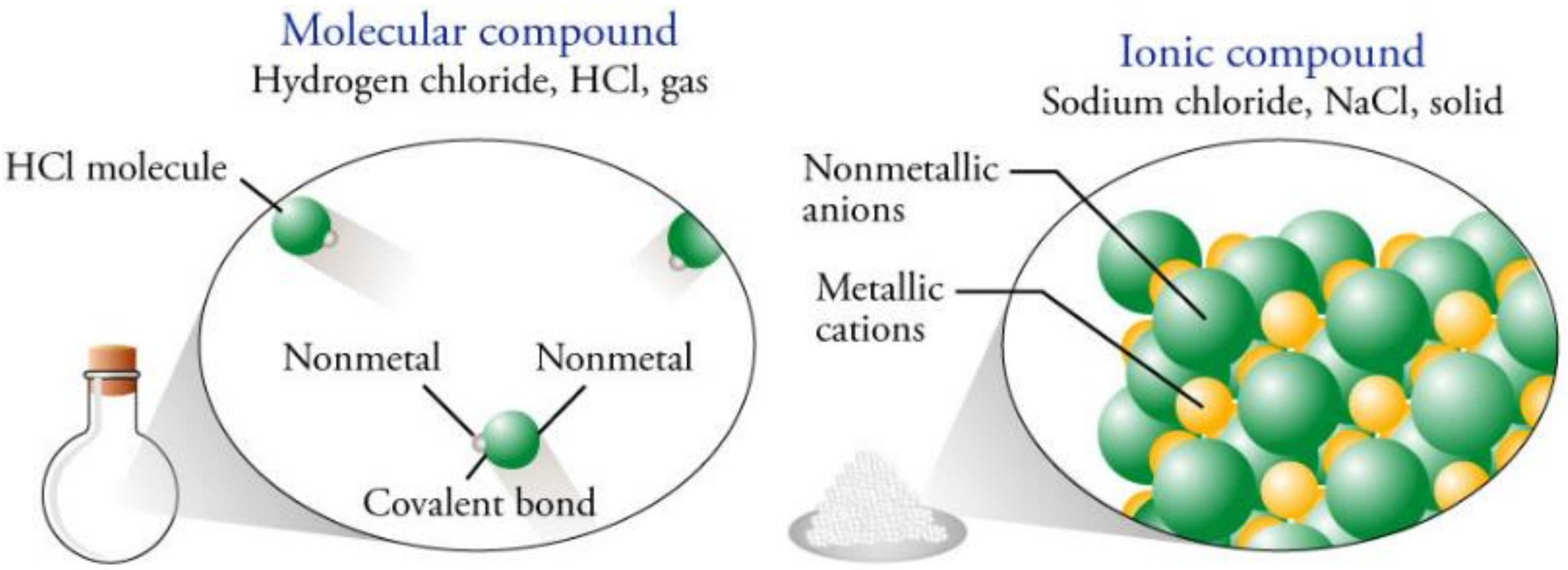
Molecular Compounds

- All nonmetallic atoms usually leads to all covalent bonds, which from molecules. These compounds are called ***molecular compounds***.



Periodic Table

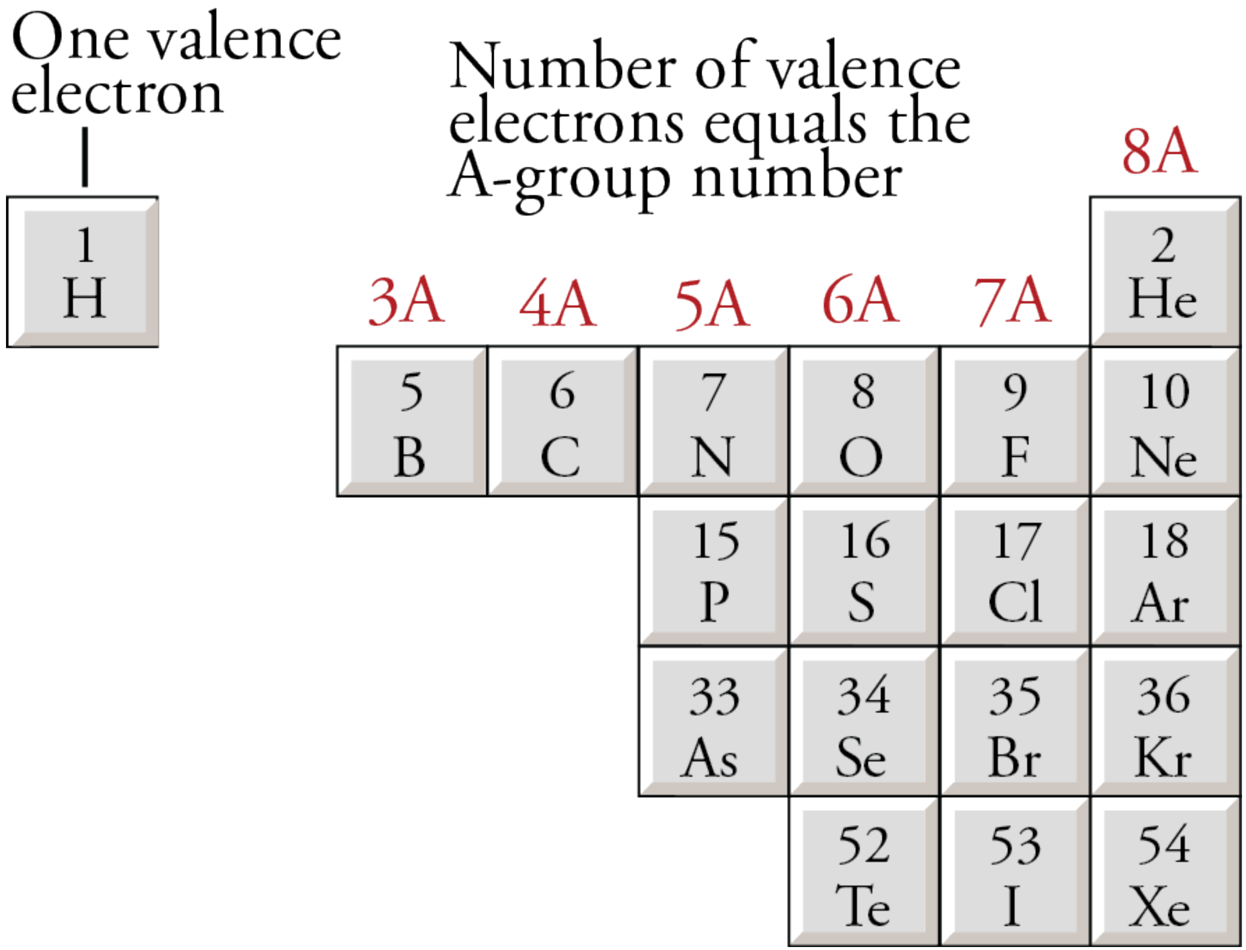
	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

6	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
7	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

Valence Electrons

- The valence electrons for each atom are the most important electrons in the formation of chemical bonds.
- The number of valence electrons for the atoms of each element is equal to the element's A-group number on the periodic table.

Valence Electrons and A-Group Numbers



Electron-Dot Symbols

- **Electron-dot symbols** show valence electrons.

