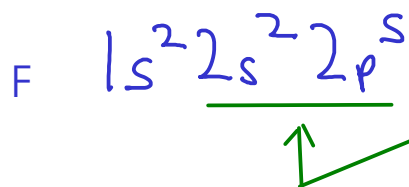
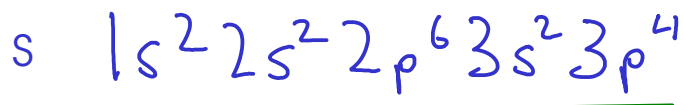


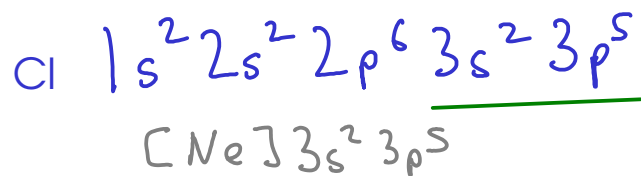
## EXAMPLES:



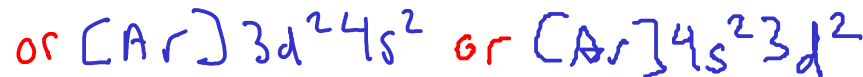
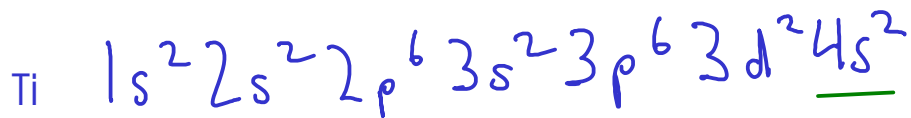
Remember - valence electrons are ALL of the electrons in the outermost SHELL (n)! More than one subshell (l) may be included in the valence electrons



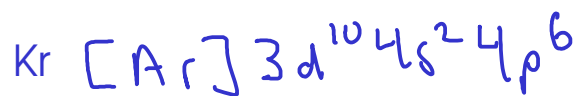
TITANIUM is a transition metal that commonly forms either +2 or +4 cations. The 4s electrons are lost when the +2 ion forms, while the 4s AND 3d electrons are lost to form the +4!



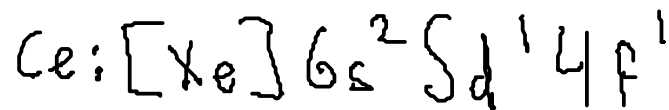
You can order the subshells in numeric order OR in filling order



Noble gas core notation. Use the previous noble gas on the table, then add the electrons that it doesn't have to the end.



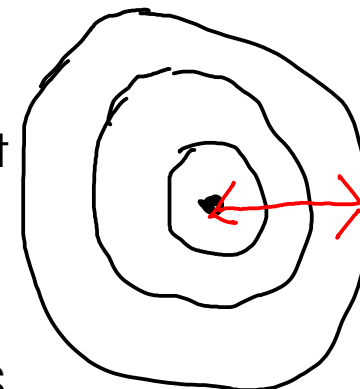
Sample f-block element



## PERIODIC TRENDS

### ATOMIC RADIUS

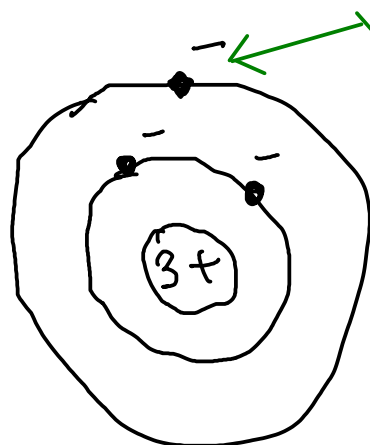
- The distance between the nucleus of the atoms and the outermost shell of the electron cloud.
- Relates to the size of the atom.
- As you go DOWN A GROUP ( ↓ ), the atomic radius INCREASES.



- Why? As you go down a group you are ADDING SHELLS!

