DRAWING DOT STRUCTURES FOR SIMPLE MOLECULES

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

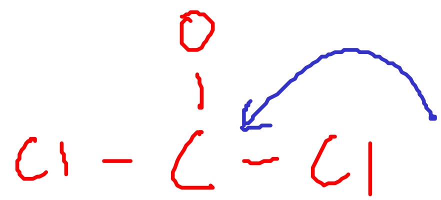
3. Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

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

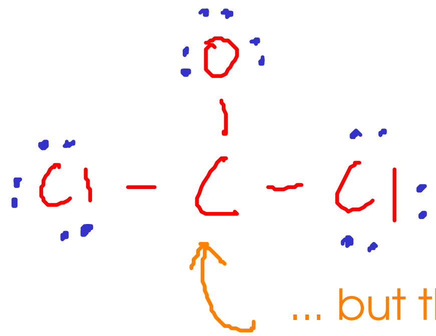
$COCl_2$

C: 4
O: 6
Cl: 7x2 = 14

24 e^-



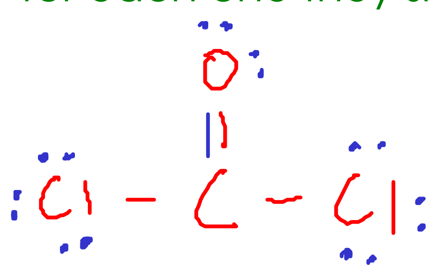
Choose CARBON as central atom



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

... but the CARBON ATOM has a share in only SIX electrons, when it should have EIGHT.

We'll pick OXYGEN to share the another pair of electrons. Why? Oxygen needed to gain two more electrons, so it's more likely to share two (form two bonds) than chlorine. Atoms usually "gain" an electron for each one they share.



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

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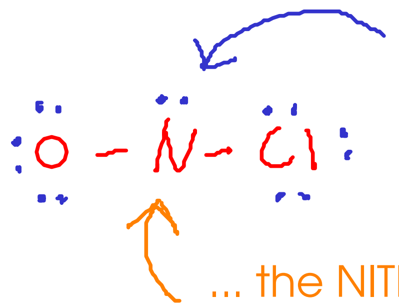
NOCl

N: 5
O: 6
Cl: 7

18 e^-

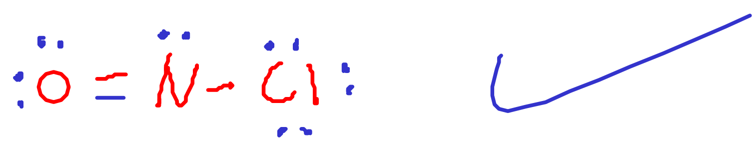
Pick NITROGEN as the central atom, since it needs to gain three more electrons - more than either O or Cl.



We ran out of space on the outer atoms, so the last two electtons go onto the central nitrogen atom.

... the NITROGEN atom has a share in only SIX electrons!

We'll use OXYGEN for the double bond again - same reason as the last molecule.



Using a pair of electrons we'd previously put on oxygen, we can fix this structure.

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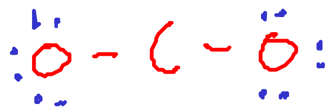
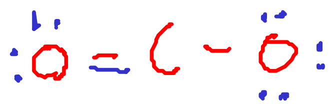
CO_2

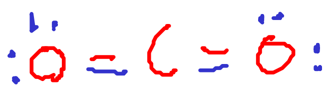
C: 4
O: 6 x 2
$16 e^-$



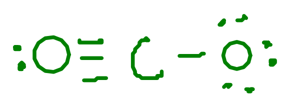
... but carbon has a share in only FOUR electrons!



... and now it's got SIX.



Adding a second double bond gives all atoms a share in eight electrons.



The two oxygen atoms are in the same chemical environment, so they should bond the same way, not in the arrangement on the left.

EXPERIMENTALLY, we find that the oxygen atoms in carbon dioxide are the SAME distance from the central carbon atom. That doesn't acree with the triple/single bond structure we drew here, but DOES agree with the double/double bond structure we drew earlier.

