs? The way the shape of a molecule is described depends on the ATOMS in the molecule, even though lone pairs play a role in the positions of the atoms.

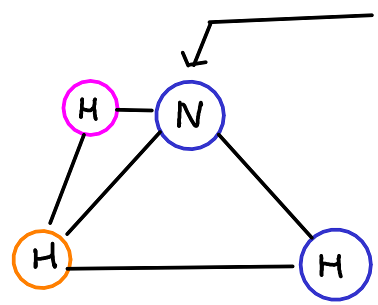


Since there are four "things" around the nitrogen atom, we would expect them to be approximately 109.5 degrees apart (in other words, TETRAHEDRAL). BUT ... only three of these things are atoms.

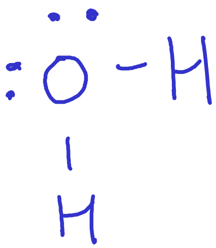
The atoms are arranged in a PYRAMID shape, so we call this molecule PYRAMIDAL!

The lone pair takes one position in the tetrahedron





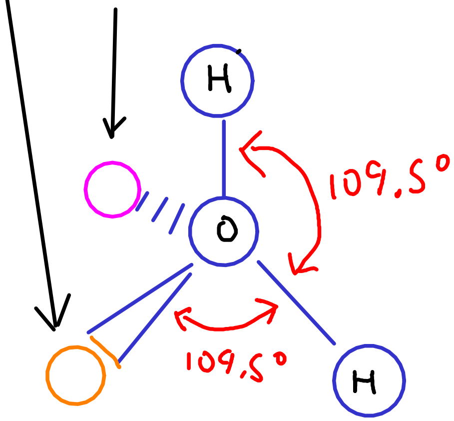
By just looking at the atoms, you can see the pyramid - with the central nitrogen atom as the top and the hydrogen atoms forming the base of the pyramid.



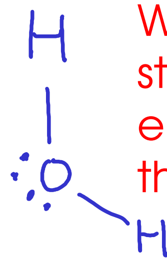
Since there are four "things" around the oxygen atom, we would expect them to be approximately 109.5 degrees apart (in other words, TETRAHEDRAL). BUT... only two of these things are atoms.

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

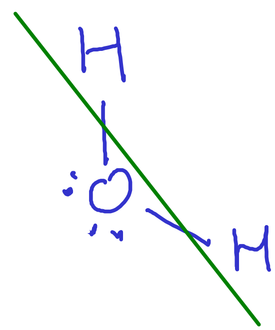


* These atoms are in the same plane, like carbon dioxide. But they are not arranged linearly!



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.

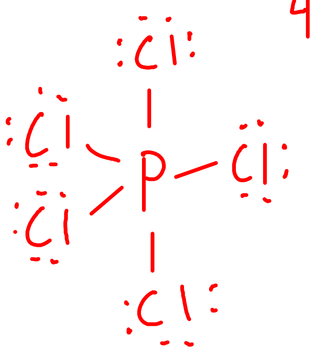


SHAPES OF EXPANDED VALENCE MOLECULES

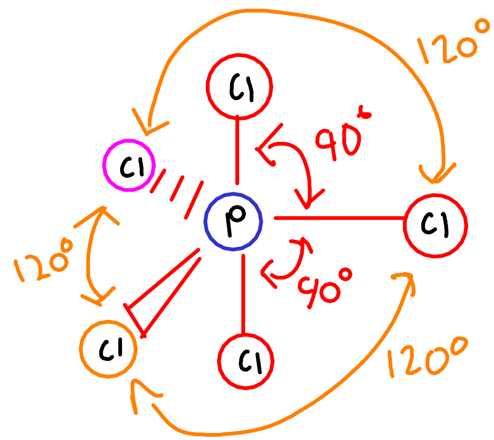
PCl_5: P : 5

Cl : 7×5

40

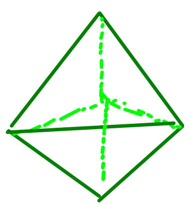


There are five atoms bonded to the central phosphorus atom, and they will attempt to get as far apart as possible from one another!



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.

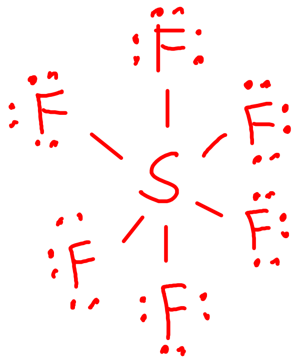


There are acually two DIFFERENT bond angles in this structure. It's called TRIGONAL BIPYRAMIDAL.