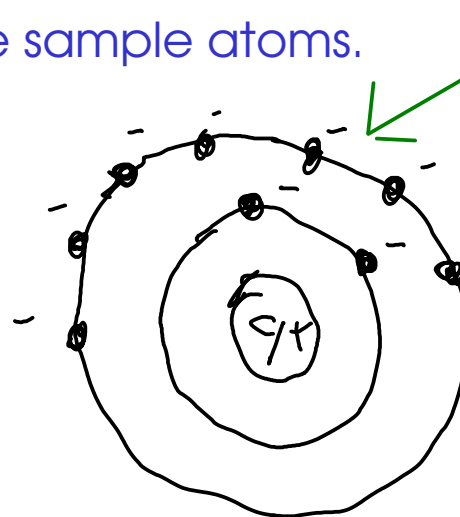
- As you go ACROSS A PERIOD ( → ), the atomic radius DECREASES

Why? Let's look at some sample atoms.



Outer electron sees an effective +1 charge (shielded from +3 nucleus by 2 electrons)

lithium  $1s^2 2s^1$



Outer electrons see an effective +7 charge (shielded from +9 nucleus by 2 electrons)

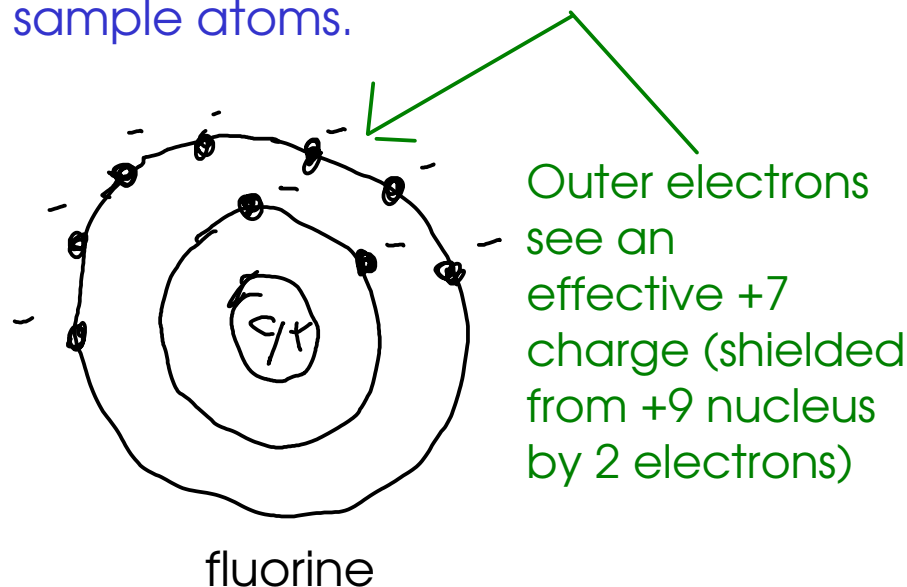
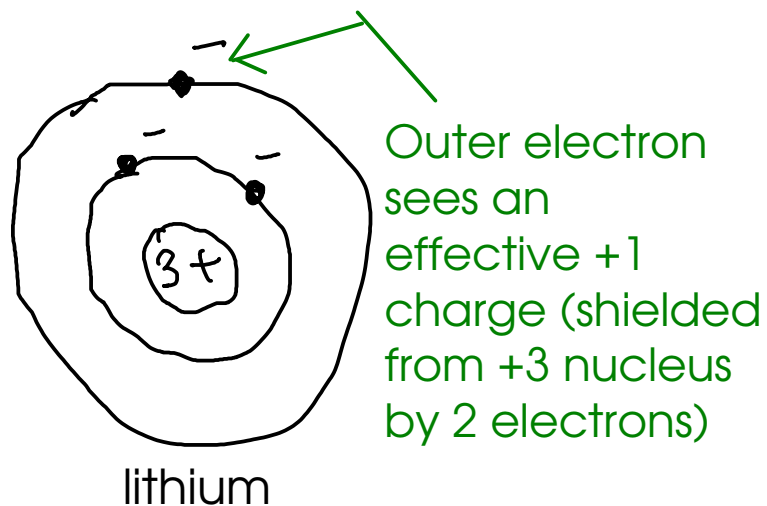
fluorine  $1s^2 2s^2 2p^5$

... so fluorine's outer shell is pulled closer to the nucleus than lithium's!