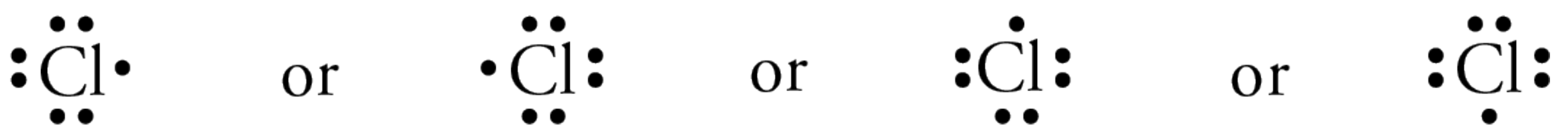
- The pairs of valence electrons in an electron dot symbol are called ***lone pairs***.

Drawing Electron-dot Symbols

- Think of each element symbol as having four sides: top, bottom, right, and left.
- Describe each valence electron with a dot.
- Add one dot to each side. If there are more than four valence electrons, pair the electrons already added.

Electron-dot Symbol for Chlorine

- The electron dot symbol for chlorine can have any one of the forms shown here.



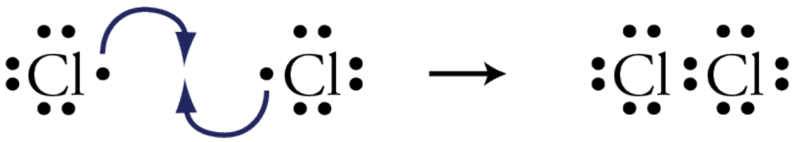
Octets of Electrons

- The very stable noble gas atoms other than helium have eight valence electrons, so there must be something stable about having an electron-dot symbol with eight dots.

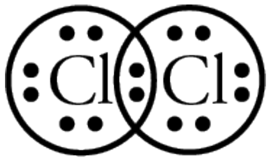
- For this reason, covalent bonds often form to pair unpaired electrons and give the atoms of the elements other than hydrogen and boron eight valence electrons (an octet of valence electrons) around them.

Formation of Cl_2

- Each chlorine atom has one unpaired valence electron, so our guideline suggests that it will form one covalent bond, and this bond can be to another chlorine atom.
- The unpaired electrons from the two chlorine atoms pair up to form a covalent bond.

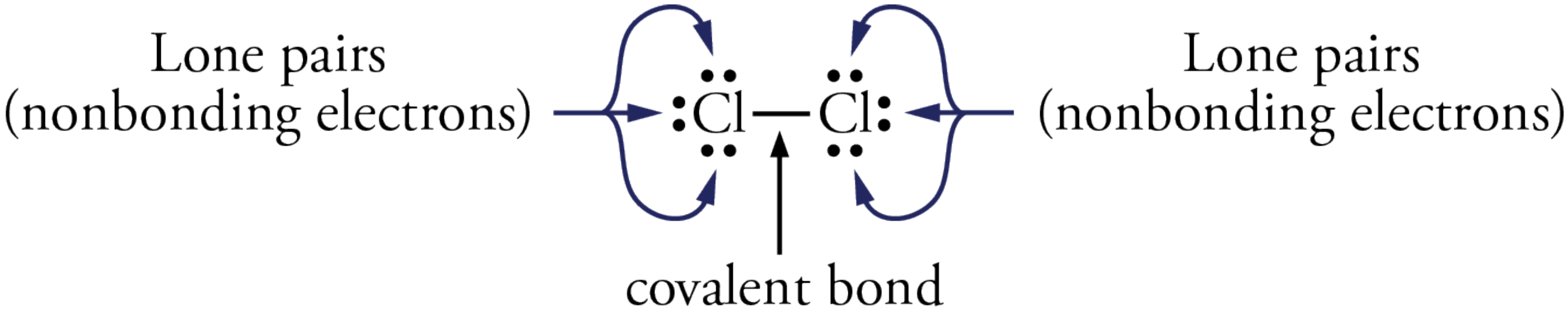


- Note that each chlorine atom now has an octet of eight electrons around it.



Lewis Structures

- ***Lewis structures*** represent molecules using element symbols, lines for bonds, and dots for lone pairs.

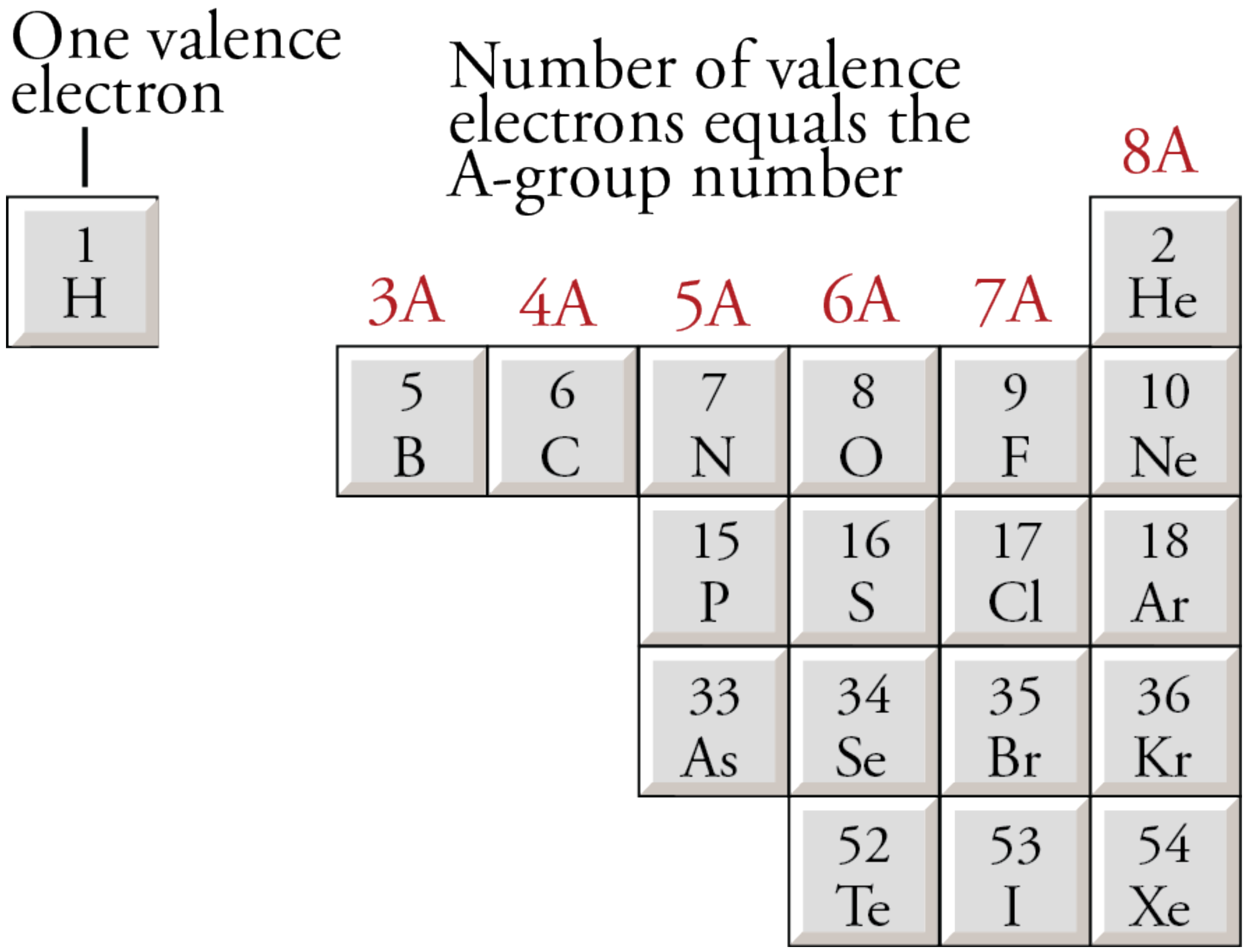


Bonding for Hydrogen

- Hydrogen atoms have only one electron, so they form one covalent bond.
- When a hydrogen atom forms a bond to a chlorine atom, they form hydrogen chloride, HCl.

