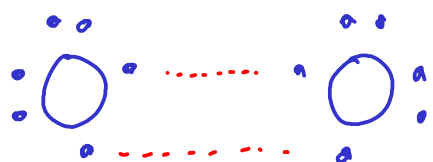


Let's look at OXYGEN ...



We know that oxygen exists in air as the diatomic molecule O_2



The oxygen atoms share TWO pairs of electrons. This is called a DOUBLE BOND

OR

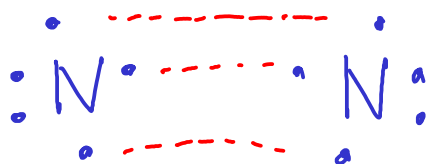


Each oxygen atom has a share in eight electrons!

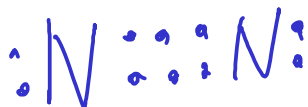
A few notes on the double bond:

- ① - For atoms to share more than one pair of electrons, they have to move closer to one another than they would if they were only sharing one pair of electrons. This BOND DISTANCE is measurable!
- ② - It takes more energy to break a double bond between two atoms than it would to break a single bond between the same two atoms. This BOND ENERGY is also measurable!

Let's look at NITROGEN ...



We know that nitrogen exists in air as the diatomic molecule N_2



The nitrogen atoms share THREE pairs of electrons. This is called a TRIPLE BOND

OR



Nitrogen gas is fairly inert ... it's hard to break the triple bond in nitrogen gas apart!

A few notes on the triple bond:

- ① - For atoms to share three pairs of electrons, they have to move closer to one another than they would if they were sharing one or two pairs of electrons. Triple bonds have the shortest BOND DISTANCE of all covalent bonds.
- ② - It takes more energy to break a triple bond between two atoms than it would to break either a single or double bond between the same two atoms. The triple bond has the largest BOND ENERGY of all three kinds of covalent bonds.

SO FAR, we've seen that ...

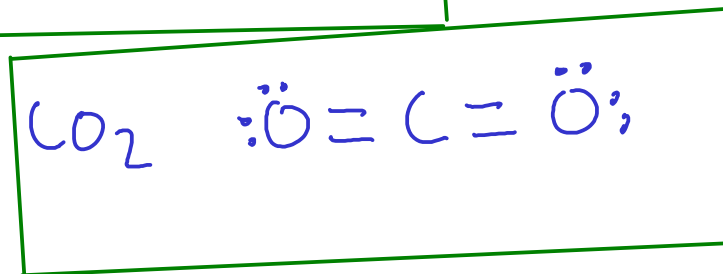
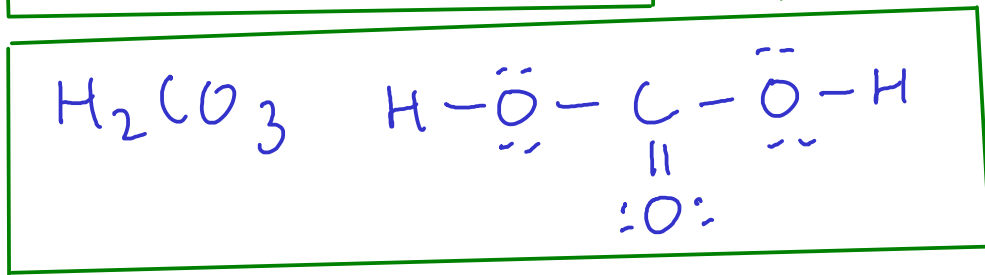
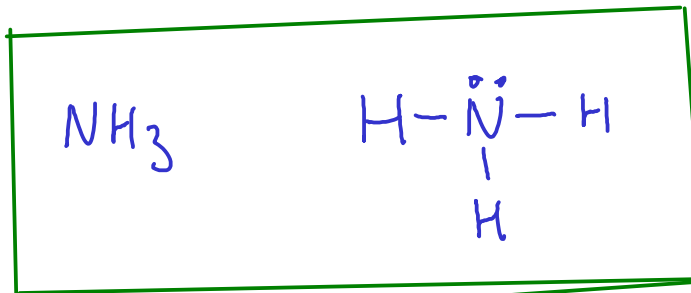
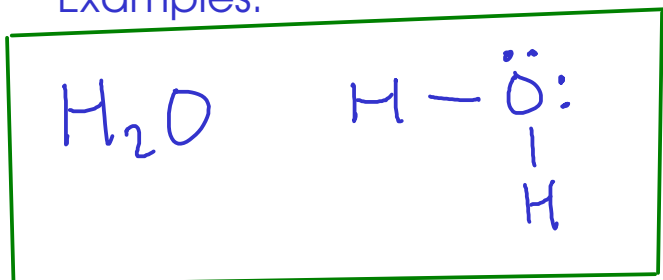
- ① Atoms may share one, two, or three pairs of electrons with each other.
- ② Atoms will usually share enough electrons so that each atom ends up with a share in EIGHT electrons - the "octet rule"

- HYDROGEN will only end up with two electrons!