## (FIRST) IONIZATION ENERGY

- The amount of energy required to remove a single electron from the outer shell of an atom.
- Relates to reactivity for metals. The easier it is to remove an electron, the more reactive the metal.
- As you go DOWN A GROUP ( ↓ ), the ionization energy DECREASES.
  - Why? As you go down a group, you are ADDING SHELLS. Since the outer electrons are farther from the nucleus and charge attraction lessens with distance, this makes electrons easier to remove as the atoms get bigger!
- As you go ACROSS A PERIOD ( → ), the ionization energy INCREASES.

- Why? Let's look at some sample atoms.



... since fluorine's outer electrons are held on by a larger effective charge, they are more difficult to remove than lithium's.

## THE FIRST TWO PERIODIC TRENDS IN A NUTSHELL

LARGER  
IONIZATION  
ENERGYSMALLER  
RADIUS

IA H											IIIA IVA VA VIA VIIA					VIIIA He	
Li	Be											B	C	N	O	F	Ne
Na	Mg	IIIB	IVB	VB	VIB	VII B	VIII B		IB	IIB	Al	Si	P	S	Cl	Ar	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac*	Rf	Db	Sg	Bh	Hs	Mt	* "inner" transition metals go here								

LARGER  
RADIUSSMALLER  
IONIZATION  
ENERGY

## ELECTRON AFFINITY

- the electron affinity is the ENERGY CHANGE on adding a single electron to an atom.
  - Atoms with a positive electron affinity cannot form anions.
  - The more negative the electron affinity, the more stable the anion formed!
- General trend: As you move to the right on the periodic table, the electron affinity becomes more negative.

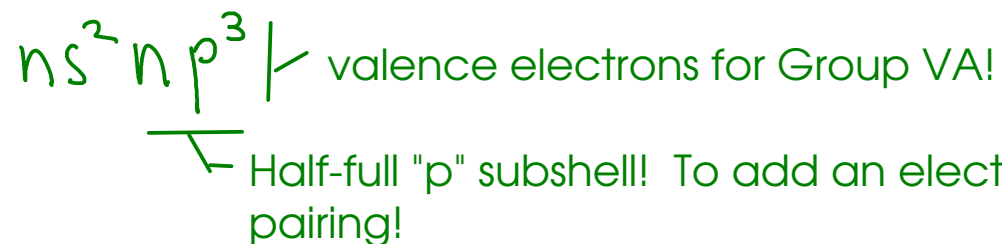
## EXCEPTIONS

- Group IIA does not form anions (positive electron affinity)!



- To add an electron, the atom must put it into a higher-energy (p) subshell.

- Group VA: can form anions, but has a more POSITIVE electron affinity than IVA



- Group VIIIA (noble gases) does not form anions



## CHEMICAL BONDS

- A CHEMICAL BOND is a strong attractive force between the atoms in a compound.

### TWO TYPES OF CHEMICAL BOND

Type	Held together by ...	Example
Ionic bonds	attractive forces between oppositely charged ions	sodium chloride
<u>Covalent</u> bonds	sharing of valence electrons between two atoms (sometimes more - "delocalized bonds")	water

Some compounds are held together by one type of bond, others (such as ionic compounds containing polyatomic ions) are held together by both!

... so how can you tell what kind of bond you have? You can use the traditional rules of thumb:

- Metal-Nonmetal bonds will be ionic
  - Nonmetal-nonmetal bonds are usually covalent
- Metalloids act like NONMETALS, here.

... but for better information about bonding, you can use ELECTRONEGATIVITY.

<p><b>ELECTRONEGATIVITY:</b> -A number describing how tightly an atom will hold bonded electrons.</p>	<p>Openstax p 346: Chart of electronegativities</p>
---	---

... in other words, how ELECTRON-GREEDY an atom is!