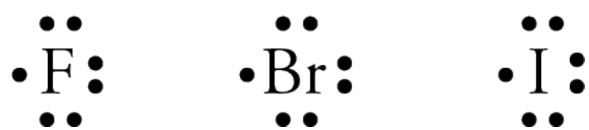
- Note that the chlorine atom has its octet, but the hydrogen atom only has two electrons total.

Valence Electrons and A-Group Numbers

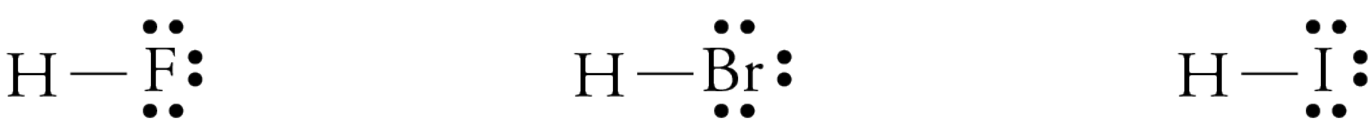


Bonding for the Halogens

- All of the halogens in group 7A have seven valence electrons and the following electron-dot symbols.

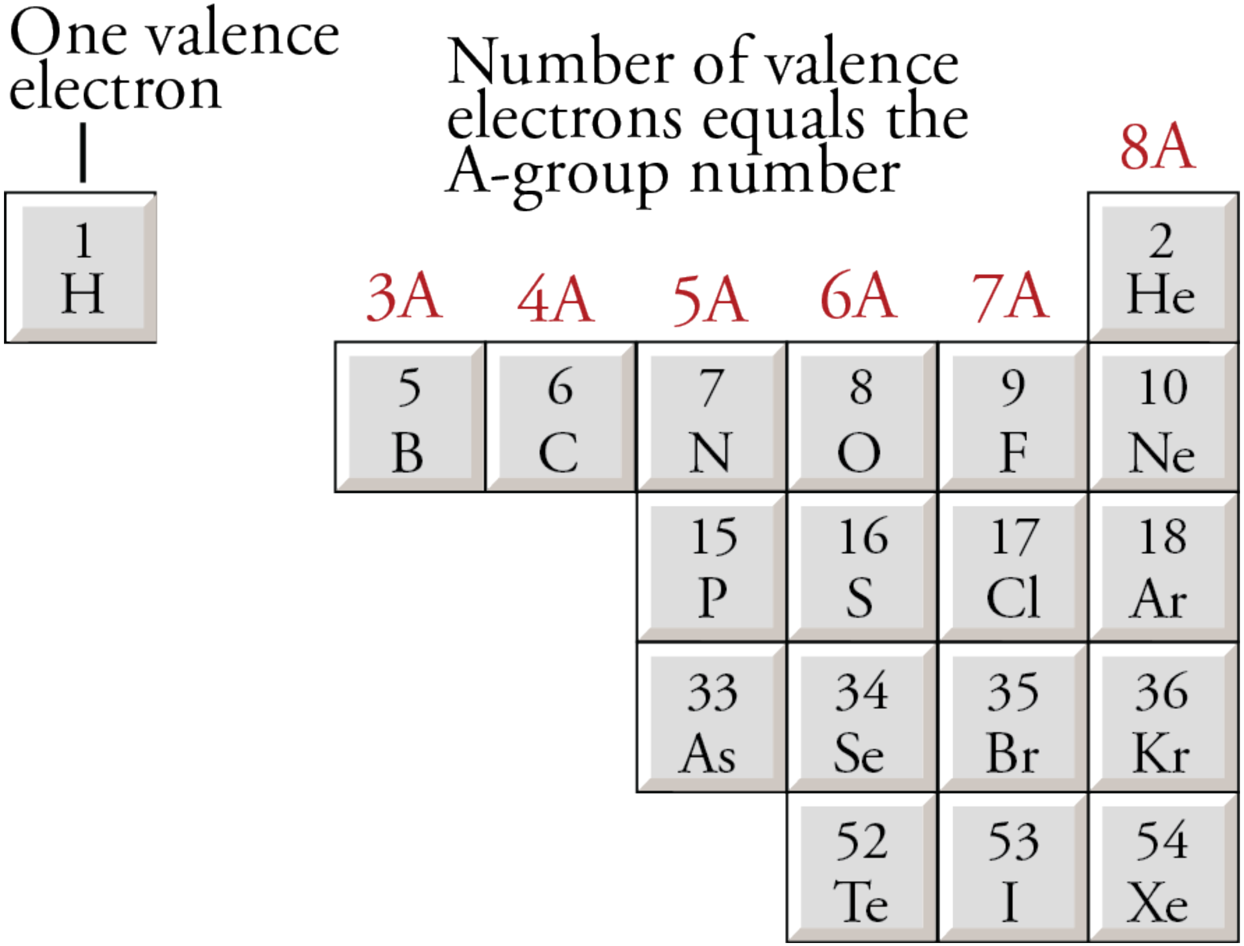


- We expect them to form one covalent bond and have three lone pairs.



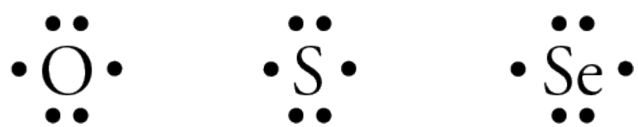
Hydrogen fluoride Hydrogen bromide Hydrogen iodide

Valence Electrons and A-Group Numbers

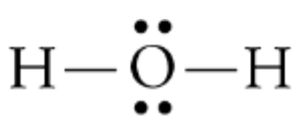


Bonding for Oxygen, Sulfur, and Selenium

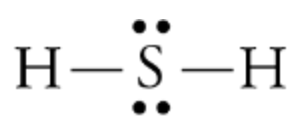
- O, S, and Se are in group 6A, so their atoms have six valence electrons and the following electron-dot symbols.



- We expect them to form two covalent bonds and have two lone pairs.

