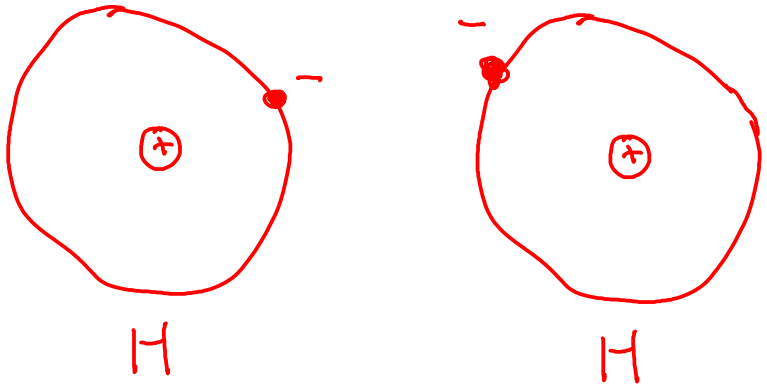
MOLECULAR COMPOUNDS

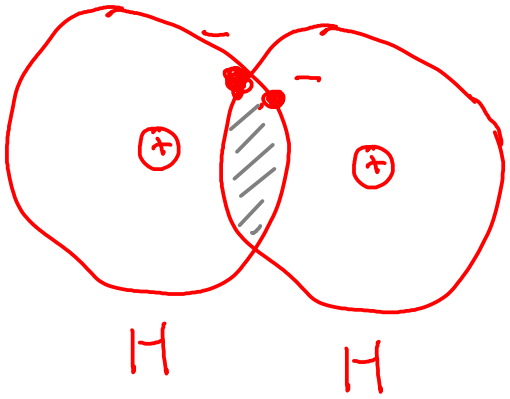
- Form when atoms SHARE electrons instead of transferring them. This results in the formation of MOLECULES ... groups of atoms held together by electron-sharing.

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



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

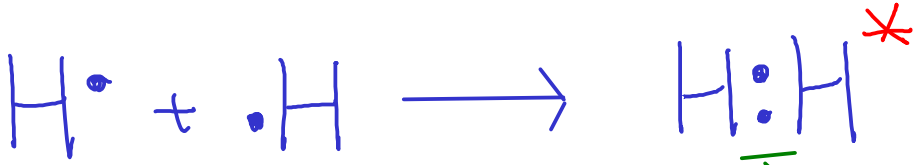
This idea is called
VALENCE BOND THEORY



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.

This is the DIATOMIC MOLECULE, H_2

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

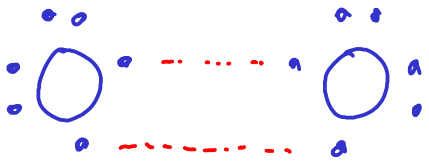


a shared pair of electrons. This is called a SINGLE BOND

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.

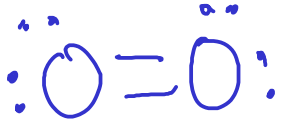
Let's look at OXYGEN ...



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



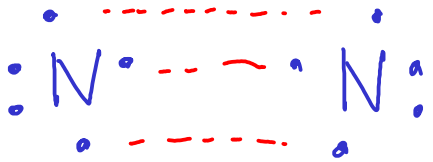
Each oxygen atom has a share in eight electrons!

A few notes on the double bond:

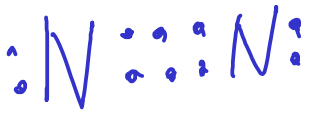
1. - For atoms to share more than one pair of electrons, they have to move closer to one another than they would if they were only sharing one pair of electrons. This BOND DISTANCE is measurable!

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.



OR

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

The STABILITY of the nitrogen molecule (in other words, its relative inertness compared to molecules like hydrogen and oxygen) is probably due to the triple bond.

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.

SO FAR, we've seen that ...