Bonds with ...	are ...	Examples
Little or no difference in electronegativity between atoms	NONPOLAR COVALENT	C-C, C-H, etc.
Larger differences in electronegativity between atoms	* POLAR COVALENT	H-F, C-F, C-Cl, etc.
Very large differences in electronegativity between atoms	IONIC	NaCl, KBr, etc.

\* A POLAR bond is a bond where electrons are shared unevenly - electrons spend more time around one atom than another, resulting in a bond with slightly charged ends

- You may look up electronegativity data in tables, but it helps to know trends!

INCREASING  
ELECTRO-  
NEGATIVITY

	IA	IIA											IIIA	IVA	VA	VIA	VIIA
2	Li	Be											B	C	N	O	F
3	Na	Mg	IIIB	IVB	VB	VIB	VII B	VIII B	IB	IIB			Al	Si	P	S	Cl
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I
6	Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At
7	Fr	Ra	Ac*	Rf	Db	Sg	Bh	Hs	Mt	*"inner" transition metals go here							

### Notes:

- ① - FLUORINE is the most electronegative element, while FRANCIUM is the least!
- ② - All the METALS have low electronegativity
- ③ - HYDROGEN is similar in electronegativity to CARBON

... so C-H bonds are NONPOLAR

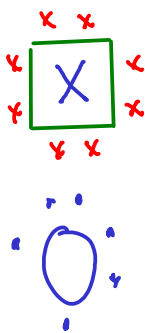


## LEWIS NOTATION / ELECTRON-DOT NOTATION

- Lewis notation represents each VALENCE electron with a DOT drawn around the atomic symbol. Since the valence shell of an atom contains only "s" and "p" electrons, the maximum number of dots drawn will be EIGHT.

- To use electron-dot notation, put a dot for each valence electron around the atomic symbol. Put one dot on each "side" of the symbol (4 sides), then pair the dots for atoms that have more than four valence electrons.

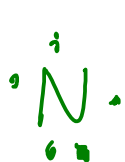
examples:



More examples



Which "side" you draw the dots on isn't important, as long as you have the right number of electrons and the right number of "pairs"



... are all equivalent!

To draw a dot structure for an atom, you need to know HOW MANY valence electrons it has! You can determine this simply from the periodic table.

The number of valence electrons equals the group number in the A/B group numbering system FOR "A" GROUPS!

	IA																	VIIIA
1	H	IIA										IIIA	IVA	VA	VIA	VIIA		He
2	Li	Be										B	C	N	O	F		Ne
3	Na	Mg	IIIB	IVB	VB	VIB	VII B	VIII B	IB	IIB		Al	Si	P	S	Cl		Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac*	Rf	Db	Sg	Bh	Hs	Mt									

2 valence electrons

1 valence electron

3 valence electrons

4 valence electrons

5 valence electrons

6 valence electrons

7 valence electrons

8 valence electrons (except helium!)

"octet rule"