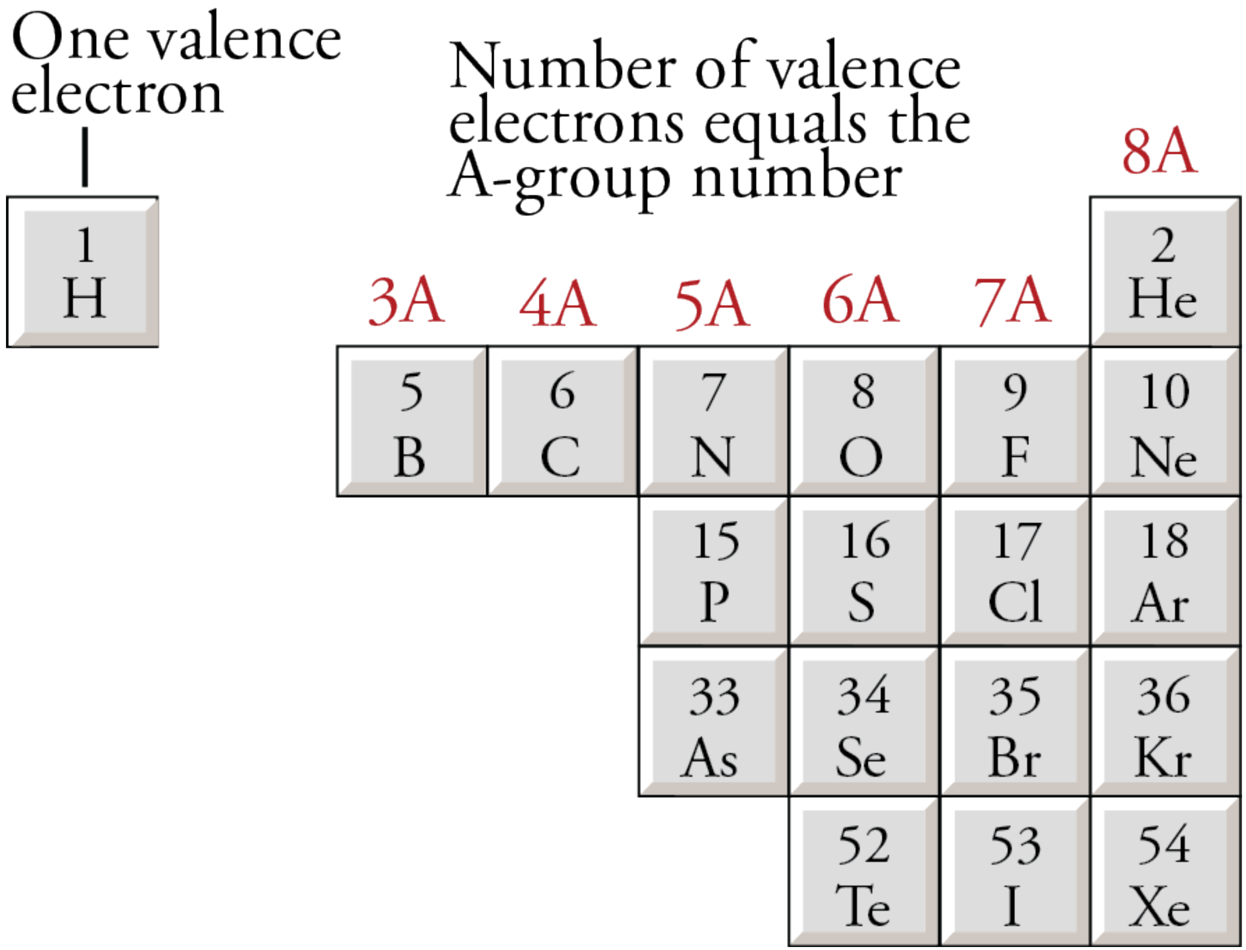


Water



Hydrogen sulfide

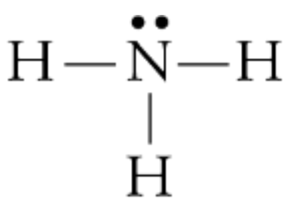
Valence Electrons and A-Group Numbers



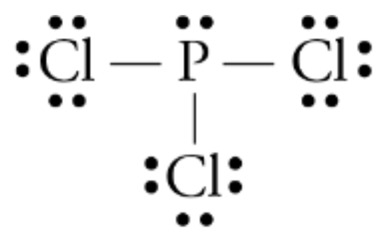
Bonding for Nitrogen and Phosphorus

- Nitrogen and phosphorus in group 5A have five valence electrons and the following electron-dot symbols.

- We expect them to form three covalent bonds and have one lone pair.

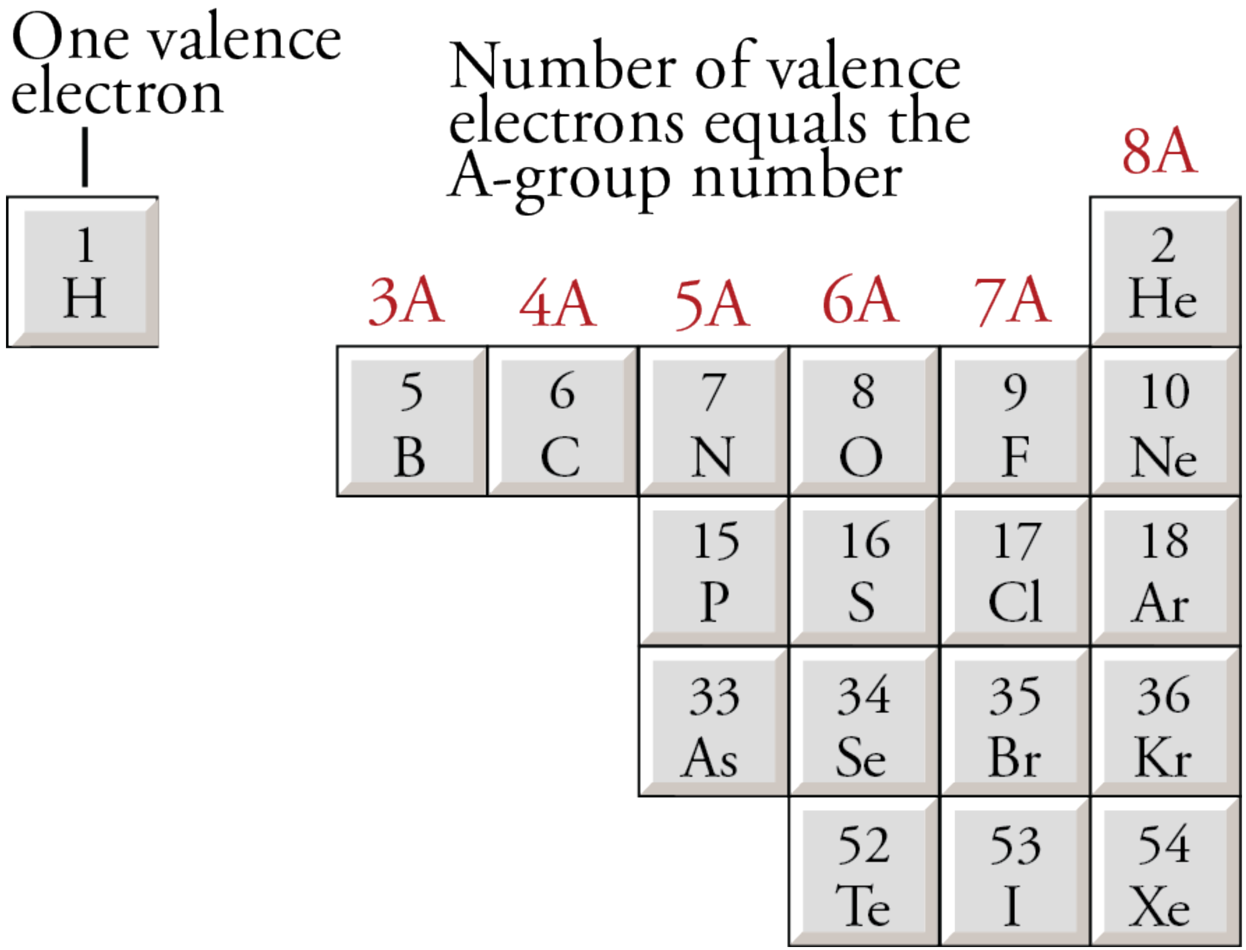


Ammonia



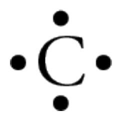
Phosphorus trichloride

Valence Electrons and A-Group Numbers

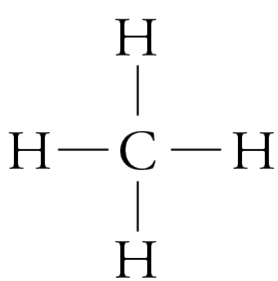


Bonding for Carbon

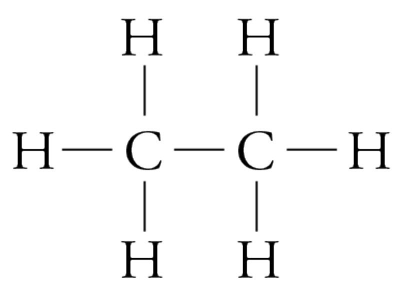
- Carbon is in group 4A, so it has four valence electrons and the following electron-dot symbol.