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

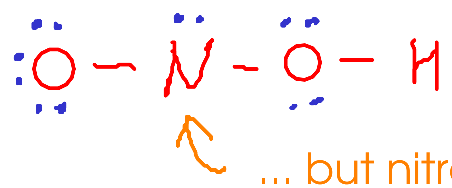
HNO_2 "nitrous acid"

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

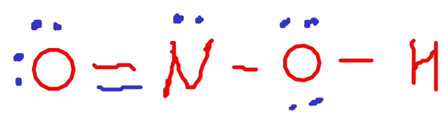
H: 1
N: 5
O: 6x2

18e⁻

In an oxyacid, hydrogen attaches directly to oxygen (and not the otherwise "central" nitrogen atom)



... but nitrogen has a share in only SIX electrons



Here, the two oxygen atoms are in DIFFERENT chemical environments, so we're not surprised that the one on the left has a double bond with N while the one on the right has a single bond.

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

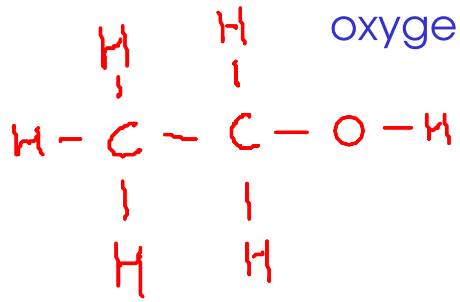
(3) Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

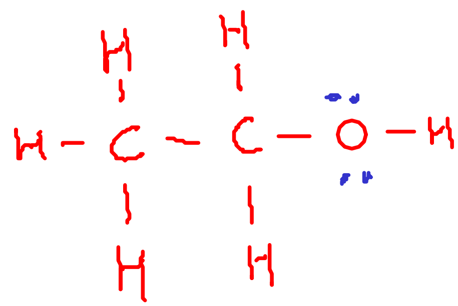
(4) Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

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 the molecule. Ethanol has THREE centers: the two carbon atoms and the oxygen atom.





A DOT STRUCTURE FOR A MOLECULE WITH DELOCALIZED BONDS

O: 3 x 6 = 18

See text, 9,7
p 350-352

① Count valence electrons

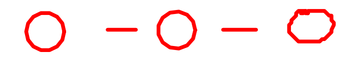
② Pick central atom and draw skeletal structure

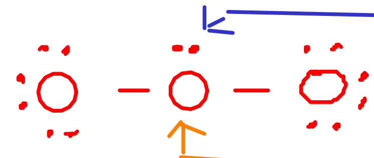
- central atom is usually the one that needs to gain the most electrons!
- skeletal structure has all atoms connected to center with single bonds

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.

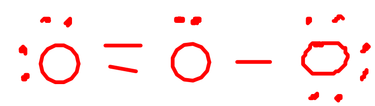
O_3 (OZONE)





OUT OF ELECTRONS

Central oxygen has only six electrons

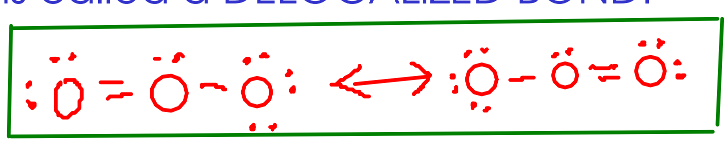


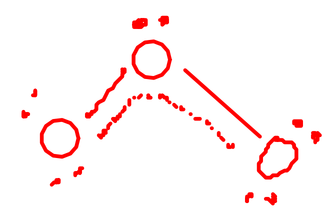
All atoms have a share in eight electrons!