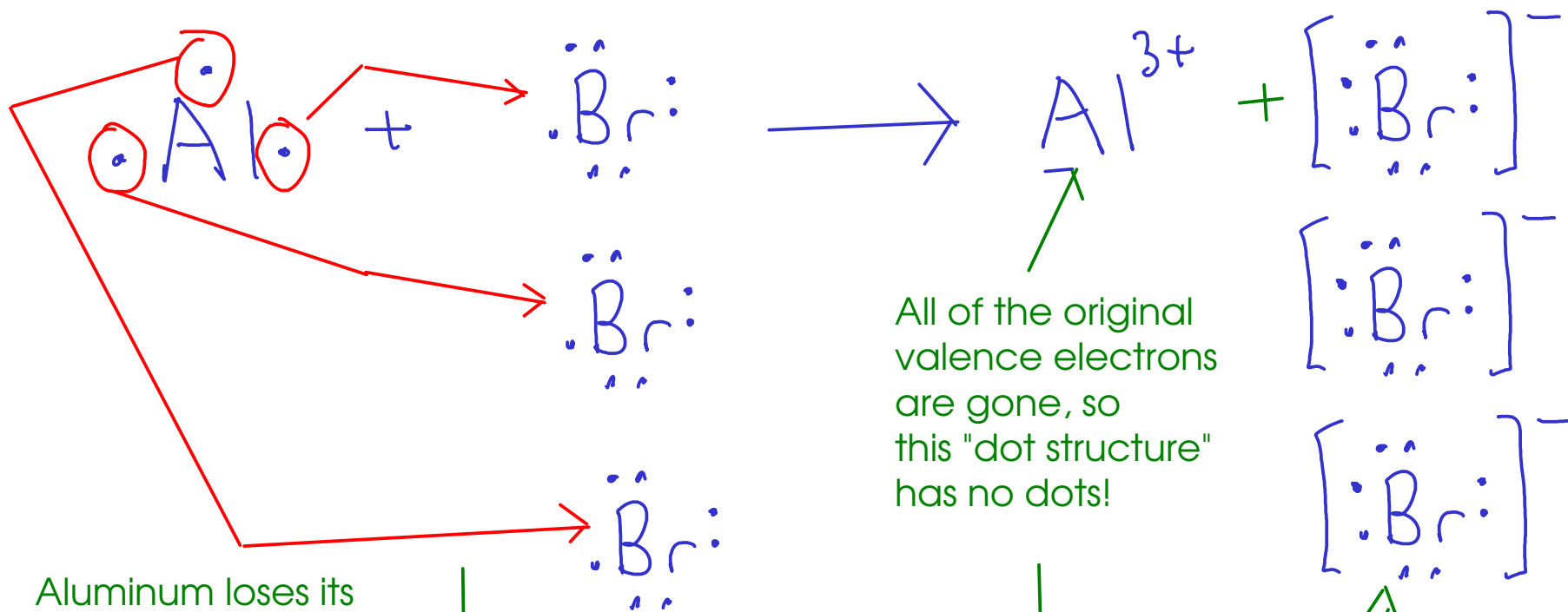
- a "rule of thumb" (NOT a scientific law) predicting how atoms will exchange or share electrons to form chemical compounds
- atoms will gain, lose, or share enough electrons so that they end up with full "s" and "p" subshells in their outermost shell.

- Why "octet"? An "s" subshell can hold two electrons, while a "p" subshell can hold six.  $2+6 = 8$

# IONIC COMPOUNDS

- When atoms react to form IONS, they often GAIN or LOSE enough electrons to end up with full "s" and "p" subshells.

example:



Aluminum loses its outer three electrons (in the 3s and 3p subshells) (leaving it with full 2s and 2p subshells).

Each bromine atom requires one more electron to get a total of eight outer electrons (full "s" and "p" subshells)

All of the original valence electrons are gone, so this "dot structure" has no dots!

Each bromide ion has eight outer electrons!

Aluminum is oxidized!

Bromine is reduced!

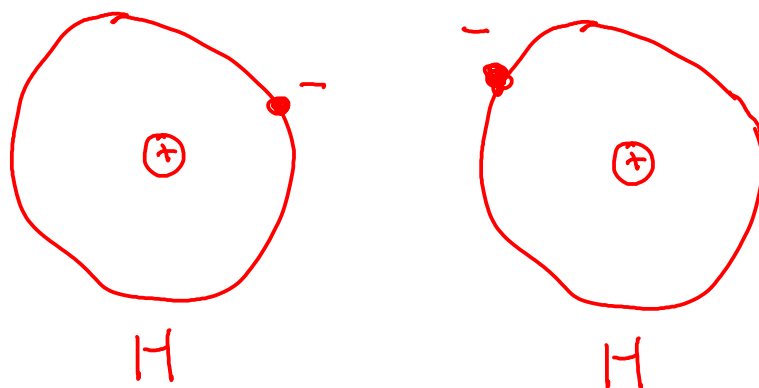
Redox reactions are much clearer when seen using dot notation!