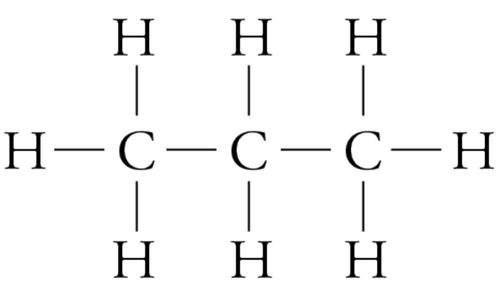
- We expect carbon atoms to form four covalent bonds and no lone pairs.



Methane



Ethane



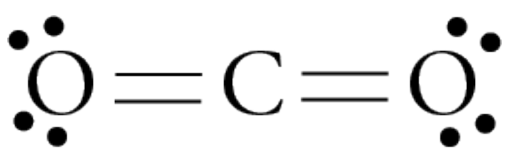
Propane

Most Common Bonding Patterns for Nonmetals

Element	# Bonds	# lone pairs
H	1	0
C	4	0
N, P	3	1
O, S, Se	2	2
F, Cl, Br, I	1	3

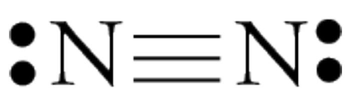
Double Bonds

- Atoms can share four electrons.
- Because we think of each covalent bond as a sharing of two electrons, we call this a double bond.
- Double bonds are described with two lines in Lewis structures.
- Carbon dioxide, CO_2, is an example.



Triple Bonds

- Atoms can share six electrons.
- Because we think of each covalent bond as a sharing of two electrons, we call this a triple bond.
- Triple bonds are described with three lines in Lewis structures.
- Nitrogen, N_2, is an example.



Drawing Lewis Structures

- Chapter 12 describes a long procedure for drawing Lewis structures for many different molecules, but there is a shortcut that works quite well for simple molecules.
- Many Lewis structures can be drawn by attempting to give each atom in a molecule its most common bonding pattern.

Most Common Bonding Patterns for Nonmetals

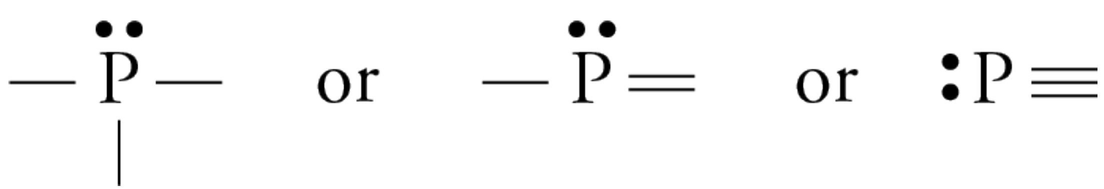
Number of lone pairs	**0**	**1**	**2**	**3**
Number of bonds	**4**	**3**	**2**	**1**

3A	4A	5A	6A	7A	8A
					2 He
5 B	6 C	7 N	8 O	9 F	10 Ne
		15 P	16 S	17 Cl	18 Ar
		33 As	34 Se	35 Br	36 Kr
			52 Te	53 I	54 Xe

https://preparatorychemistry.com/Bishop_periodic_table.pdf

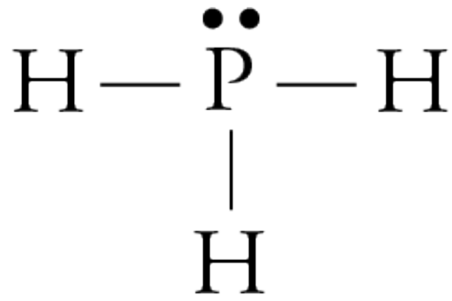
Lewis Structure for PH_3

- You find the symbol P in the third column from the left on the periodic table, which reminds you that it usually forms three bonds.
- To get four groups total, phosphorus atoms must have one lone pair.
- Therefore, we expect one of the following bonding patterns for phosphorus.



Lewis Structure for PH_3

- Hydrogen atoms form one bond with no lone pairs.
- The following Lewis structure has the most common bonding patterns for both P and H.



Most Common Bonding Patterns for Nonmetals

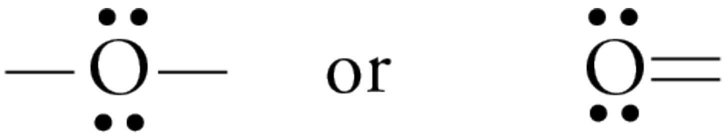
	3A	4A	5A	6A	7A	8A
Number of lone pairs		0	1	2	3	
Number of bonds		4	3	2	1	
						2 He
	5 B	6 C	7 N	8 O	9 F	10 Ne
			15 P	16 S	17 Cl	18 Ar
			33 As	34 Se	35 Br	36 Kr
				52 Te	53 I	54 Xe

HOCl

https://preparatorychemistry.com/Bishop_periodic_table.pdf

Lewis Structure for HOCl

- You find the symbol O in the second column from the left on the periodic table, which reminds you that it usually forms two bonds.
- To get four groups total, oxygen atoms must have two lone pairs.
- Therefore, we expect one of the following bonding patterns for oxygen.

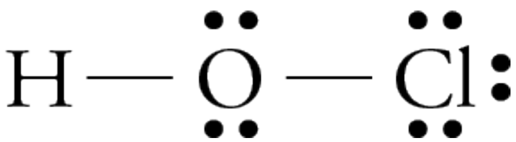


Lewis Structure for HOCl

- Hydrogen atoms form one bond with no lone pairs.
- You find the symbol Cl in the first column from the left on the periodic table, which reminds you that it usually forms one bond.
- To get four groups total, chlorine atoms must have three lone pairs.
- We expect the following bonding pattern for chlorine atoms.

