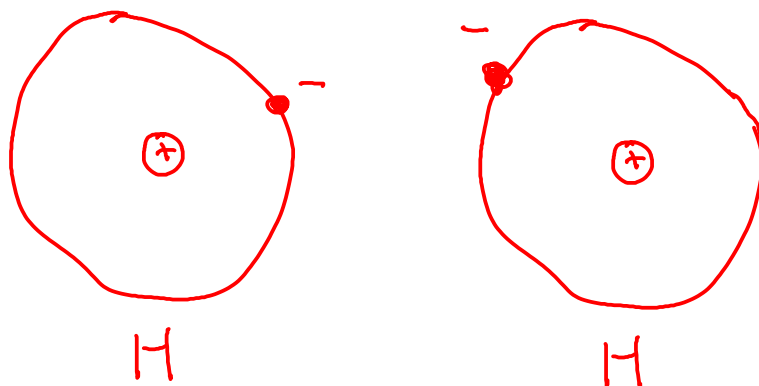


## MOLECULAR COMPOUNDS

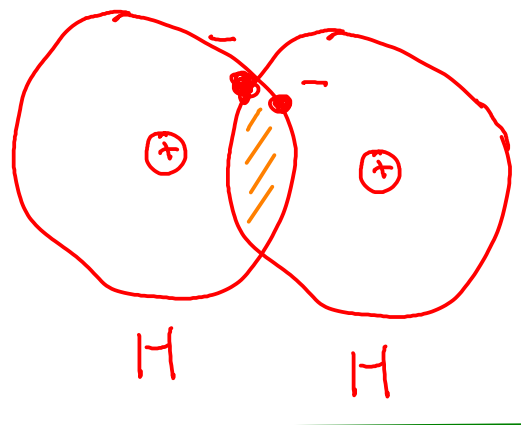
- Form when atoms SHARE electrons instead of transferring them. This results in the formation of MOLECULES ... groups of atoms held together by electron-sharing.

How might atoms SHARE electrons? By coming together close enough so that their atomic ORBITALS overlap each other:

This idea is called  
VALENCE  
BOND  
THEORY!



Each hydrogen atom has a single electron in a 1s orbital.

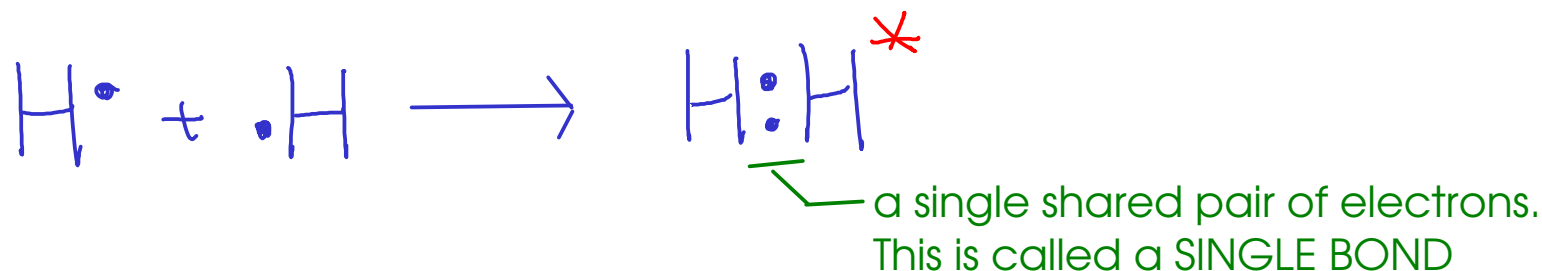


When hydrogen atoms come close enough to each other for these orbitals to OVERLAP, each hydrogen "sees" BOTH electrons, filling up the "s" orbitals of both atoms. This is a COVALENT BOND.

Co: together  
Valent: valence shells

This is the DIATOMIC MOLECULE,  $H_2$

... so how would this look using dot notation?

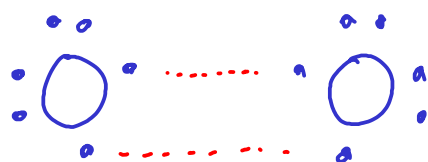


In dot structures, SHARED PAIRS of electrons are often written as DASHES to make the structures look neater.



\* Why doesn't hydrogen end up with eight electrons? Because hydrogen has only the first shell, which contains only a single "s" subshell (NO "p" subshell). This "s" subshell is full with two electrons, and that's all hydrogen needs to get.

Let's look at OXYGEN ...