## MOLECULAR COMPOUNDS

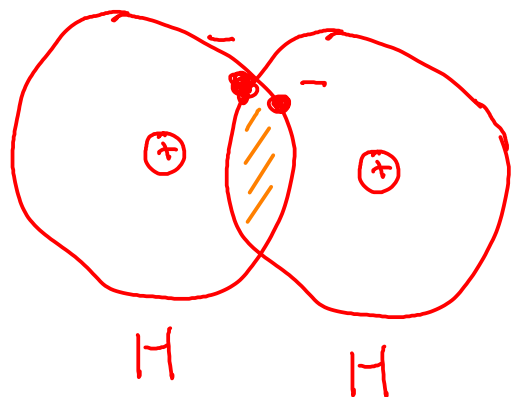
- Form when atoms SHARE electrons instead of transferring them. This results in the formation of MOLECULES ... groups of atoms held together by electron-sharing.

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.

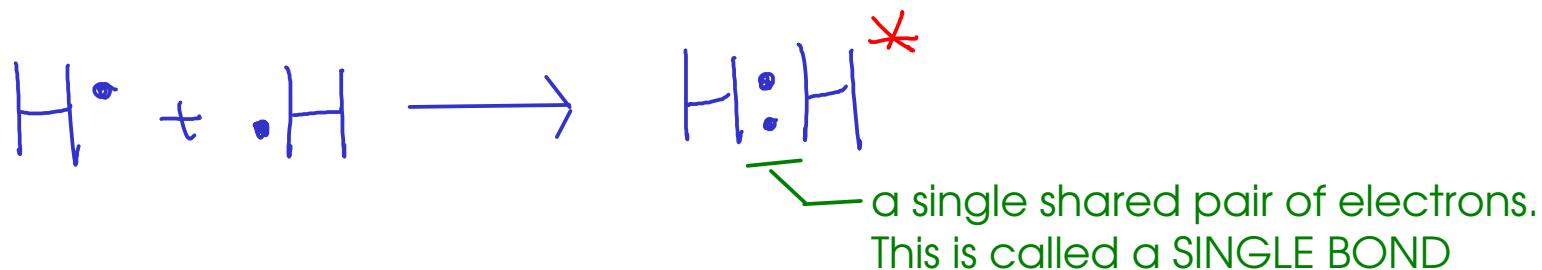


When hydrogen atoms come close enough to each other for these orbitals to OVERLAP, each hydrogen "sees" BOTH electrons, filling up the "s" orbitals of both atoms. This is a COVALENT BOND.

Co: together  
Valent: valence shells

This is the DIATOMIC MOLECULE,  $H_2$

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

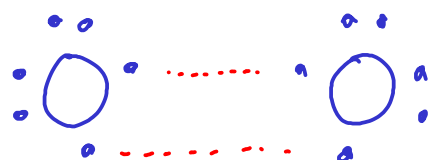


In dot structures, SHARED PAIRS of electrons are often written as DASHES to make the structures look neater.



\* 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

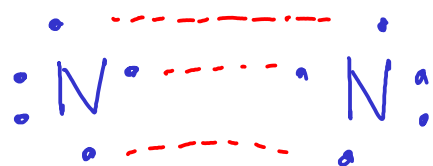


Each oxygen atom has a share in eight electrons!

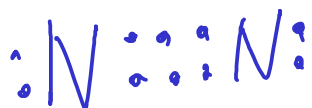
A few notes on the double bond:

- 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 LENGTH 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 STRENGTH 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 LENGTH 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 STRENGTH of all three kinds of covalent bonds.



SO FAR, we've seen that ...