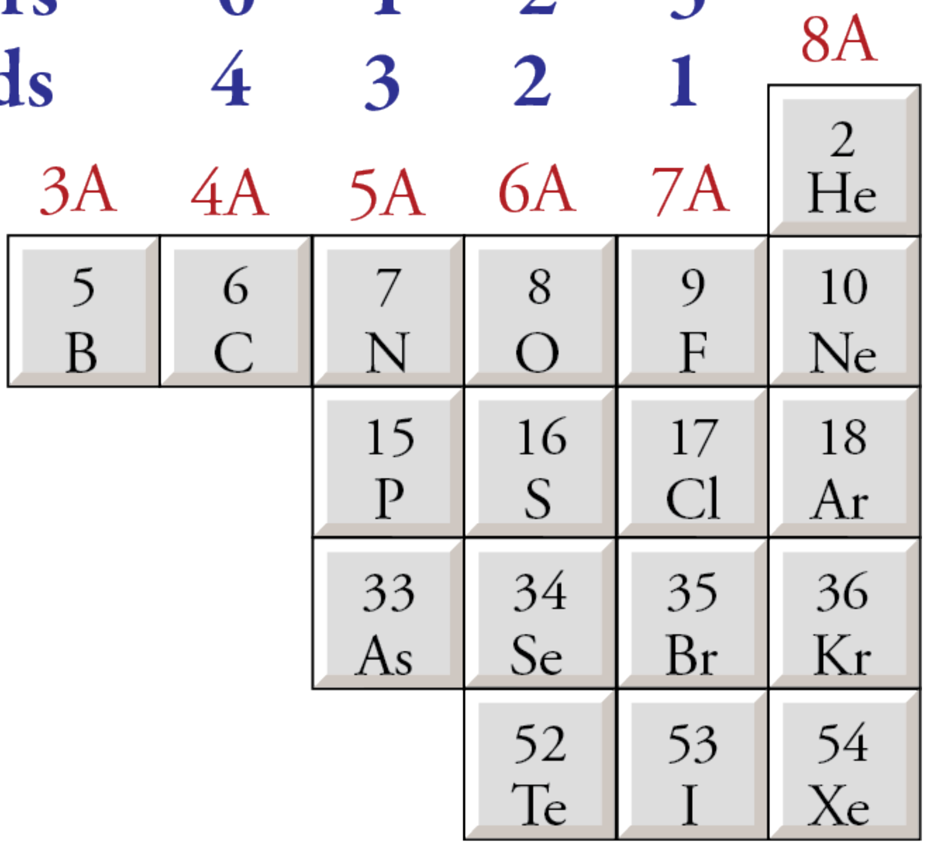
Lewis Structure for HOCl

- For the oxygen atom to get two bonds, it must be in the center of our structure.
- The following Lewis structure has the most common bonding patterns for both H, O, and Cl.



Most Common Bonding Patterns for Nonmetals

Number of lone pairs	0	1	2	3
Number of bonds	4	3	2	1

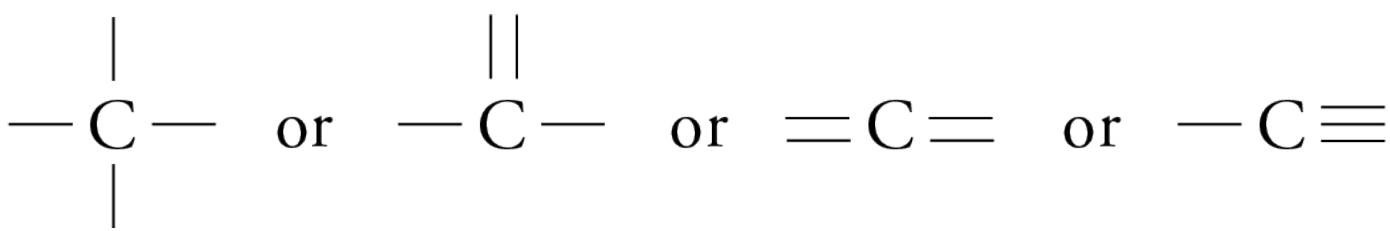


CCl_3F

https://preparatorychemistry.com/Bishop_periodic_table.pdf

Lewis Structure for CCl_3F

- You find the symbol C in the fourth column from the left on the periodic table, which reminds you that it usually forms four bonds.
- To get four groups total, carbon atoms must not have any lone pairs.
- Therefore, we expect one of the following bonding patterns for carbon.

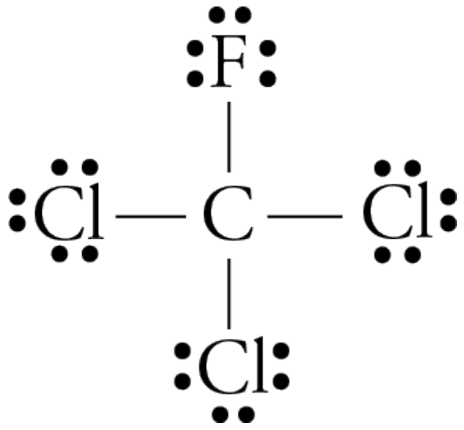


Lewis Structure for CCl_3F

- You find the symbols for Cl and F in the first column from the left on the periodic table, which reminds you that their atoms usually forms one bond.
- To get four groups total, chlorine and fluorine atoms must have three lone pairs.
- We expect the following bonding patterns for these atoms.

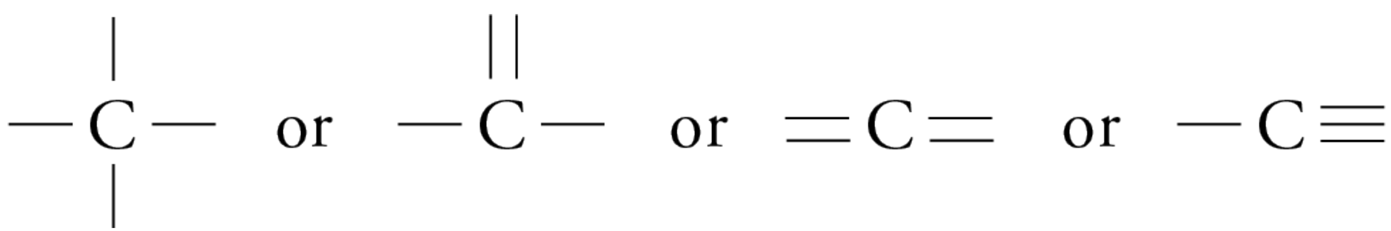
Lewis Structure for CCl_3F

- For the carbon atom to get four bonds, it must be in the center of our structure.
- The following Lewis structure has the most common bonding patterns for both C, Cl, and F.



Lewis Structure for C_2H_2

- You find the symbol C in the fourth column from the left on the periodic table, which reminds you that it usually forms four bonds.
- To get four groups total, carbon atoms must not have any lone pairs.
- Therefore, we expect one of the following bonding patterns for carbon.



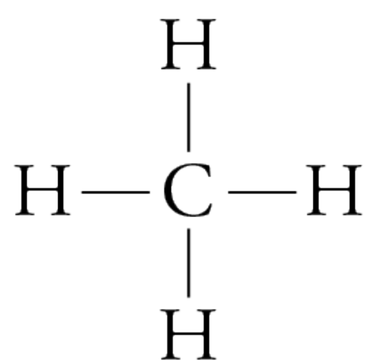
Lewis Structure for C_2H_2

- Carbon atoms commonly bond to each other, so we might start our Lewis structure by bonding the two carbon atoms to each other. This is necessary because hydrogen atoms only form one bond, so they cannot be between the carbon atoms.
- We could put both hydrogen atoms on the same carbon, but it's often best to arrange your symbols in a symmetrical manner.
- The only way to get four lines for each carbon atom is to put a triple bond between the carbon atoms.

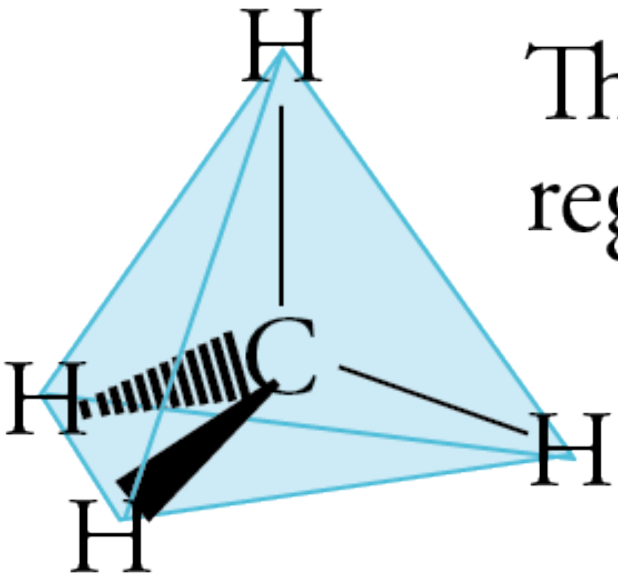
$$\mathrm{H{-}C{\equiv}C{-}H}$$

Lewis Structure for Methane, CH_4

- Carbon atoms usually have 4 bonds and no lone pairs.
- Hydrogen atoms have 1 bond and no lone pairs.