We know that oxygen exists in air as the diatomic molecule  $O_2$



The oxygen atoms share TWO pairs of electrons. This is called a DOUBLE BOND

OR

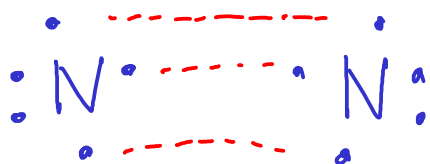


Each oxygen atom has a share in eight electrons!

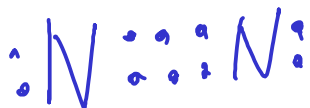
A few notes on the double bond:

- ① - For atoms to share more than one pair of electrons, they have to move closer to one another than they would if they were only sharing one pair of electrons. This BOND DISTANCE is measurable!
- ② - It takes more energy to break a double bond between two atoms than it would to break a single bond between the same two atoms. This BOND ENERGY is also measurable!

Let's look at NITROGEN ...



We know that nitrogen exists in air as the diatomic molecule  $N_2$



The nitrogen atoms share THREE pairs of electrons. This is called a TRIPLE BOND

OR



Nitrogen gas is fairly inert ... it's hard to break the triple bond in nitrogen gas apart!

A few notes on the triple bond:

- ① - For atoms to share three pairs of electrons, they have to move closer to one another than they would if they were sharing one or two pairs of electrons. Triple bonds have the shortest BOND DISTANCE of all covalent bonds.
- ② - It takes more energy to break a triple bond between two atoms than it would to break either a single or double bond between the same two atoms. The triple bond has the largest BOND ENERGY of all three kinds of covalent 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.



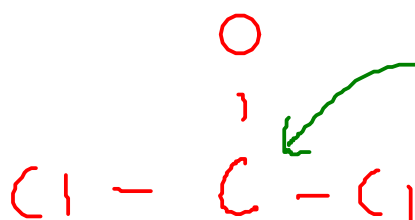
$$\text{C} - 1 \times 4$$

$$\text{O} - 1 \times 6$$

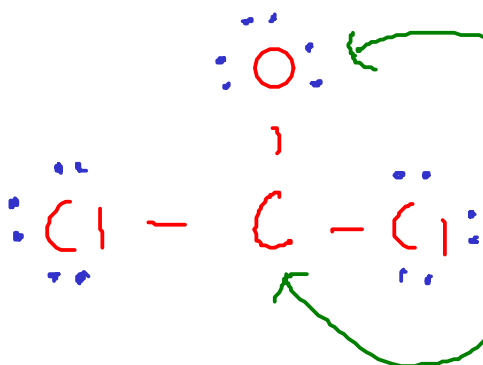
$$\text{Cl} - 2 \times 7$$

---


$$24 \text{ e}^-$$



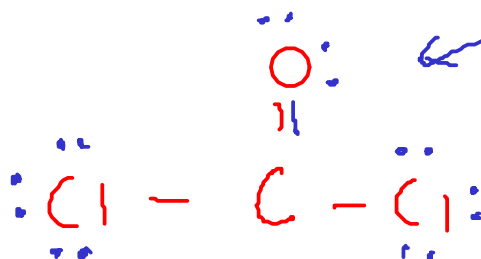
We choose CARBON as our central atom, since it needs to gain more electrons than oxygen or chlorine...



Distribute remaining electrons, then stop when you reach 24 total.

... but the central CARBON has a share in only 6 valence electrons!

To get carbon more electrons, we need to make a double bond ... but where do we get the electrons? Cl or O? Pick O, since it needed to gain more electrons than Cl and is more likely to bond twice.



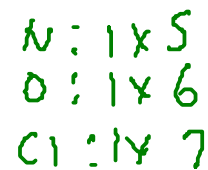
This structure has each atom with a share in eight valence electrons!

- Count valence electrons
- 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

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

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



We pick NITROGEN as central atom, since it needs more electrons than O or Cl...



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

Even with the lone pair, nitrogen still has only six valence electrons. We'll need a double bond! Like before, we'll pick oxygen to share a second pair of electrons.



This structure has all atoms with eight valence electrons!

① Count valence electrons

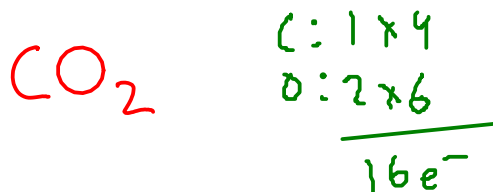
② Pick central atom and draw skeletal structure

- 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.



$\text{O} - \text{C} - \text{O}$  Use carbon as central atom

$\text{:}\ddot{\text{O}} - \text{C} - \ddot{\text{O}}\text{:}$  ... but carbon has only four valence electrons here!

