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.

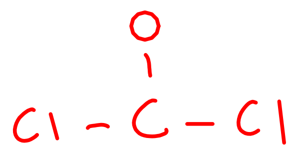
(4) Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

$COCl_2$

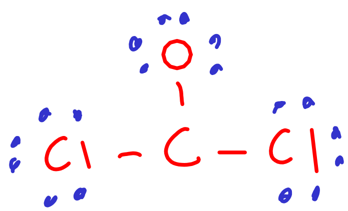
C : 1 x 4
O : 1 x 6
Cl : 2 x 7 = 14

24 valence electrons

Pick CARBON as central atom. Choose C because it needs more electrons to get an octet (4) than the other two elements (O needs 2, Cl needs 1).

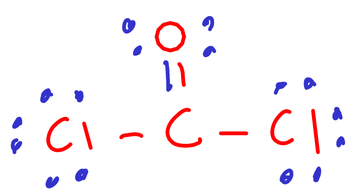


<-- Skeletal structure



Distributed electrons starting on outer atoms, stop when we reached 24 (our initial count)

Problem: We don't have enough electrons around C (6, not 8). How to fix? Make a double bond by reallocating one of the lone pairs. Which? Pick O, since it needed to gain two more electrons initially and should be capable of forming two bonds to do it.



Adding the double bond to the structure fixes this molecule!

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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.

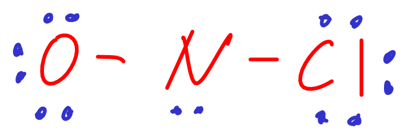
NOCl

N : 1 x 5
O : 1 x 6
Cl : 1 x 7

18 e^-

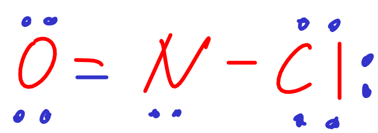
Pick N for central atom (needs more electrons than either O or Cl)

<- skeletal structure



We ran out of space on the outer atoms while we still had two electrons left, so the last pair went on N.

Even with the pair, N doesn't have enough electrons (6 instead of 8). How to fix? Make a double bond by reallocating a pair of electrons from oxygen (same reasoning as last example)



This structure has all atoms satisfied.

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.

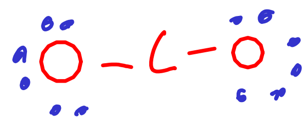
4. Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

CO_2

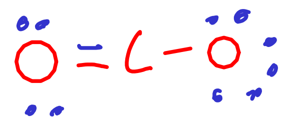
C: 1 × 4
O: 2 × 6

16 e^-

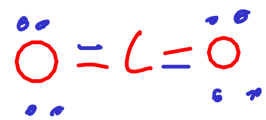
Pick C for central atom.



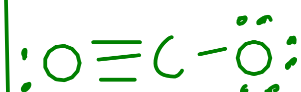
C has a share in only four valence electrons!



... now 6



A second double bond fixes this structure!



What about this structure?

We don't think this structure is correct because it make two atoms of the same element do vastly different things (single bond vs triple bond) when they are put into the same situation (both bonding to a carbon atom and nothing else)

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

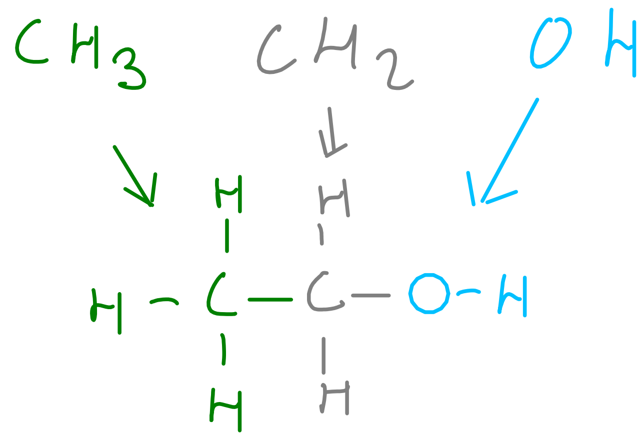
3. Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

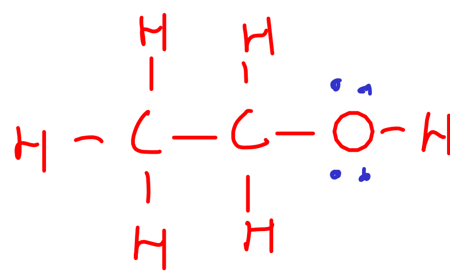
4. Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

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.





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.

