DRAWING DOT STRUCTURES FOR SIMPLE MOLECULES

1. Count valence electrons

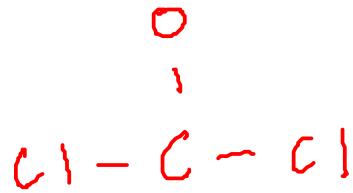
2. Pick central atom and draw skeletal structure
   - central atom is usually the one that needs to gain the most electrons!
   - skeletal structure has all atoms connected to center with single bonds

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

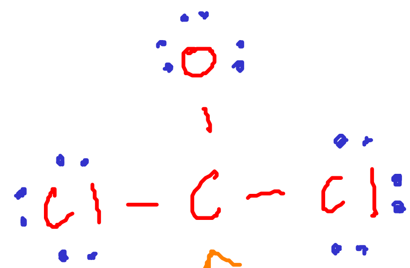
4. Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

$COCl_2$

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

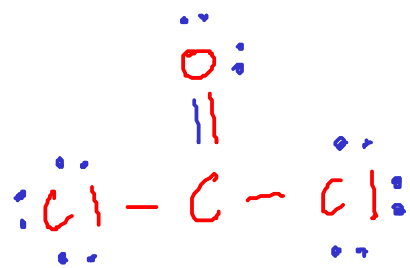


Choose CARBON as central atom



Distribute remaining electrons. We stop here because all 24 electrons have been used (6 of them qre in the bonds

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



We pick OXYGEN for the double bond. Why? Oxygen needs two additional electrons, so it's likely to be able to share two (to get two more).

This structure looks better. Each atom has a share in eight electrons.

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NOCl

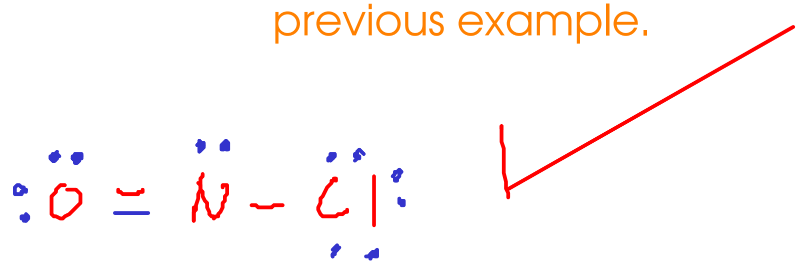
N : 5
O : 6
Cl : 7

18 e⁻

We pick NITROGEN as the central atom, since it needs the most electrons. (3 more)

We ran out of space on the outside, so the last two electrons go onto nitrogen

... but NITROGEN still has a share in only SIX electrons, so we need a double bond. We pick oxygen again for the double bond, just as we did in the previous example.



Using a pair of electrons from the oxygen atom "fixes" this structure.

(1) Count valence electrons

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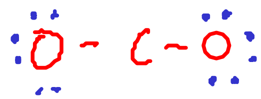
CO_2

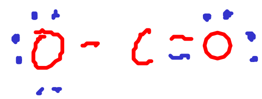
C : 4

O : 2×6 = 12

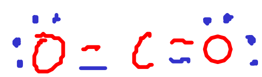
16 electrons



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

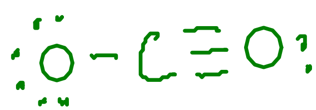


... now carbon has six electrons.



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

Why not this structure?



The two oxygen atoms are in identical environments, and HSOULD bond in exactly the same way to the central carbon atom, not in the way drawn in the structure on the left...

EXPERIMENTALLY, we can verify that the oxygen atoms are the same distance from the carbon atom, which does NOT agree with the single/triple bond structure.

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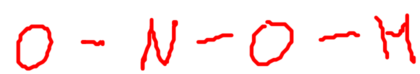
4. Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

HNO_2 "nitrous acid"

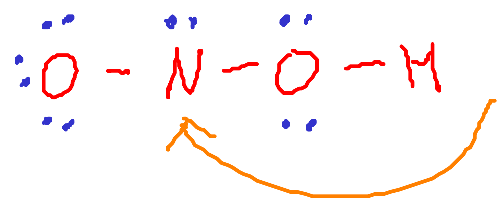
In oxyacids, the acidic hydrogen atoms are attached to OXYGEN atoms in the structure!