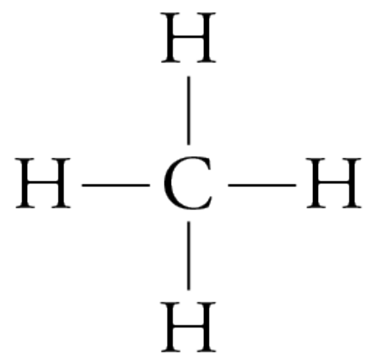


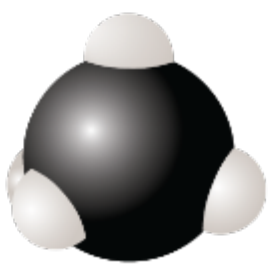
Tetrahedral Geometry



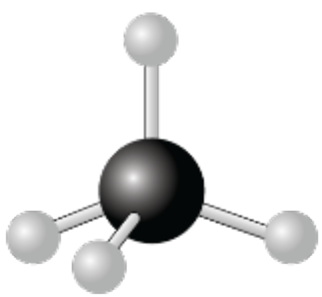
The shaded shape is a regular tetrahedron.

Methane, CH_4

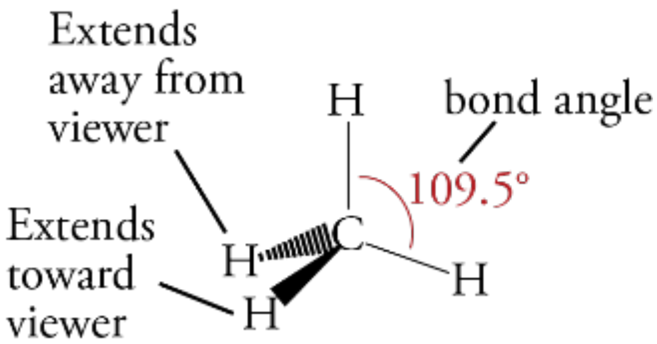




Space-filling model

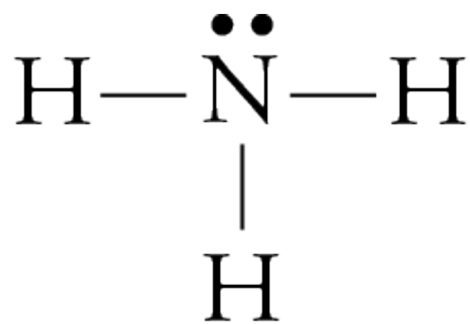


Ball-and-stick model



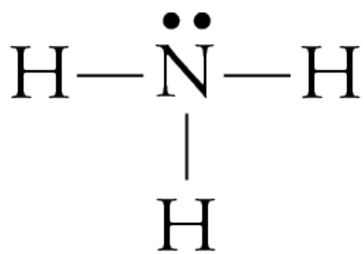
Geometric Sketch

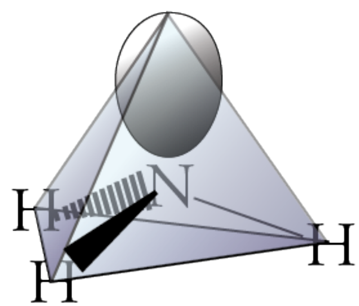
Ammonia, NH_3



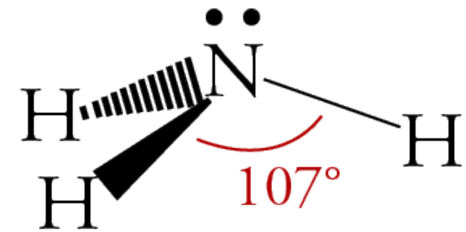
- The ammonia molecule has four electron groups around the central nitrogen atom: three single bonds and one lone pair.
- Each of the following is considered an electron group.
  - Single bond
  - Multiple bond (double or triple bond)
  - Lone pair

Ammonia, NH_3





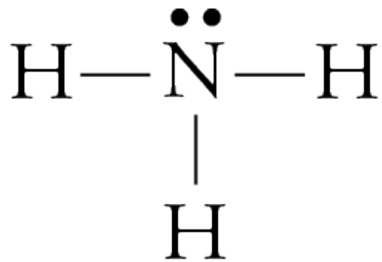
Electron group geometry (tetrahedral)

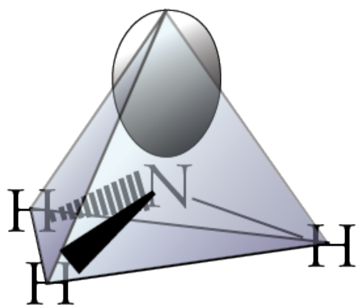


Molecular geometry (trigonal pyramid)

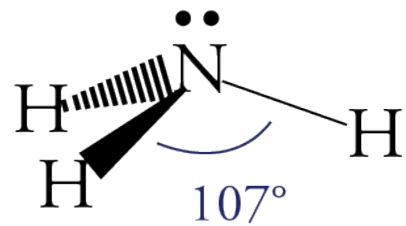
- **Electron group geometry** describes the arrangement of all of the electron groups, including lone pairs.
- **Molecular geometry** just describes the arrangement of the atoms.

Ammonia, NH_3

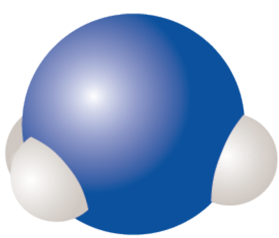




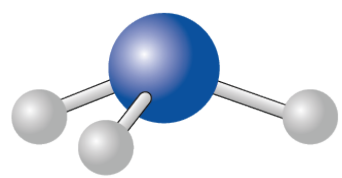
Electron group geometry
(tetrahedral)



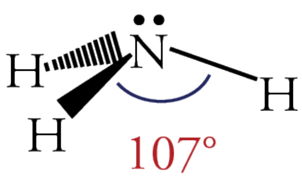
Molecular geometry
(trigonal pyramid)



Space-filling model

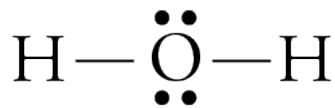


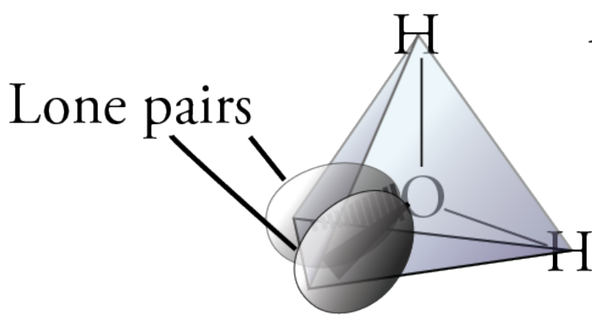
Ball-and-stick model



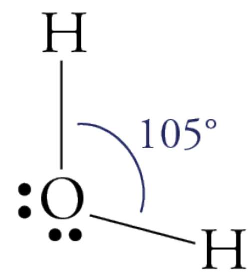
Geometric sketch

Water, H_2O

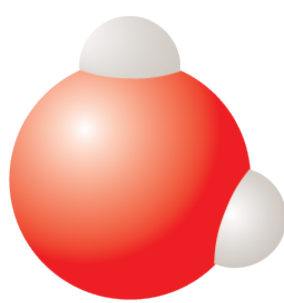




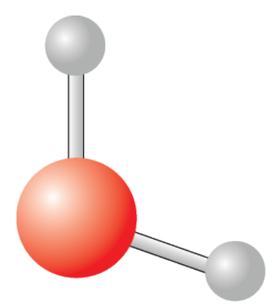
Electron group geometry (tetrahedral)