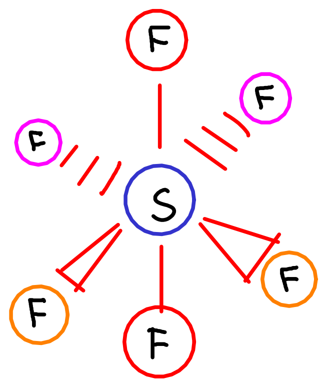
There are several derivatives of the trigonal bipyramidal shape (like the tetrahedral shape) - depending on how many things around the central atom are atoms!

SF_6:

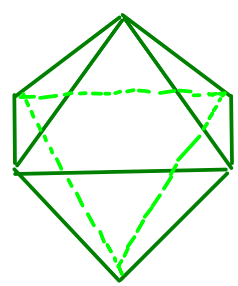
S : 6
F : 7x6
48



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



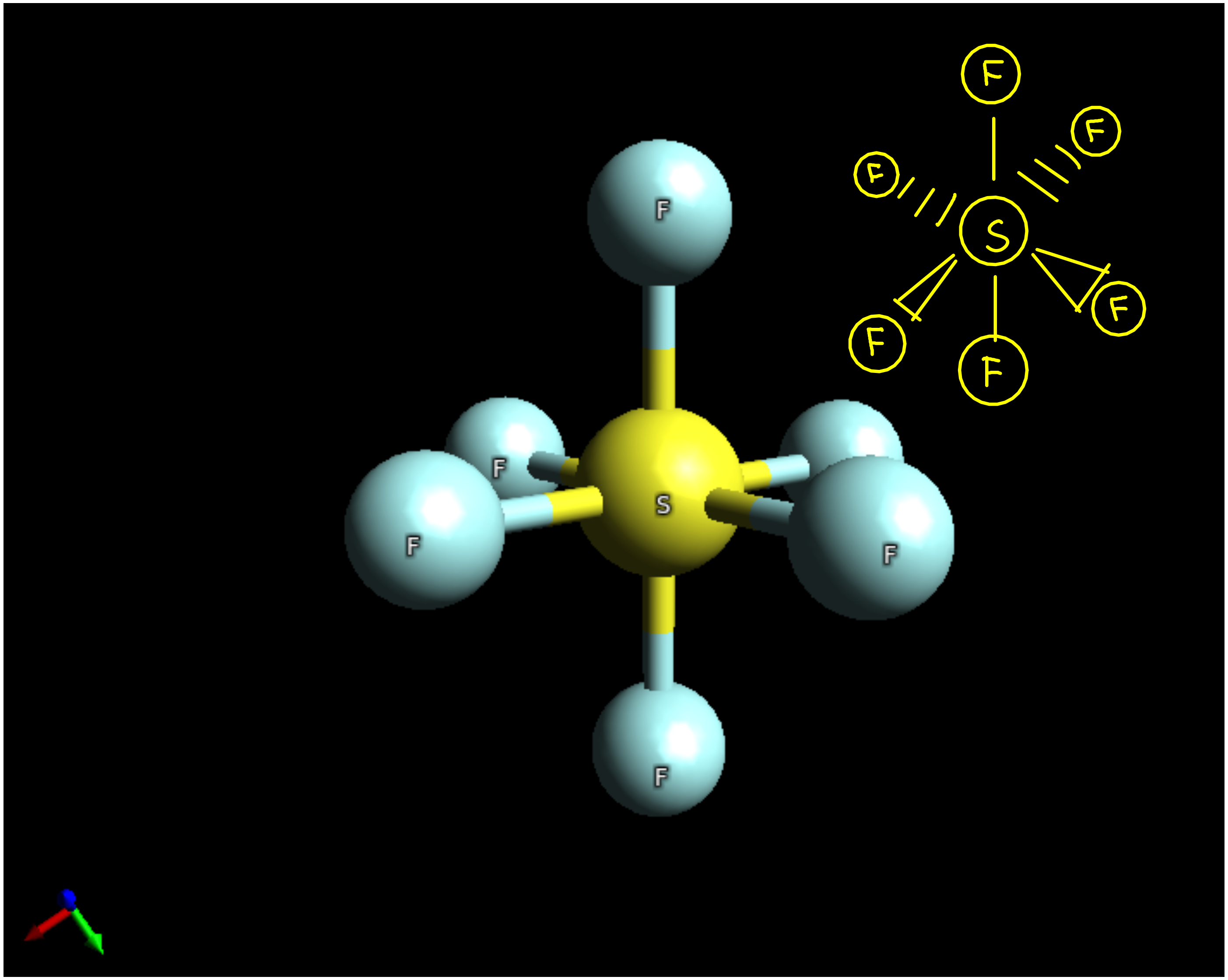
All bond angles in this arrangement are 90 degrees!



