SO FAR, we've seen that ...

1. Atoms may share one, two, or three pairs of electrons.

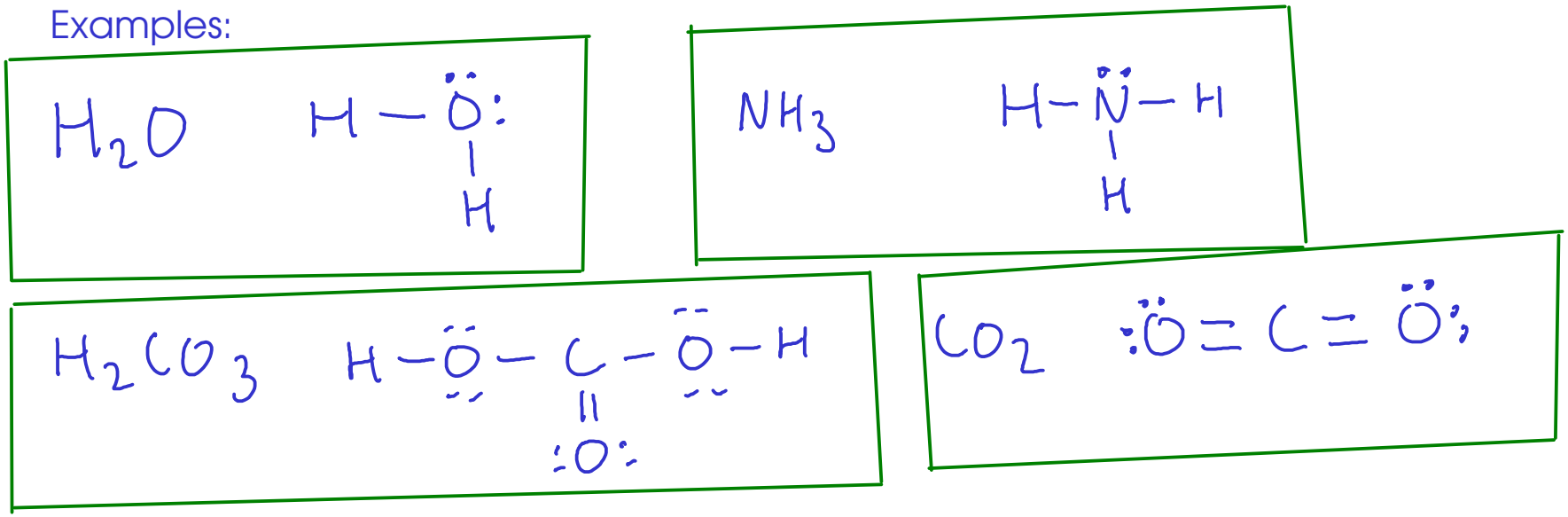
2. Atoms will usually share enough electrons so that each atom ends up with a share in EIGHT electrons - the "octet rule"

   - 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:



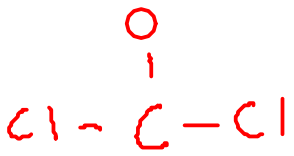
DRAWING DOT STRUCTURES FOR SIMPLE MOLECULES

$COCl_2$

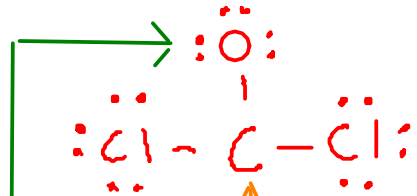
C : 4
O : 6
Cl : 7 x 2
24

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



Choose CARBON as the central atom, since it needs 4 more electrons. Draw skeleton.

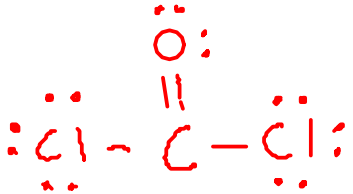


Distribute electrons. Stop here because we used all 24.

CARBON has a share in only 6 electrons!

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

We'll pick OXYGEN to share two pairs of electrons. It's likely to be able to share more than one pair since it needs to gain TWO electrons in bonding.



This structure looks better - all atoms have a share in eight electrons.

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

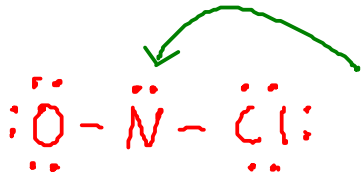
4. Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

NOCl

N : 5 x 1
O : 6 x 1
Cl : 7 x 1
16 e⁻

O - N - Cl

We use NITROGEN as the central atom, since it needs to gain more electrons than oxygen or chlorine



We ran out of space on the outer atoms, so we put the last pair of electrons onto NITROGEN.