H: 1
N: 5
O: 6 x 2

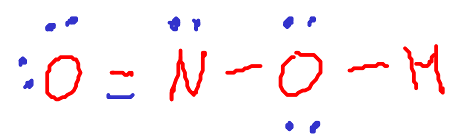
$18 e^-$



OXYACID ... we attach H to an oxygen atom, even though N is our central atom.



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



Here, the two oxygen atoms are in DIFFERENT chemical environments. The oxygen on the right is also bonded to a hydrogen atom, so we're not surprised that it bonds differently to nitrogen than the one on the left.

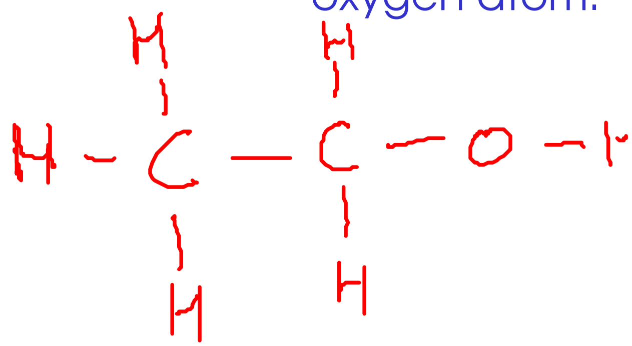
A DOT STRUCTURE FOR A LARGER MOLECULE

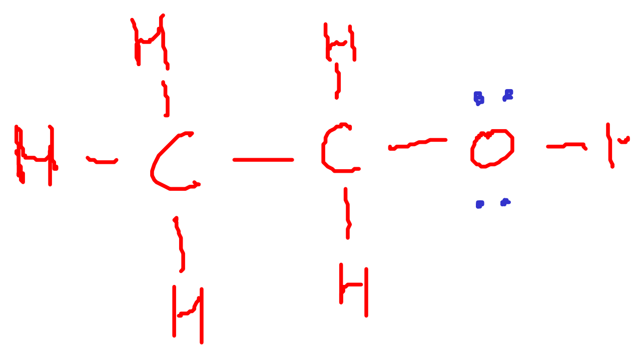
1. Count valence electrons
2. Pick central atom and draw skeletal structure
   - central atom is usually the one that needs to gain the most electrons!
   - skeletal structure has all atoms connected to center with single bonds
3. Distribute remaining valence electrons around structure, outer atoms first.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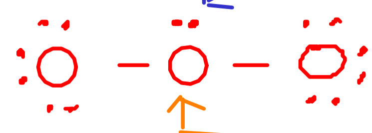
3. Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

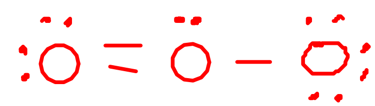
4. Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

O_3 (OZONE)



OUT OF ELECTRONS

Central oxygen has only six electrons

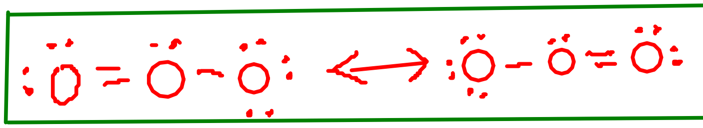


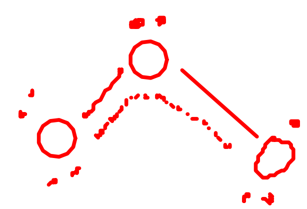
All atoms have a share in eight electrons!

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.