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!

Here's a ball-and-stick rendering of the sulfur hexafluoride molecule:



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.

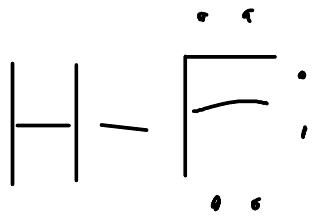
... but how can we tell whether or not a bond will be POLAR? Use ELECTRONEGATIVITY! Usually no actual calculation is required - trends are often good enough to see whether a bond is polar.

REMINDER: ELECTRONEGATIVITY
-A number that describes how tightly 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 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

δ^+ δ^-

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

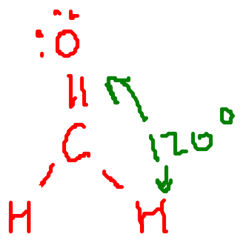
For a molecule to be polar, it must ...

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



Shape? This molecule is TRIGONAL PLANAR. There are THREE THINGS around the central carbon: =O, -H, and -H

Polar? 1) Polar bonds? YES ... C=O is polar. C-H is nonpolar
2) Arrangement? Electrons are pulled towards the oxygen end of the molecule, making the H side positive, so POLAR.

CO_2

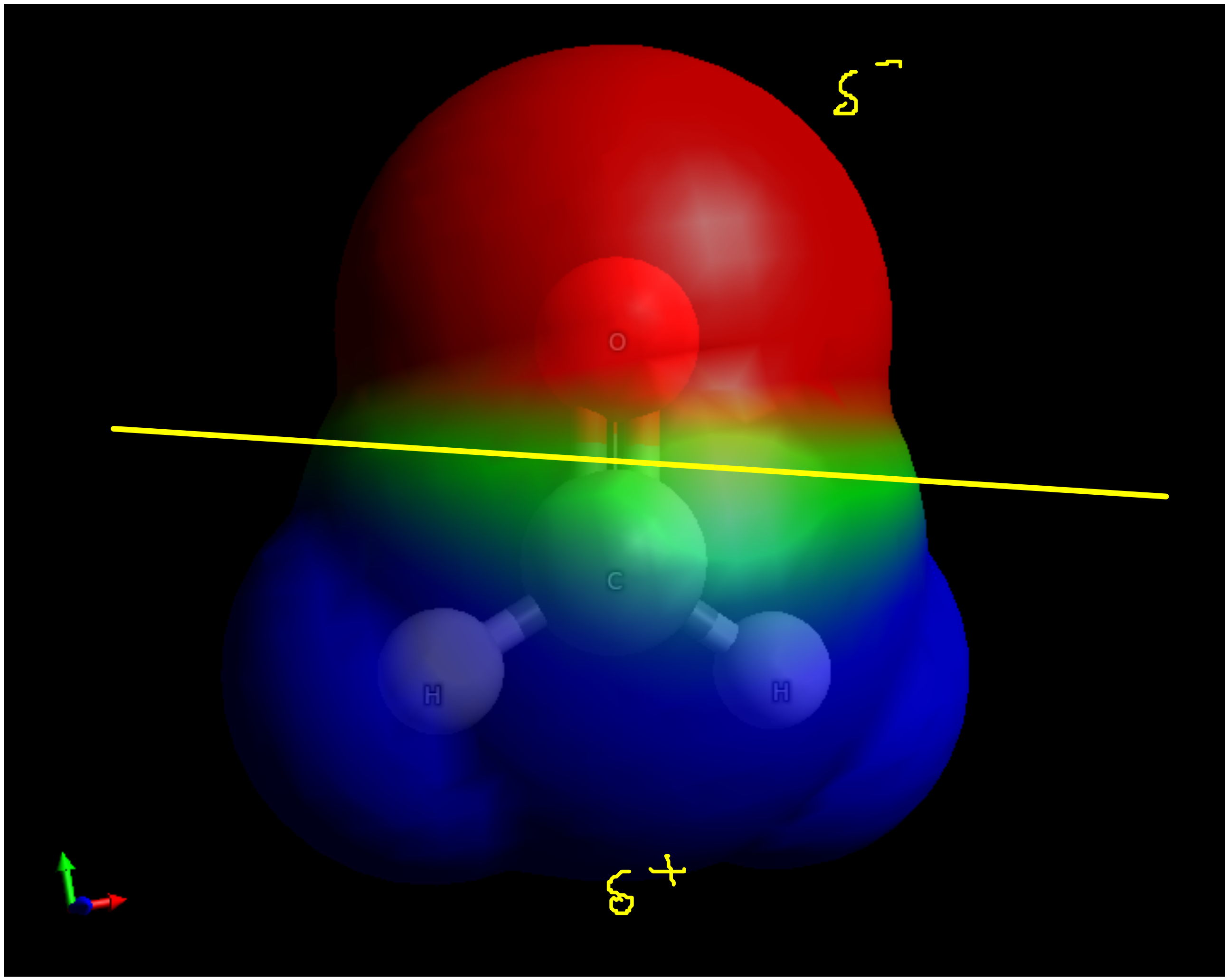
C : 4
O : 6x2
16

Shape? LINEAR. There are only two things around carbon, and they will be 180 degrees apart.

Polar? 1) Polar bonds? C=O bonds are polar.
2) Arrangement? The oxygen atoms are electronegative, but are on opposite sides of the molecule, so there's no negative "side". This is a NONPOLAR molecule.

H_2CO

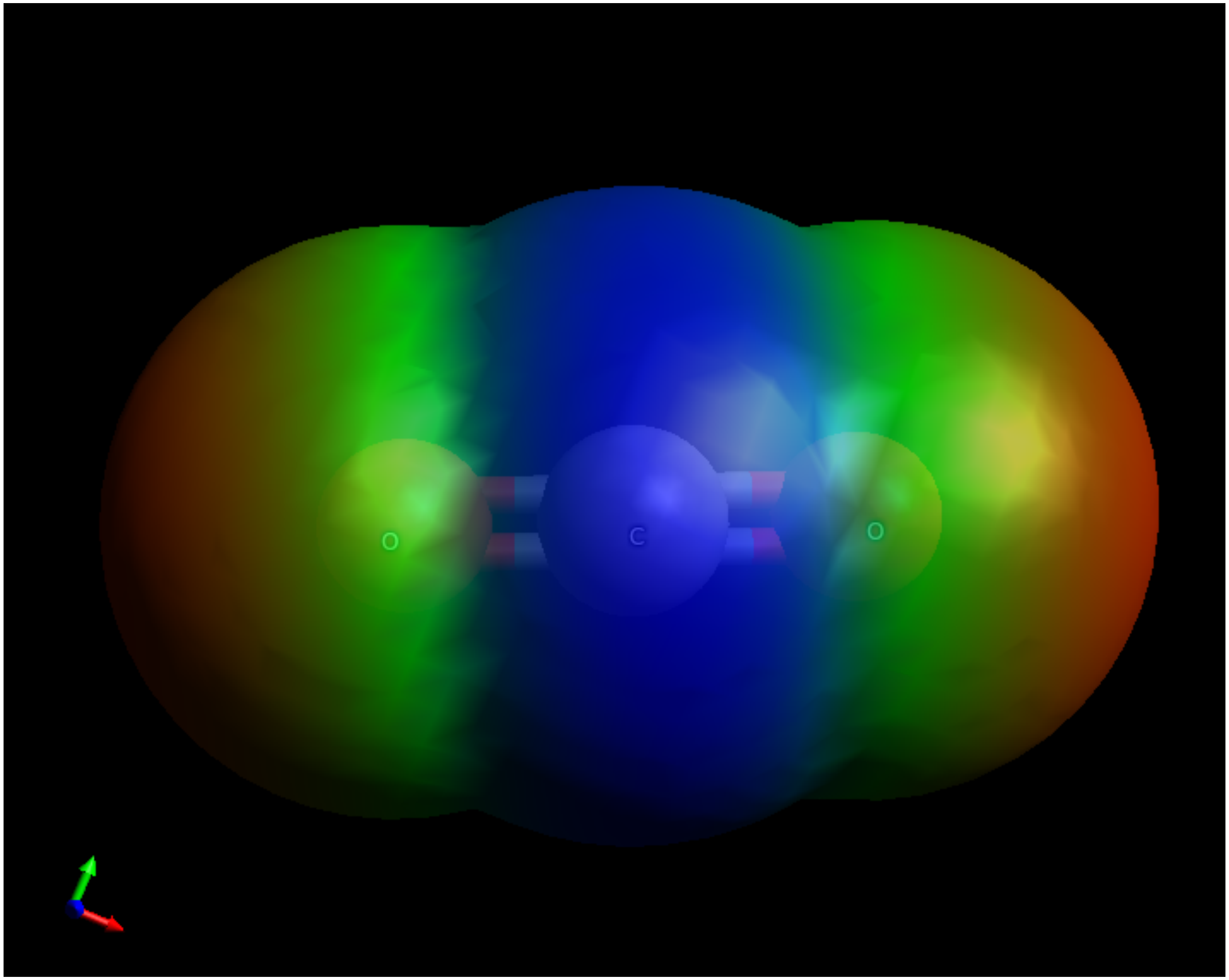
This ball-and-stick model shows electrostatic potential - red for more negative and blue for more positive



