SO FAR, we've seen that ...

(1) Atoms may share one, two, or three pairs of electrons with each other.

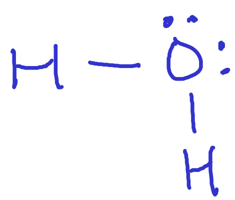
(2) Atoms will usually share enough electrons so that each atom ends up with a share in EIGHT electrons - the "octet rule"

- 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.

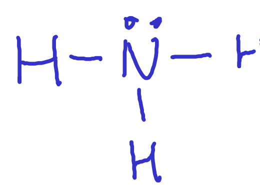
NOW, how could we come up with dot structures for some more complicated (and therefore, more interesting) molecules?

Examples:

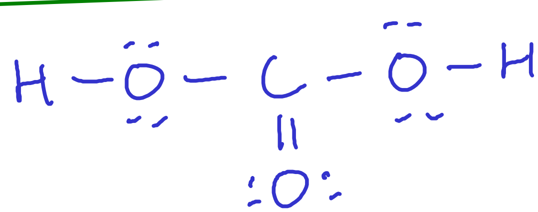
H_2O



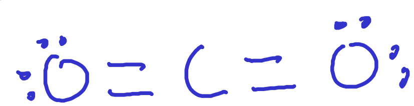
NH_3



H_2CO_3



CO_2



(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

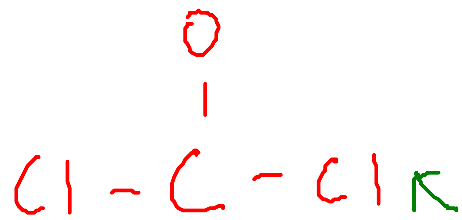
(3) Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

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

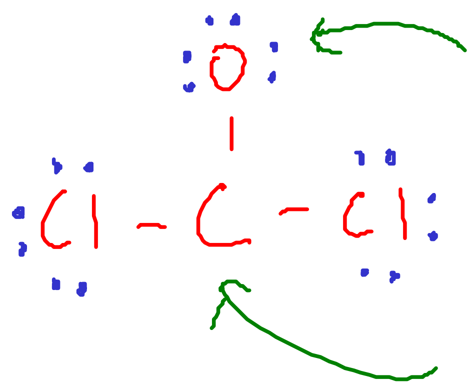
$COCl_2$

C: 4
O: 6
Cl: 7 x 2 = 14

$24\ e^-$



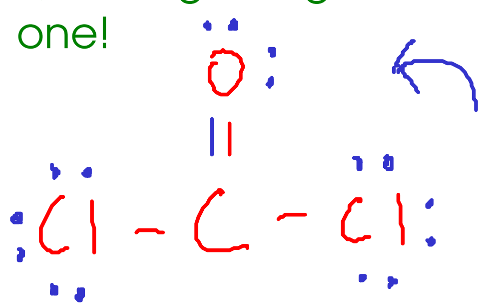
Choose CARBON as the central atom, since it needs more electrons than the others!



Distribute remaining electrons. We stop here because we have used all 24 ...

... but the CARBON atom has a share in only six electrons.

We'll pick OXYGEN to form a double bond, since it needed to gain two additional electrons (started with 6), and gaining an electron usually involves sharing one!



This structure looks better, since all the atoms have enough 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

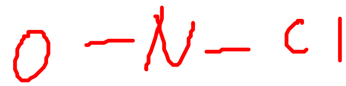
(3) Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

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

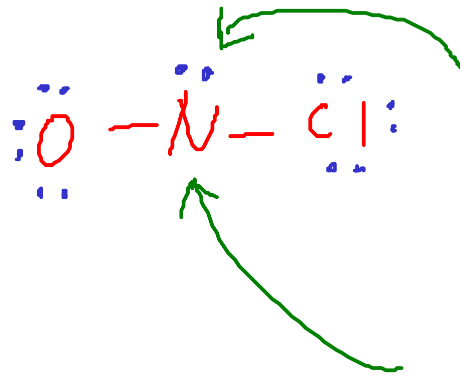
NOCl

N: 5
O: 6
Cl: 7

18 e^-

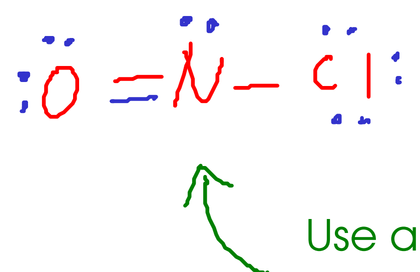


We pick NITROGEN as the central atom, since it needs more electrons than the other two.



We ran out of space on the outer atoms, so the last pair of electrons goes onto the central nitrogen.

NITROGEN has a share in only six electrons, so we'll need a double bond!



Use a pair of electrons from oxygen to make a double bond (same reason as the previous example)

(1) Count valence electrons

(2) Pick central atom and draw skeletal structure

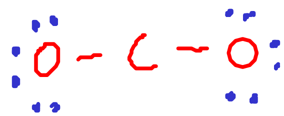
- central atom is usually the one that needs to gain the most electrons!
- skeletal structure has all atoms connected to center with single bonds

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

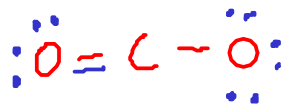
(4) Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

CO_2

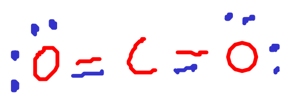
C: 4
O: 6 x 2
16 e^-



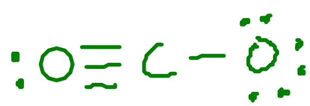
... but CARBON has a share in only four electrons!



... now it's got six.



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



The two oxygen atoms are in identical environments and SHOULD be bonded to the carbon atom in the same way.