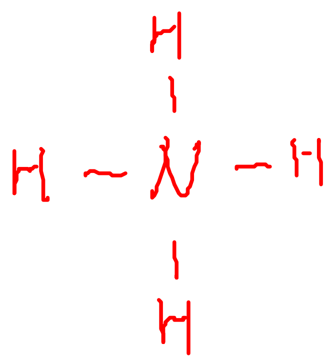
(4) Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

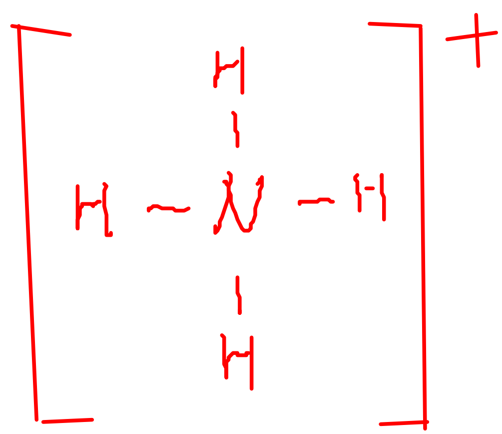
NH_4^+

N : 5
H : 1 x 4
———
9
− 1
———
8

An ODD number of electrons? Lewis structure for molecule generally have even numbers of electrons!

Subtract an electron, since ammonium ion has a positive (+1) charge.

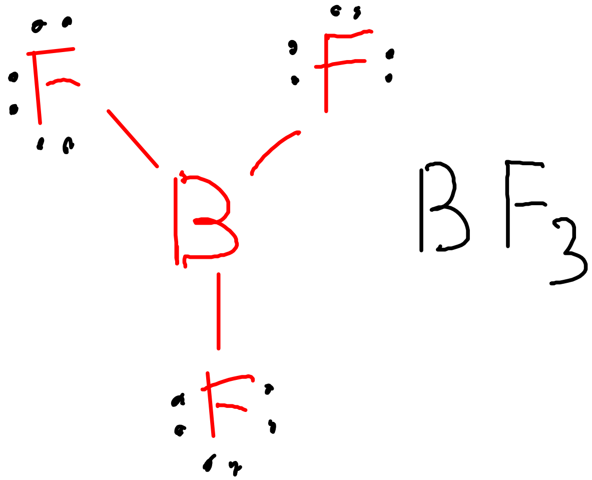




Draw brackets around the structure, and indicate the overall charge at the upper right - just like we usually do with ions.

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!

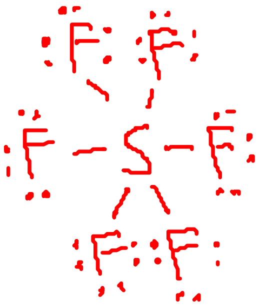
- Any atom in period three or greater can do this. SULFUR and PHOSPHORUS compounds commonly do this!

  ... 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: 7x6
48

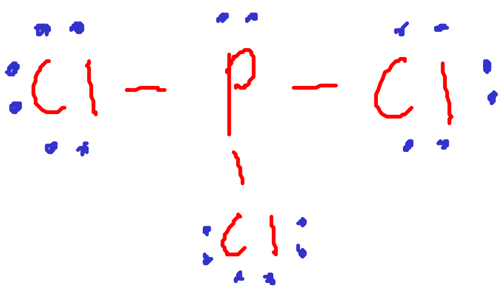
- The central SULFUR atom has a share in TWELVE total electrons, not eight!

- 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

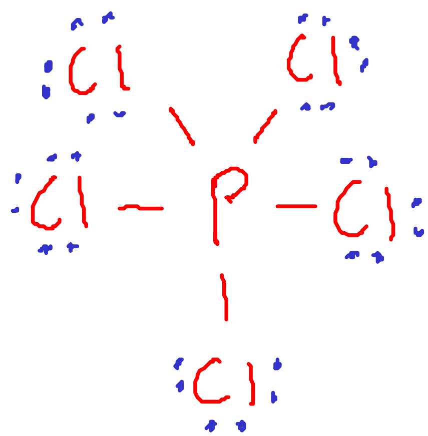
P: 5
Cl: 7x3 = 21
26



This structure obeys the octet rule.

PCl_5

P: 5
Cl: 7x5 = 35
40



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