- Some other atoms may end up with more or less than eight electrons. Exceptions to the octet rule are covered in Chapter 9.

NOW, how could we come up with dot structures for some more complicated (and therefore, more interesting) molecules?

Examples:



① Count valence electrons

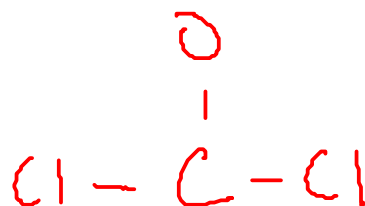
② Pick central atom and draw skeletal structure

- central atom is usually the one that needs to gain the most electrons!

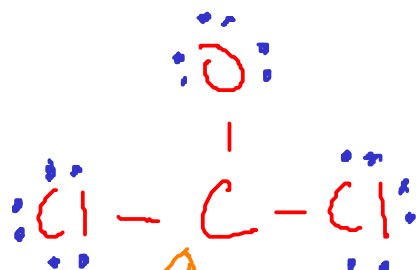
- skeletal structure has all atoms connected to center with single bonds

③ Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

④ Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

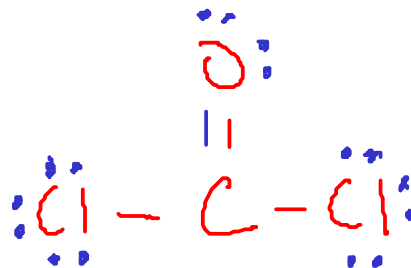


Choose CARBON as central atom since it needs the most electrons!



Distribute the remaining electrons ... stop when we have put on all 24.

... but CARBON has a share in only six electrons, when it should have 8.



We'll pick OXYGEN for the double bond ... it needed TWO electrons originally, so it's likely to share two of its own electrons to get them...



① Count valence electrons

② Pick central atom and draw skeletal structure

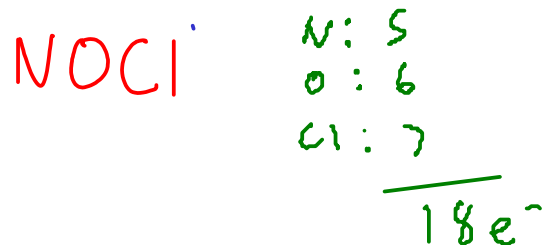
- central atom is usually the one that needs to gain the most electrons!

- skeletal structure

has all atoms connected to center with single bonds

③ Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

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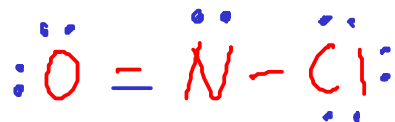


We pick NITROGEN as the central atom, since it needs to gain 3 electrons (more than Cl or O)



We ran out of space on the "outside", so we put the last two electrons on the central atom...

Since NITROGEN has a share in only SIX electrons, we will make a double bond using electrons from oxygen ... (same reason as for the last structure)



① Count valence electrons

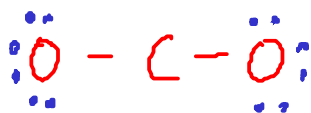
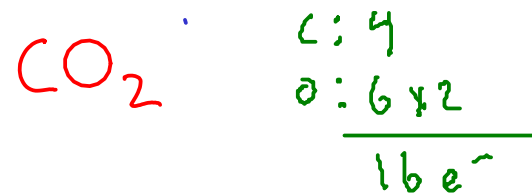
② Pick central atom and draw skeletal structure

- central atom is usually the one that needs to gain the most electrons!

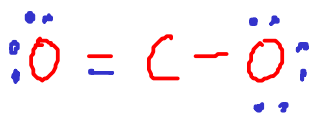
- skeletal structure has all atoms connected to center with single bonds

③ Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

④ Check octet rule - each atom should have a share in 8 electrons (H gets 2). If not, make double or triple bonds.



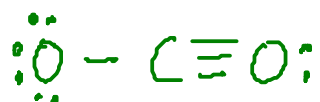
... but each carbon has a share in only FOUR electrons!



... and now, six.



Adding a second double bond gives carbon a share in eight electrons!



The two oxygen atoms are in identical chemical environments, and should bond to the carbon center in exactly the same way!

EXPERIMENTALLY, we find that the two carbon atoms are the same distance from the central carbon (in other words, they have the same bond length), which supports the earlier structure with two double bonds.