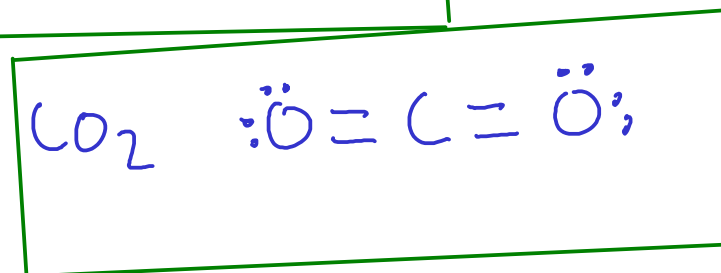
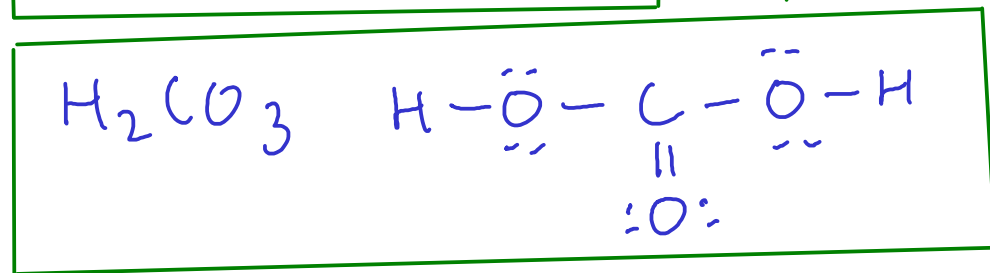
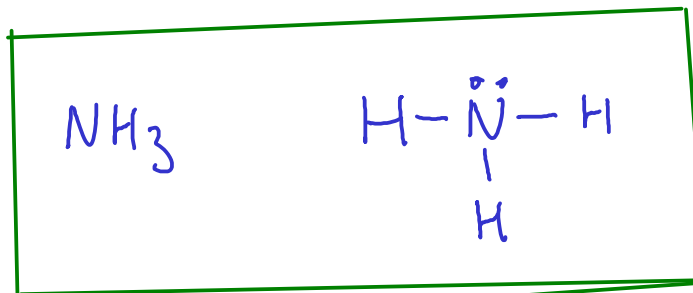
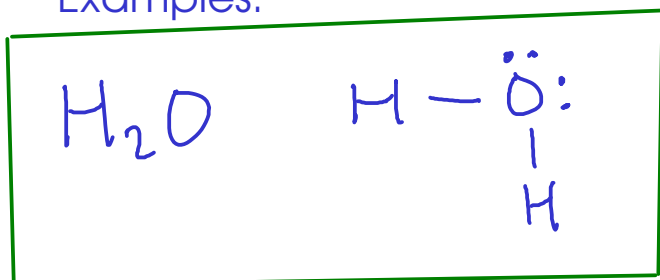
- ① Atoms may share one, two, or three pairs of electrons with a single other atom.
- ② Atoms will usually share enough electrons so that each atom ends up with a share in EIGHT electrons - the "octet rule"

- HYDROGEN will only end up with two electrons!

- Some other atoms may end up with more or less than eight electrons.

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

- 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

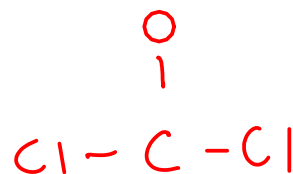
- Distribute remaining valence electrons around structure, outer atoms first. Follow octet rule until you run out of electrons.

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



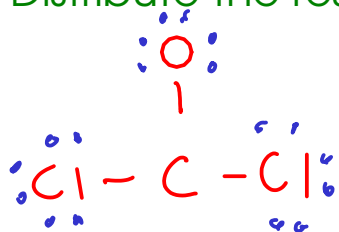
$$\begin{array}{r} \text{C: } 1 \times 4 \\ \text{O: } 1 \times 6 \\ \text{Cl: } 2 \times 7 = 14 \\ \hline 24 \text{ valence } e^- \end{array}$$

Choose CARBON as central atom, since it needs to gain FOUR MORE electrons to satisfy the octet rule. (Oxygen only needs two more, and chlorine needs one more!)



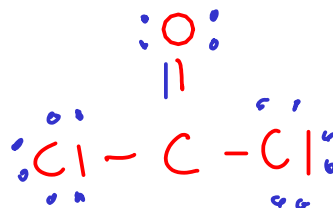
Draw skeletal structure.

Distribute the rest of the valence electrons.



Stop when you reach the total number of valence electrons (here, 24...)

But Carbon has a share in only six valence electrons. Fix it by taking a lone pair and making it a bonding pair with oxygen. Which? Pick OXYGEN, since it needed two electrons and is likely to form two bonds.



Making a double bond with oxygen fixes this structure.