We see that NITROGEN has a share in only SIX electrons, so we make a double bond. Choose OXYGEN to form the double bond (same reasons as the previous example).

Each atom now has a share in eight electrons,

1. Count valence electrons

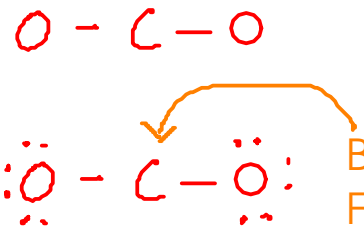
2. Pick central atom and draw skeletal structure
   - central atom is usually the one that needs to gain the most electrons!
   - skeletal structure has all atoms connected to center with single bonds

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

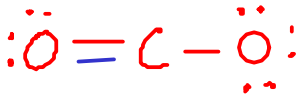
4. Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

CO_2

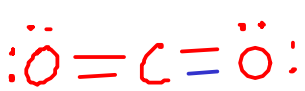
C: 4
O: 6 x 2
16 e⁻



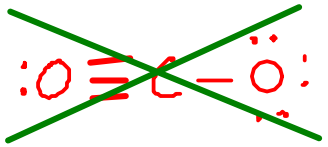
But CARBON has a share in only FOUR electrons



Adding one double bond gives carbon a share in more electrons, but only 6 now.



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



These two oxygen atoms SHOULD bond the same way to the carbon center. They are identical atoms in an identical environment.

EXPERIMENTALLY, we find that the two oxygen atoms are the SAME distance from the central carbon atom, so the structure with two double bonds is the correct one.

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

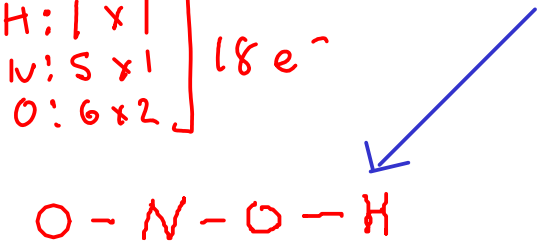
3. Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

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

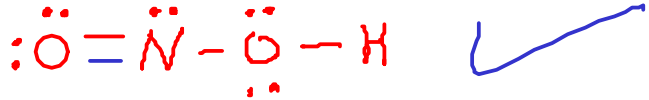
HNO_2 "nitrous acid"

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

H: 1 x 1
N: 5 x 1
O: 6 x 2
] 18 e⁻



NITROGEN has a share in only SIX electrons



Notice that the two oxygen atoms are NOT bonded the same way (as in carbon dioxide), but that's because the two oxygen atoms here are bonded to DIFFERENT THINGS.

A DOT STRUCTURE FOR A LARGER MOLECULE

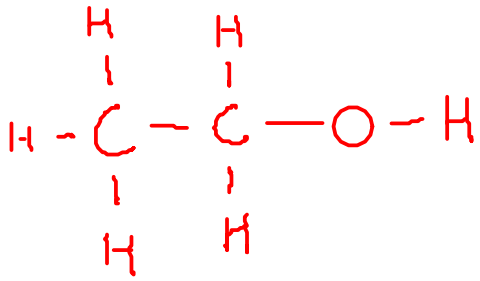
CH_3CH_2OH ETHANOL!

C : 4 x 2 = 8
H : 1 x 6 = 6
O : 6 x 1 = 6
| 20

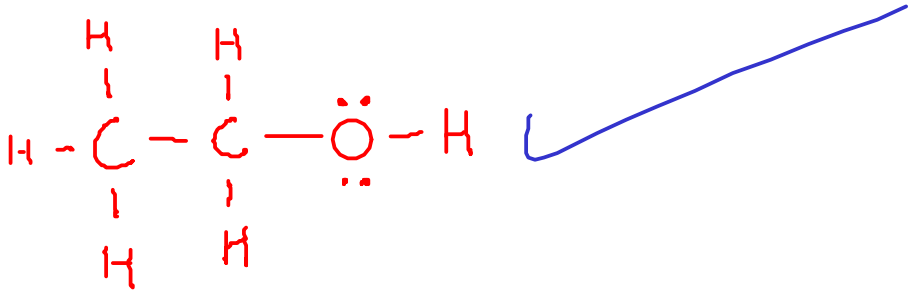
This formula gives us a hint to the structure of the molecule. Ethanol has THREE centers: the two carbon atoms and the oxygen atom.