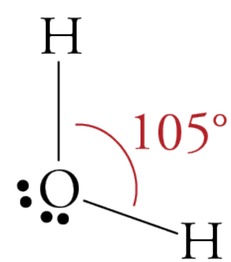
Molecular geometry (bent)



Space-filling model

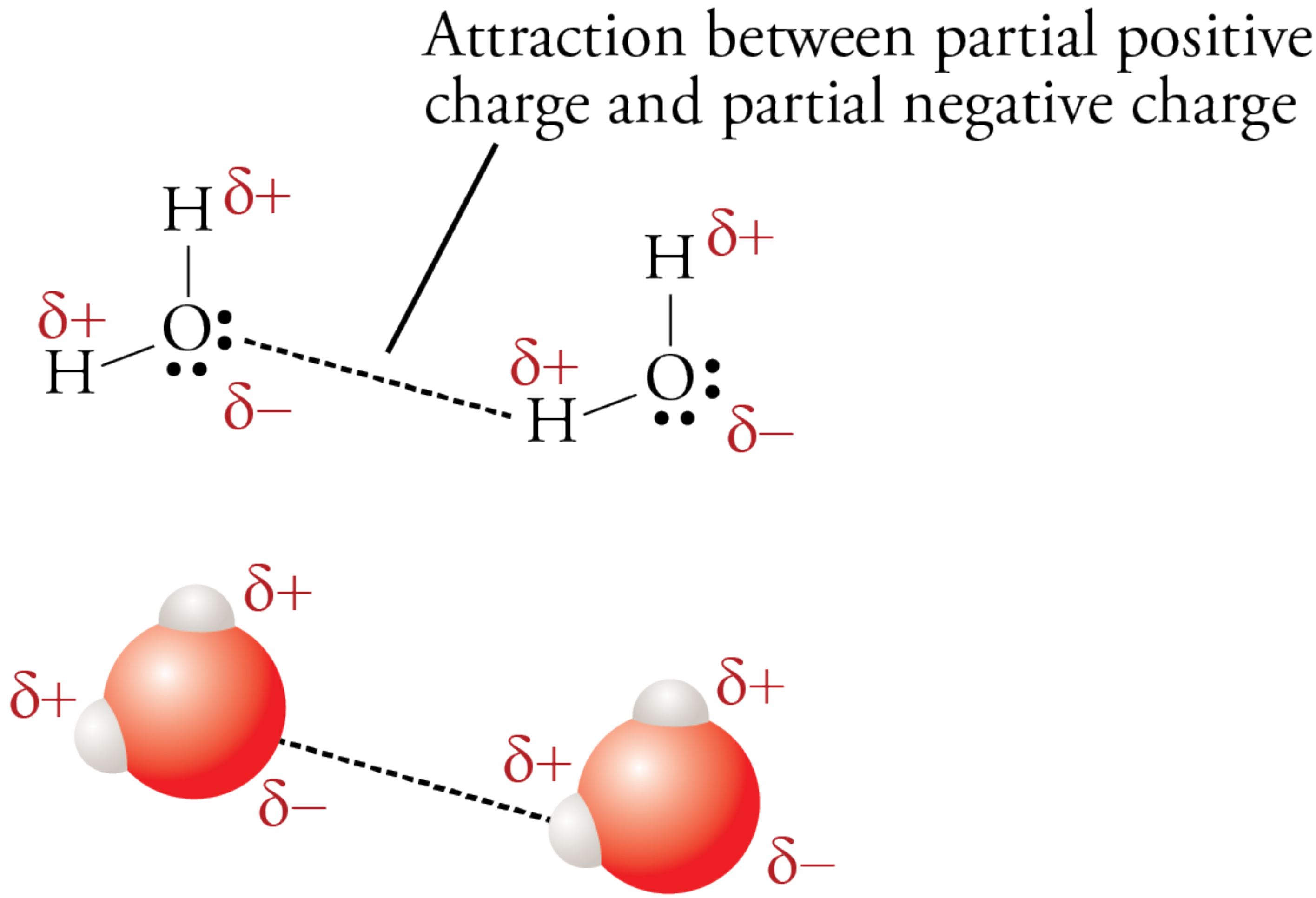


Ball-and-stick model

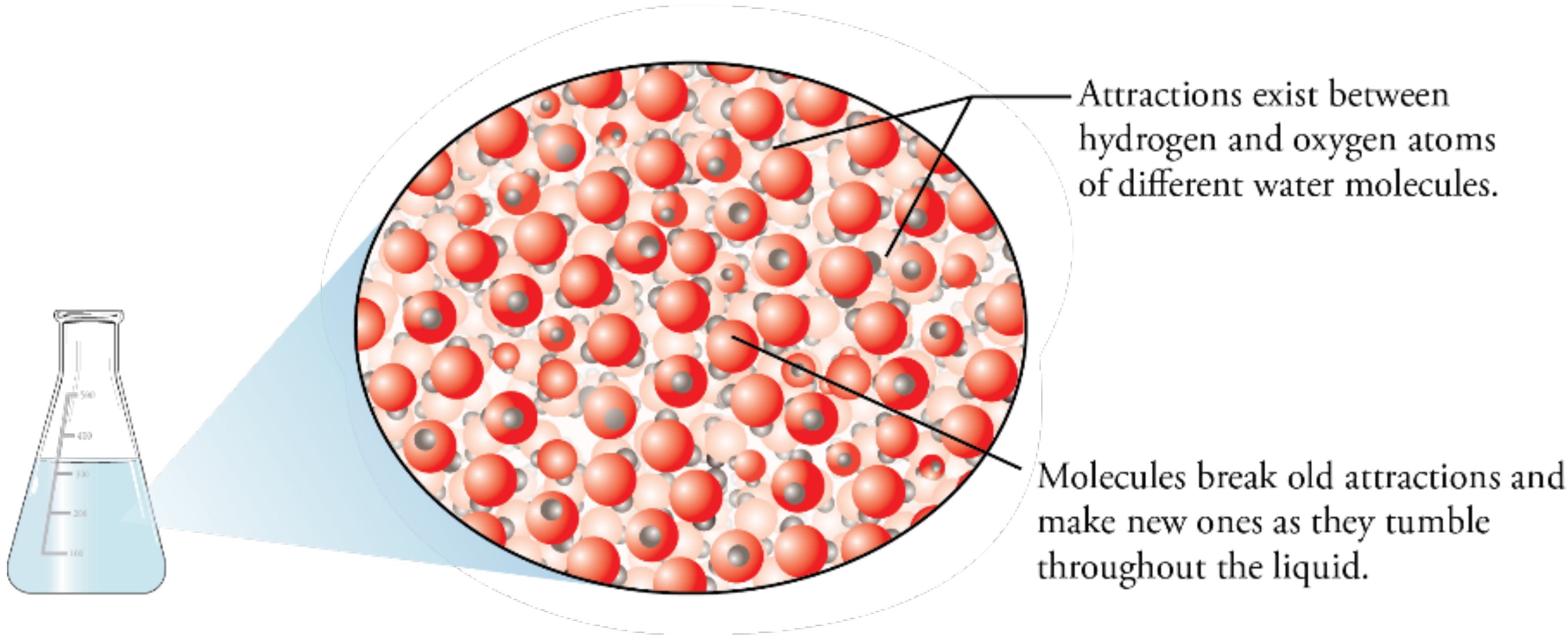


Geometric Sketch

Water Attractions



Liquid Water



Water Animation

https://preparatorychemistry.com/water_Canvas.html

https://preparatorychemistry.com/