oxygen "side", slightly negative

hydrogen "side", slightly positive

$\boxed{CO_2}$

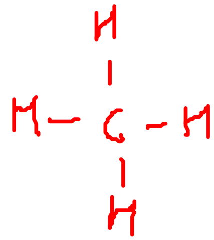


This molecule is NONPOLAR. No positive "side" or negative "side" methane, CH_4

C: 4

H: 4x1

8



Shape? TETRAHEDRAL. Four atoms around the central carbon atom, all 109.5 degrees apart.

Polar? 1) Polar bonds? C-H bonds are nonpolar. NONPOLAR MOLECULE.

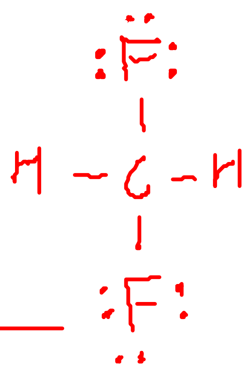
CH_2F_2

C: 4

H: 2x1 = 2

F: 2x7 = 14

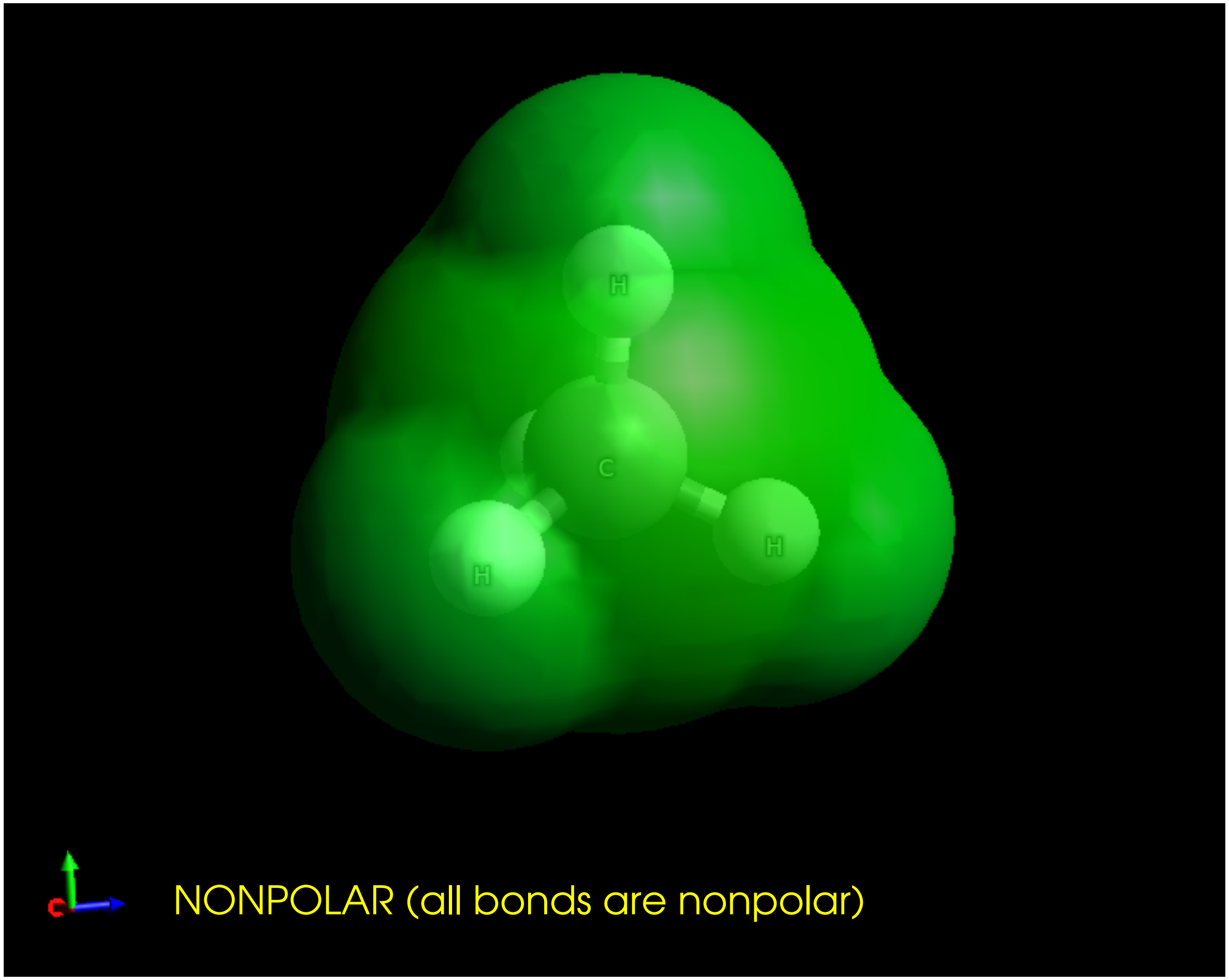
20



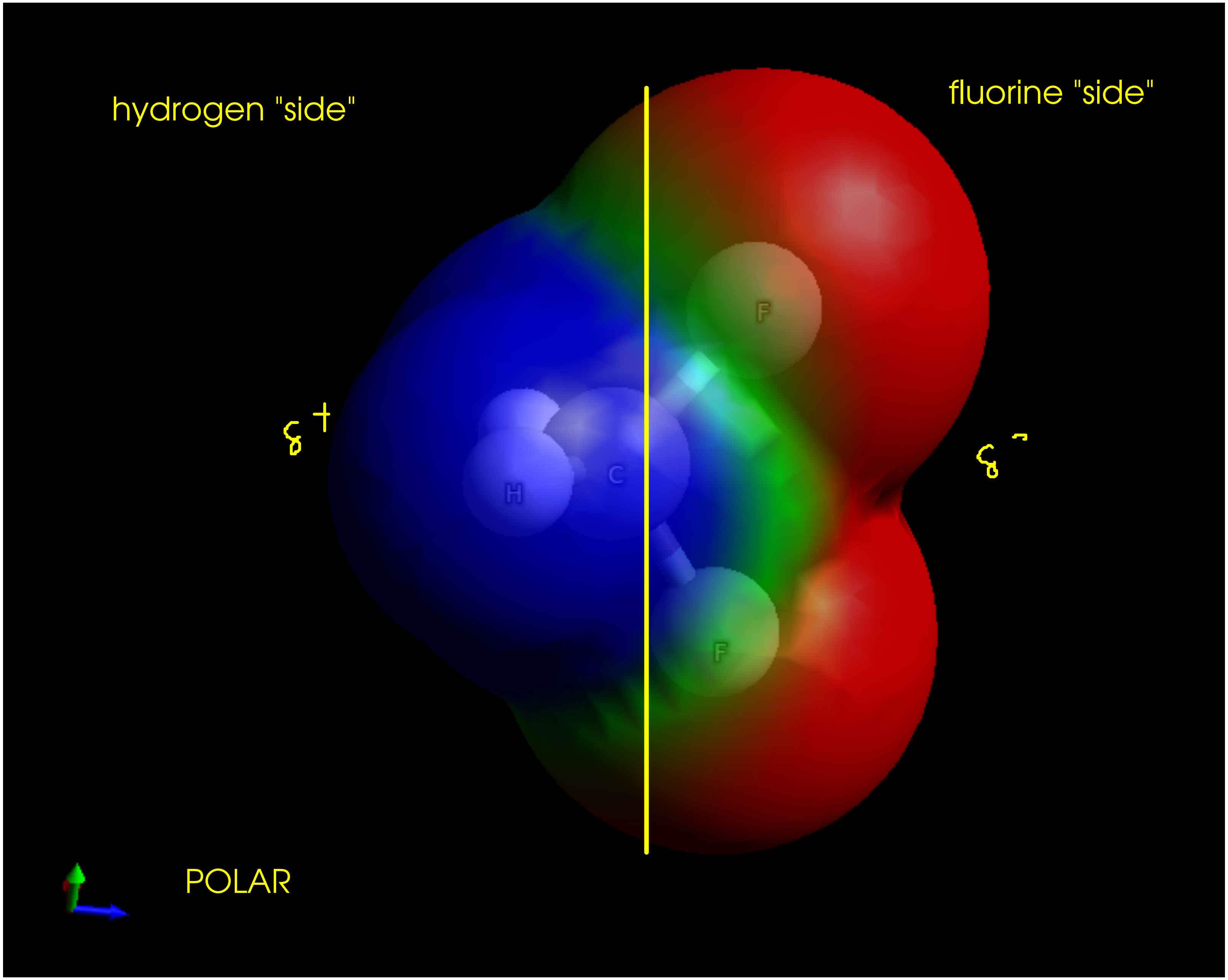
Shape? TETRAHEDRAL. Four atoms around the central carbon atom, just like methane.