Experimentally (by easuing bond distance), we find that in the real molecule, the distance between both oxygen atoms and the carbon atom is the same! Not consistent with the triple bond - single bond structure drawn in green.

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.

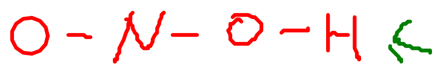
4. Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

HNO_2 "nitrous acid"

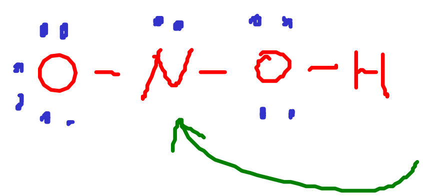
In oxyacids, the acidic hydrogen atoms are attached to OXYGEN atoms in the structure!

H: 1 x 1
N: 1 x 5
O: 2 x 6

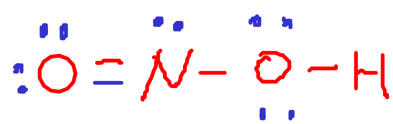
$18 e^-$



OXYACID, so the acidic H must be attached to O...



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



Here, the two oxygen atoms are in different chemical environments (the one on the right is also bonded to H), so we aren't surprised to see a difference in bonding to the central nitrogen atom!

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.

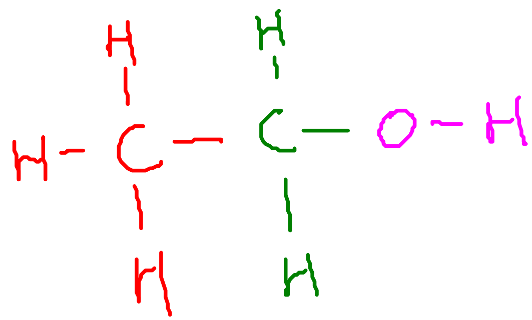
(4) Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

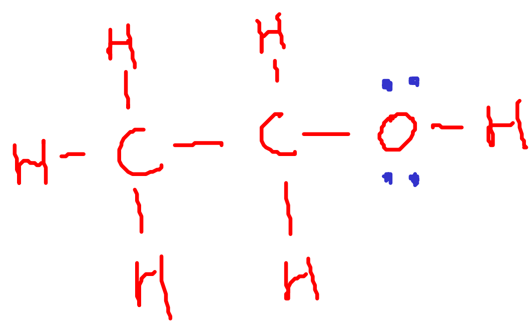
CH_3CH_2OH ETHANOL!

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 ethanol. Ethanol has THREE central atoms chained together.

CH_3 CH_2 OH





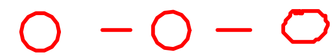
A DOT STRUCTURE FOR A MOLECULE WITH DELOCALIZED BONDS

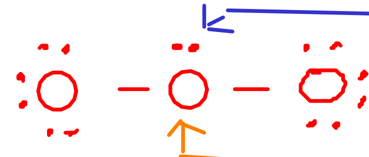
O: 3 x 6 = 18

See text, 9.7
p 350 - 352

O_3 (OZONE)

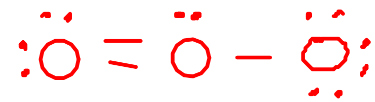
1. Count valence electrons
2. Pick central atom and draw skeletal structure
   - central atom is usually the one that needs to gain the most electrons!
   - skeletal structure has all atoms connected to center with single bonds
3. Distribute remaining valence electrons around structure, outer atoms first. 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.





OUT OF ELECTRONS

Central oxygen has only six electrons

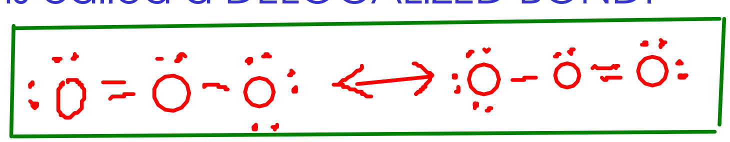


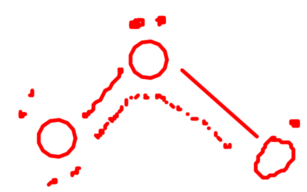
All atoms have a share in eight electrons!

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 resonsnce structures. The "double bond" electrons in these structures are actually 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 × 5

H : 4 × 1

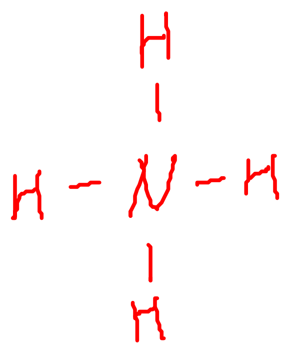
9

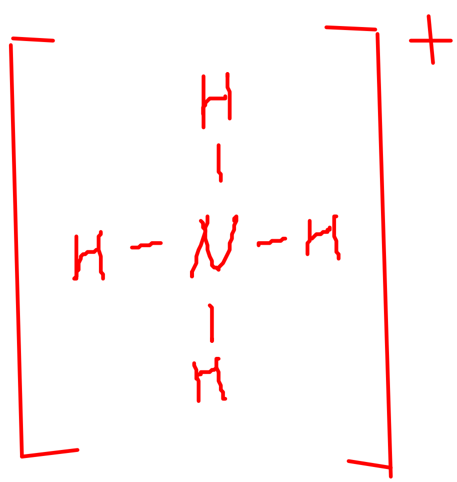
− 1

$8 e^-$

An ODD number of electrons? But dot structures for MOLECULES generally have EVEN numbers!

To get a POSITIVELY CHARGED ION, we subtract electrons. Since this one is +1, subtract one electron.





Draw brackets around the structure of the ion, and indicate the charge in the upper right, much like you indicate the charge in the normal formula of the ion.