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: 5
H: 1 x4

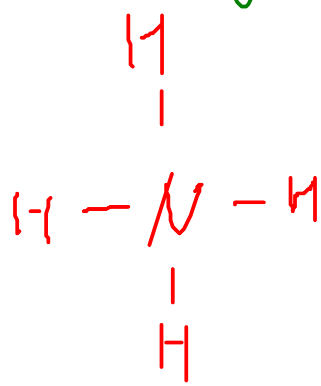
9

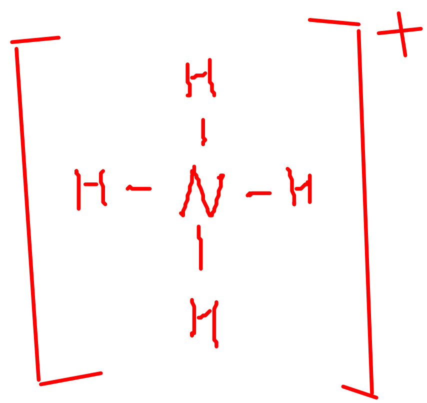
-1

8

An ODD number of electrons? But Lewis structures for molecules tend to have EVEN numbers of electrons!

Subtract an electron because of the +1 charge on the ion!



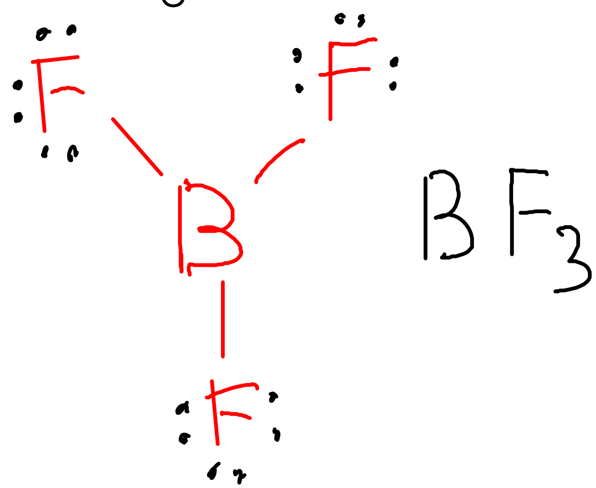


Draw brackets around the structure and indicate the charge at the upper right.

(Similar to how we usually indicate ions!)

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!

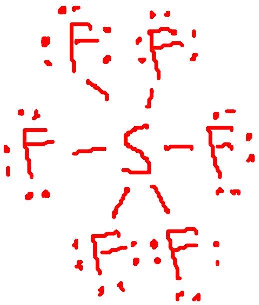
- Any atom in period three or greater can do this. SULFUR and PHOSPHORUS compounds commonly do this!

... 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!

EXAMPLES:

SF_6



S: 6
F: 7 x 6
48

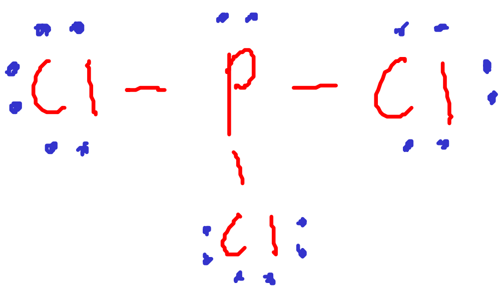
- The central SULFUR atom has a share in TWELVE total electrons, not eight!

- The SHAPE of the sulfur hexafluoride molecule in three dimensions agrees with the picture of six fluorine atoms each sharing a pair of electrons with a sulfur center.

PCl_3 vs PCl_5

PCl_3

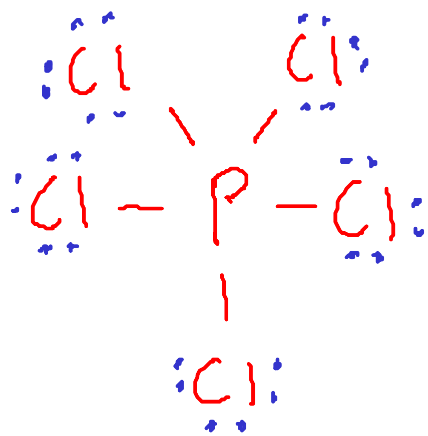
P : 5
Cl : 7 x 3 = 21
26



This structure obeys the octet rule.

PCl_5

P : 5
Cl : 7 x 5 = 35
40



This molecule does NOT obey the octet rule. Phosphorus ends up with ten electrons instead of eight.