$\text{:}\ddot{\text{O}} = \text{C} - \ddot{\text{O}}\text{:}$  ... and now six

$\text{:}\ddot{\text{O}} = \text{C} = \ddot{\text{O}}\text{:}$  Adding a second double bond brings carbon up to eight valence electrons!

$\text{:}\ddot{\text{O}} \equiv \text{C} - \ddot{\text{O}}\text{:}$  The two oxygen atoms are in an identical environment and should bond the same way.

This structure also says one oxygen is closer to the central carbon than the other. (Experimentally, we find that there is only one bond distance in carbon dioxide ... which is consistent with the double bond structure!)



① Count valence electrons

② Pick central atom and draw skeletal structure

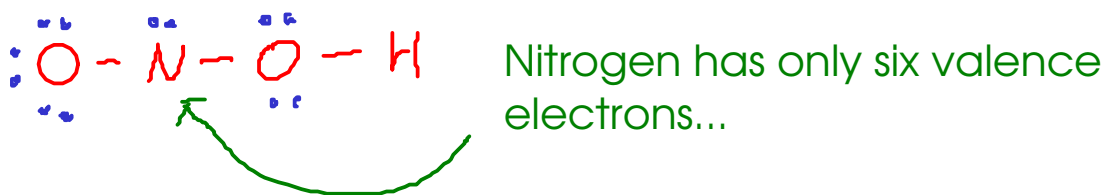
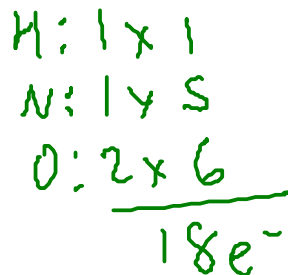
- central atom is usually the one that needs to gain the most electrons!
- skeletal structure has all atoms connected to center with single bonds

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.



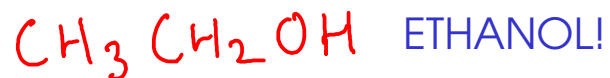
In oxyacids, the acidic hydrogen atoms are attached to OXYGEN atoms in the structure!



These two oxygen atoms are in different environments, so the one on the right isn't expected to bond EXACTLY like the one on the left/

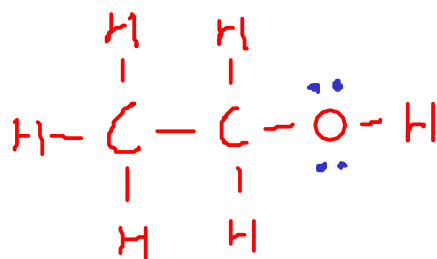
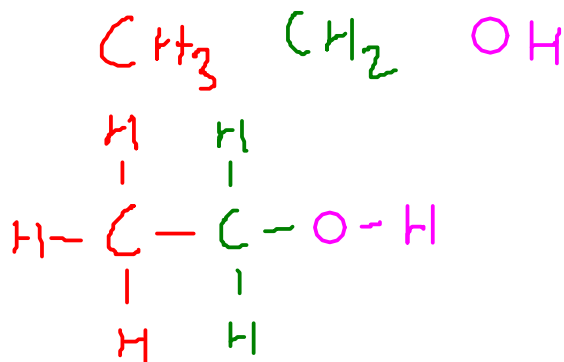
## A DOT STRUCTURE FOR A LARGER MOLECULE

- 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.



$$\begin{array}{l|l} \text{C} : 4 \times 2 = 8 & \\ \text{H} : 1 \times 6 = 6 & \\ \text{O} : 6 \times 1 = 6 & \\ \hline & 20 \end{array}$$

This formula gives us a hint to the structure of ethanol. Ethanol has THREE central atoms chained together.



## A DOT STRUCTURE FOR A MOLECULE WITH DELOCALIZED BONDS

$$O = 3 \times 6 = 18$$

See text, 9.7  
p 356-357

① Count valence electrons

② Pick central atom and draw skeletal structure

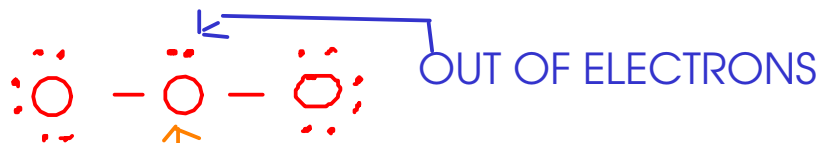
- central atom is usually the one that needs to gain the most electrons!

- 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)



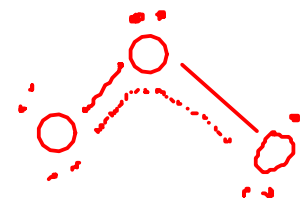
Central oxygen has only six electrons



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 resonance structures. The "double bond" electrons in these structures are actually shared between all three oxygen atoms