1. Atoms may share one, two, or three pairs of electrons.

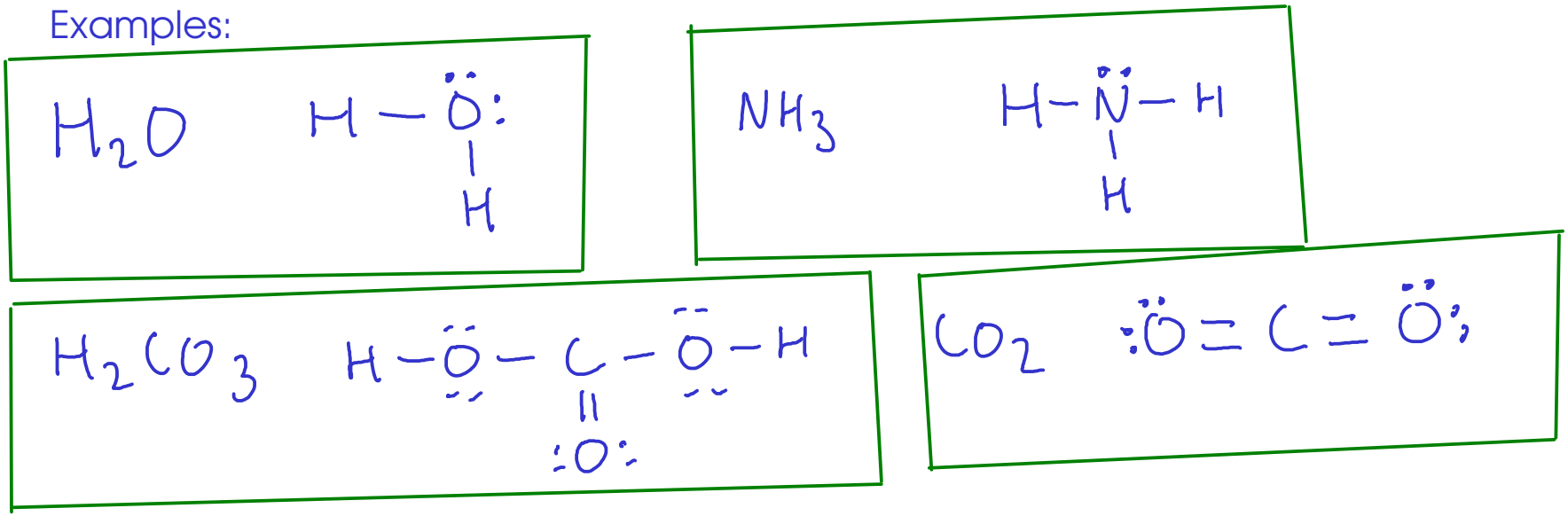
2. Atoms will usually share enough electrons so that each atom ends up with a share in EIGHT electrons - the "octet rule"

   - HYDROGEN will only end up with two electrons!

   - Some other atoms may end up with more or less than eight electrons ... but we won't worry about those in CHM 101!

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

Examples:



DRAWING DOT STRUCTURES FOR SIMPLE MOLECULES

1. Count valence electrons

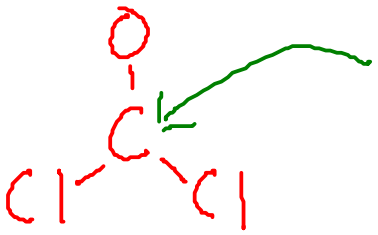
2. Pick central atom and draw skeletal structure
   - central atom is usually the one that needs to gain the most electrons!
   - skeletal structure has all atoms connected to center with single bonds

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

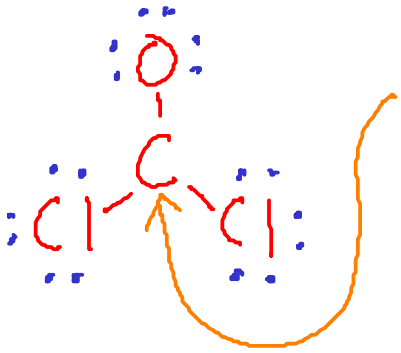
4. Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

$COCl_2$

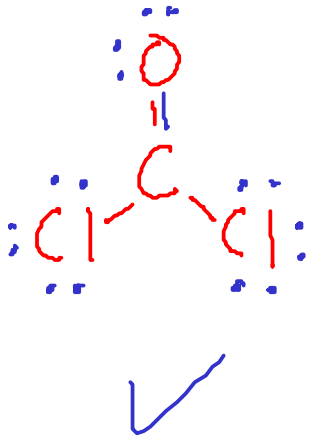
C : 4
O : 6
Cl : 2x7 = 14
24 electrons



We pick CARBON as the central atom, because it needs to gain four more electrons - more than either oxygen or chlorine. Attach the other atoms to carbon using single bonds!



But the CARBON ATOM IN THE CENTER has a share in only SIX electrons, not eight!



Where do we put the double bond? We choose OXYGEN, since it originaly needed to gain TWO electrons - suggesting that it might form two bonds instead of one, unlike the chlorine atoms which need only one more electron!