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.

A DOT STRUCTURE FOR A MOLECULE WITH DELOCALIZED BONDS

O: 3 x 6 = 18

O_3 (OZONE)

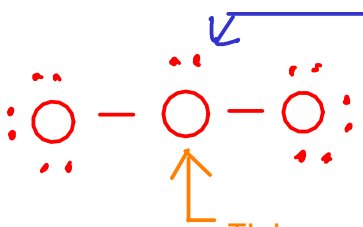
See text, 9.7 p 350-352

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.

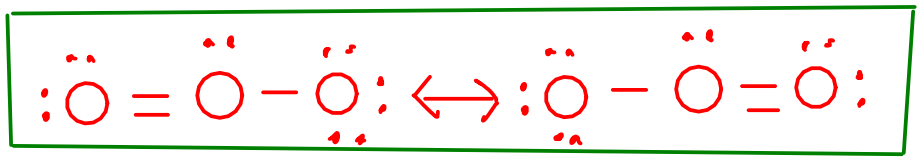


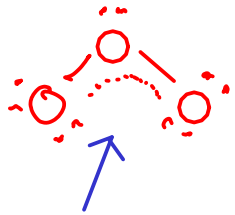
All atoms have a share in eight electrons here.

This structure suggests that one of the outer oxygen atoms is closer to the central oxygen atom than the other one!

Experimentally, we observe that both outer oxygen atoms are the SAME distance from the center.

In the molecule, electrons are actually being shared between ALL THREE oxygen atoms. This is a DELOCALIZED bond!





These are RESONANCE structures. The real structure is an "average" of these two. The "double bond"'s electrons are shared between all three oxygen atoms!

A DOT STRUCTURE FOR A POLYATOMIC ION

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.

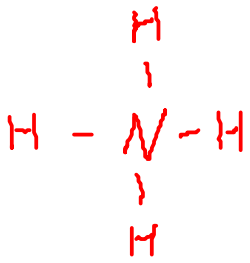
4. Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

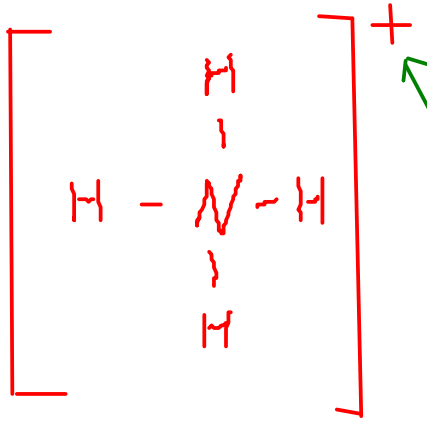
NH_4^+

N: 1 x 5
H: 4 x 1
9
-1
8

An odd number of electrons? But the structures we've seen so far all have even numbers of electrons (pairs)

Subtract an electron from the total to account for ammonium's +1 charge.

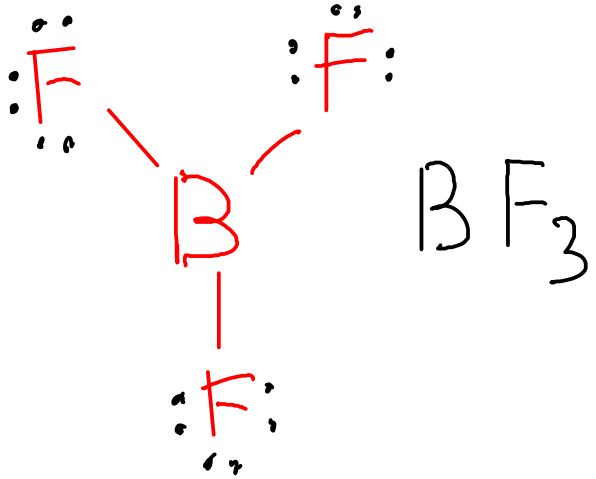




Draw brackets around the complete structure for an ion, then include the charge as shown.

EXPANDED VALENCE and other exceptions to the "octet rule"

- Some atoms do not always obey the octet rule. A few, like BORON, will bond in such a way that they end up with less than eight electrons.



... but many more bond in such a way that they end up with a share in MORE THAN EIGHT electrons!

- Any atom in period three or greater can do this. SULFUR and PHOSPHORUS compounds commonly do this!

... these atoms have unfilled "d" orbitals that may participate in bonding!

- All noble gas compounds (example: XENON compounds with oxygen and fluorine) exhibit this behavior!