Polar? 1) Polar bonds? YES ... C-F is polar
2) Arrangement? We have an uneven tetrahedron, which has a fluorine side and a hydrogen side, so the molecule is POLAR.

$\boxed{CH_4}$



$\boxed{CH_2F_2}$



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

GASES

- Gases differ from the other two phases of matter in many ways:

  - They have very low viscosity (resistance to flow), so they flow from one place to another very easily.

  - They will take the volume of their container. In other words, gas volumes are variable.

  - They are the least dense of all three phases.

  - Most gases are transparent, and many are invisible.

thermal expansion!

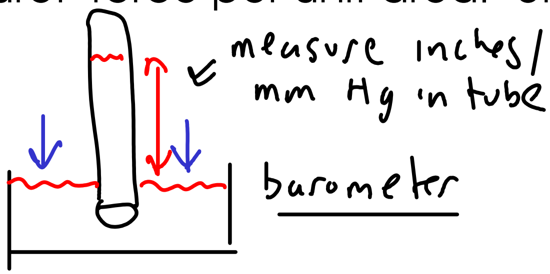
  - Gases show a much larger change of volume on heating or cooling than the other phases.

  - Gases react to changes in temperature and pressure in a very similar way. This reaction often does not depend on what the gas is actually made of.

KINETIC THEORY

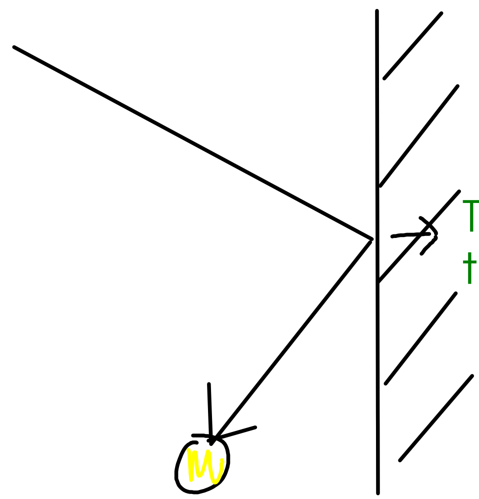
- is a way to explain the behavior of gases.
- views the properties of gases as arising from them being molecules in motion.

- Pressure: force per unit area. Units: Pascal, bar, mm Hg, in Hg, atm, etc.



$$\boxed{760 \text{ mm Hg} = 1 \text{ atm}}$$

- According to kinetic theory, pressure is caused by collisions of gas molecules with each other and the walls of the container the gas is in.



This collision exerts a force on the wall!

201 - Temperature:

- a measure of the average kinetic energy of the molecules of the gas

$$E_K = \frac{1}{2}\,m\,v^2$$

velocity

mass

- The faster the gas molecules move, the higher the temperature!

- The temperature scales used when working with gases are ABSOLUTE scales.

- ABSOLUTE: scales which have no values less than zero.

- KELVIN: metric absolute temperature scale.

$$\boxed{K = 273.15 + {}^{\circ}C}$$

Quick comparison of temperature scales!

212	100	373	Water boils
77	25	298	Room temperature
32	0	273	Water freezes
-460	-273	0	Absolute zero!
°F	°C	K	