1. Count valence electrons

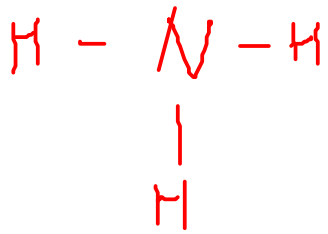
2. Pick central atom and draw skeletal structure
   - central atom is usually the one that needs to gain the most electrons!
   - skeletal structure has all atoms connected to center with single bonds

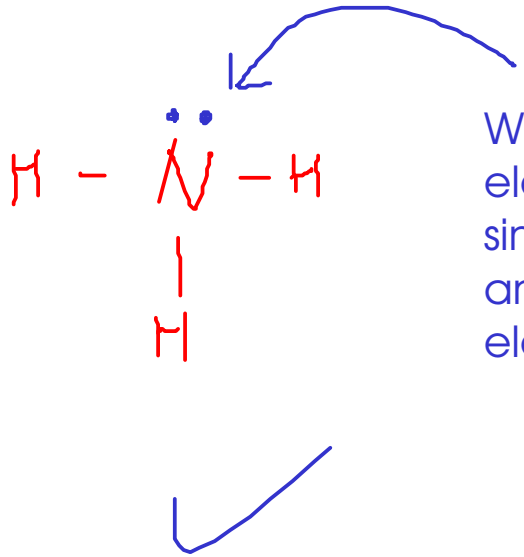
3. Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

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

NH_3

N: 5
H: 3 x 1 = 3
8 electrons





We must put the remaining TWO electrons onto NITROGEN, since HYDROGEN can't take any more than two 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.

HCN

H: 1
C: 4
N: 5
10 electrons

H - C - N

H - C - N:

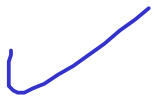
... but CARBON has a share in only FOUR electrons!

H - C = N:

... now carbon has a share in SIX electrons!

H - C ≡ N:

With a TRIPLE BOND between nitrogen and carbon, carbon finally has a share in eight electrons.



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.

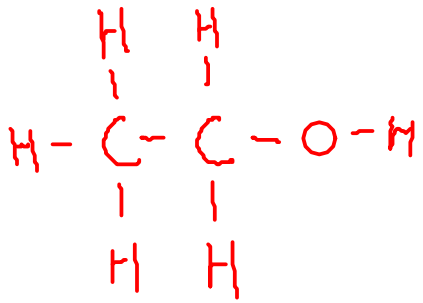
4. Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

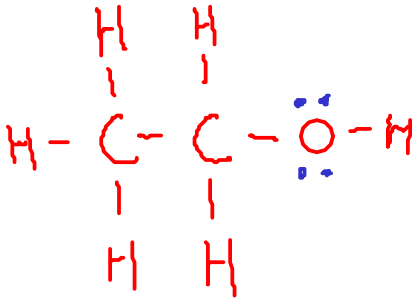
CH_3CH_2OH ← ETHANOL

C 2 x 4 = 8
H 6 x 1 = 6
O 6 = 6
20 electrons

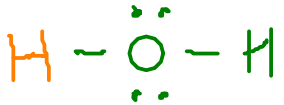
This molecule has three "parts", and three "central atoms"!

CH_3 CH_2 OH





Where do the remaining electrons go? The only place we can put them is on the oxygen atom, which leaves us with this structure!



WATER

The ALCOHOLS, like ethanol and methanol and isopropanol mix very well with water.

Small-molecule alcohols dissolve very well in water because they're structurally similar to water!

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.

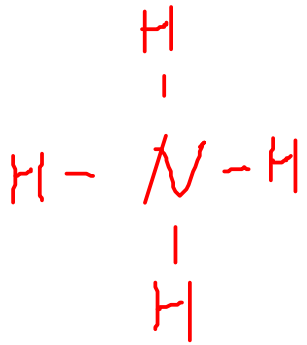
4. Check octet rule - each atom should have a share in 8 electrons (H gets 2). if not, make double or triple bonds.

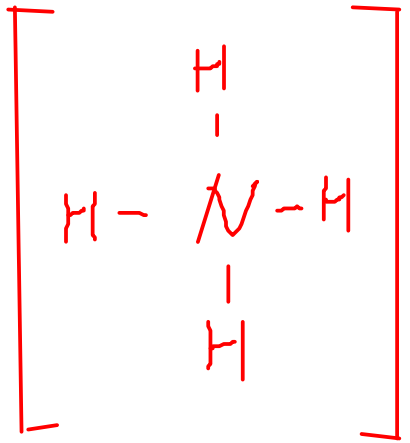
NH_4^+

N: 1 x 5
H: 4 x 1
9 electrons
−1
8 electrons ✓

Wait ... an ODD number of electrons?

Charge of +1 ... subtract one electron!





We draw brackets around the ion and indicate the charge at the upper right - similar to how we indicate charge on other ions!