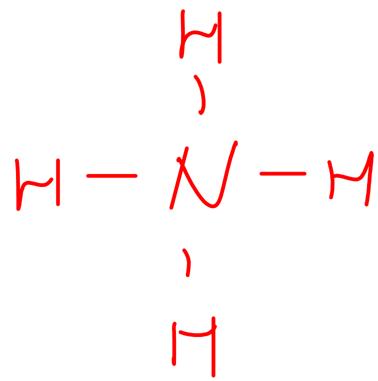
NH_4^+

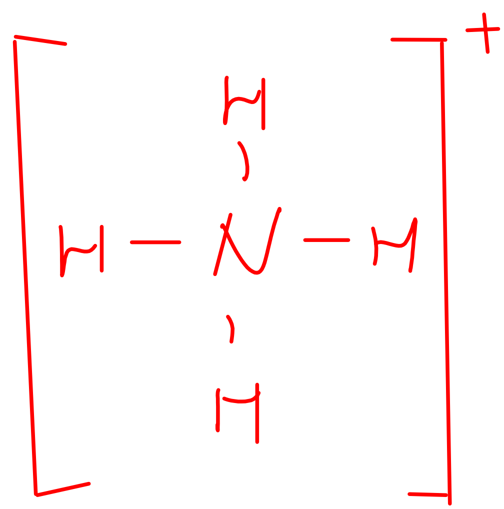
N: 1x5
H: 4x1

9 valence e^-
$-1e^-$ (+1 charge)

$8e^-$

Add or subtract valence electrons to account for the charge on the ion!





Indicate charge on ion by putting the structure in brackets and putting charge at upper right.

A DOT STRUCTURE FOR A MOLECULE WITH DELOCALIZED BONDS

(1) Count valence electrons

(2) Pick central atom and draw skeletal structure

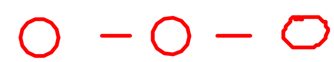
- central atom is usually the one that needs to gain the most electrons!
- skeletal structure has all atoms connected to center with single bonds

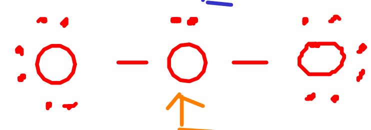
(3) Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

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

O_3 (OZONE) O: 3 x 6 = 18

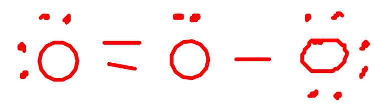
See Openstax p362-363





OUT OF ELECTRONS

Central oxygen has only six electrons

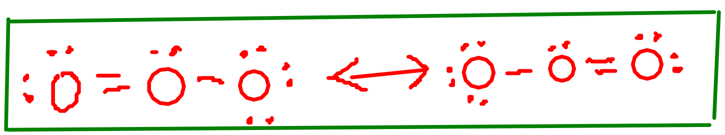


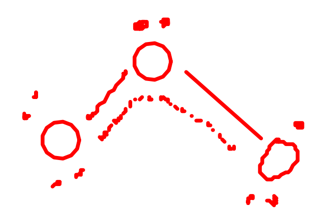
All atoms have a share in eight electrons!

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.

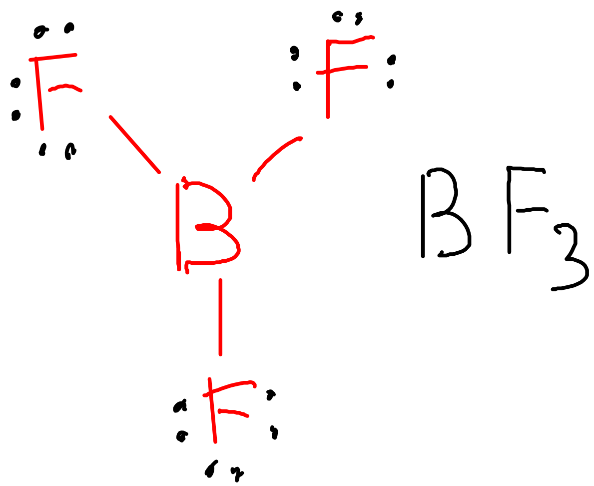




The structures in the green box are called RESONANCE STRUCTURES. The "real" structure of ozone is an "average" of the two resonsnce structures. The "double bond" electrons in these structures are actually shared between all three oxygen atoms

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!

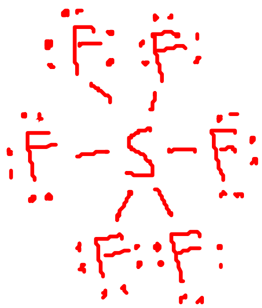
  ... these atoms have unfilled "d" orbitals that may participate in bonding!

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

EXAMPLES:

SF_6

S: 6
F: 7x6
48



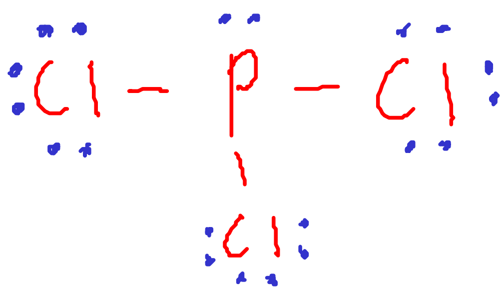
- The central SULFUR atom has a share in TWELVE total electrons, not eight!

- 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

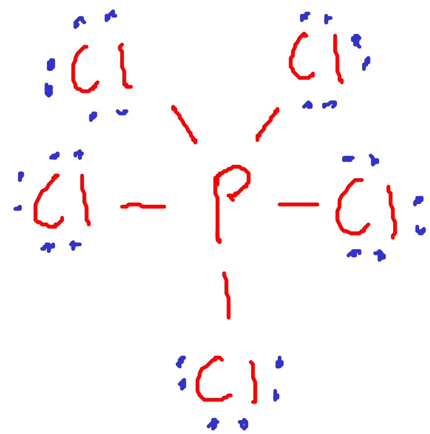
P : 5
Cl : 7x3 = 21
26



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.