① Count valence electrons

② Pick central atom and draw skeletal structure

- central atom is usually the one that needs to gain the most electrons!
- skeletal structure has all atoms connected to center with single bonds

③ Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

④ Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

HNO_2 "nitrous acid"

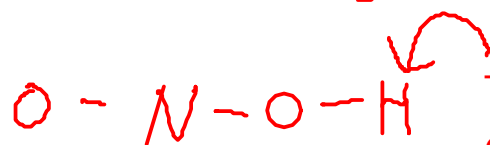
In oxyacids, the acidic hydrogen atoms are attached to OXYGEN atoms in the structure!

H: 1 x 1

N: 1 x 5

O: 2 x 6

18e⁻



This OXYACID ... has a hydrogen atom directly bonded to oxygen!



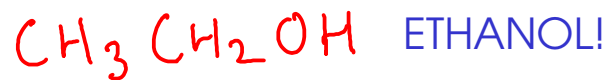
... but NITROGEN has a share in only six electrons!



Here, the two oxygen atoms bond differently to the nitrogen center, but they are in different CHEMICAL ENVIRONMENTS ... the oxygen on the right is also attached to hydrogen!

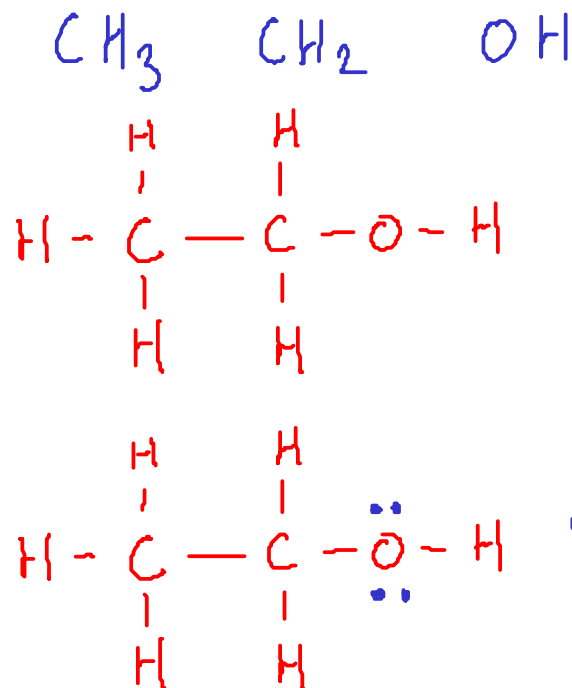
A DOT STRUCTURE FOR A LARGER MOLECULE

- ① Count valence electrons
- ② Pick central atom and draw skeletal structure
 - central atom is usually the one that needs to gain the most electrons!
 - skeletal structure has all atoms connected to center with single bonds
- ③ Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.
- ④ Check octet rule - each atom should have a share in 8 electrons (H gets 2). If not, make double or triple bonds.



$$\begin{array}{l|l} \text{C} : 4 \times 2 = 8 & \\ \text{H} : 1 \times 6 = 6 & \\ \text{O} : 6 \times 1 = 6 & \\ \hline & 20 \end{array}$$

This formula gives us clues about the structure of this large molecule. It has three parts, and three central atoms!



Notice that the structures of ethanol and water are fairly similar. Because of this similarity, we expect ethanol and water to mix well (as they are observed to do!)

A DOT STRUCTURE FOR A MOLECULE WITH DELOCALIZED BONDS

$$O = 3 \times 6 = 18$$

See text, 9.7
p 350-352

① Count valence electrons

② Pick central atom and draw skeletal structure

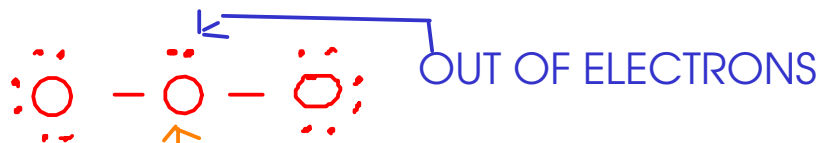
- central atom is usually the one that needs to gain the most electrons!

- skeletal structure has all atoms connected to center with single bonds

③ Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

④ Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

O_3 (OZONE)



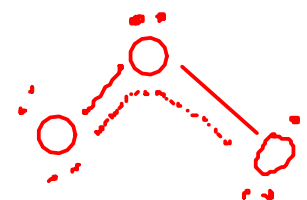
Central oxygen has only six electrons



The structure we drew implies that one of the outer oxygen atoms is closer to the central oxygen atom than the other one.

Experimentally, though, we find the two oxygen atoms to be the SAME distance from the center.

In the ozone molecule, electrons are actually being shared between ALL THREE oxygen atoms at the same time. This is called a DELOCALIZED BOND.



The structures in the green box are called RESONANCE STRUCTURES. The "real" structure of ozone is an "average" of the two resonance structures. The "double bond" electrons in these structures are actually shared between all three oxygen atoms