A Bit of Review

- Valence electrons
  - Most atoms will gain or lose electrons in order to get a full valence electron shell
  - The number of valence electrons in a neutral atom can be found from the periodic table!!
  - Octet "rule": Most elements need **<u>8 e⁻</u>** to have a full valence electron shell
    - 2 major exceptions: H and He (2 valence e^-)

1

Valance e^- and the formation of ions

Na $\xrightarrow{e^-}$ Na^+ **Cation**

1 valence e^- → same as Ne **Octet**

Charge =+1

Name; Sodium ion

O $\xrightarrow{2e^-}$ O^{2-} **Anion**

6 valance e^- → same as Ne **Octet**

Charge = -2

Name: Oxide ion

2

Valance electrons of an element = Group Number

IA 1	IIA 2	IIIB 3	IVB 4	VB 5	VIB 6	VIIB 7	VIII 8	VIII 9	VIII 10	IB 11	IIB 12	IIIA 13	IVA 14	VA 15	VIA 16	VIIA 17	VIIIA 18
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (99)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (271)	111 Rg (272)	112 -- (277)		114 -- (285)		116 -- (289)		

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (147)	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th (232)	91 Pa (231)	92 U (238)	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

3

Valance electrons— practice

Element	# Valance e^-
C	4
H	1
O	6
Br	7
Mg	2
Ca	2

Total # of valance e- for

CO_2

$4 + 6(2) = 16\ e^-$

4

HOW ATOMS BOND AND MOLECULES ATTRACT

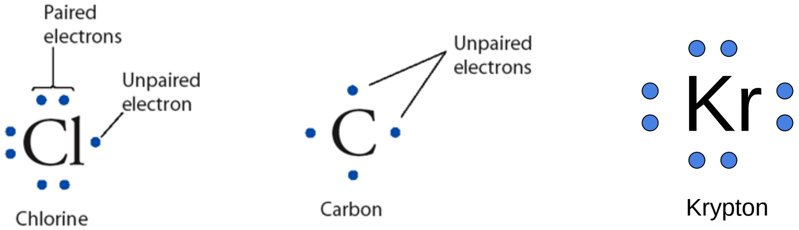
5

Electron-Dot Structures

Valence electrons: Electrons in the outermost shell of an atom. These are the ones that can participate in chemical bonding.

•*Electron-dot structure*: A two dimensional model showing the valence electrons surrounding the atomic symbol.

The number of dots around each atom is equal to the number of valence electrons the atom has.



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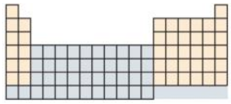
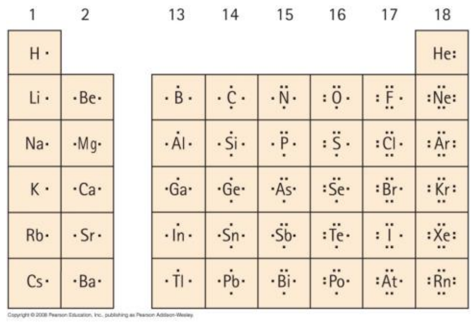
Electron-Dot Structures



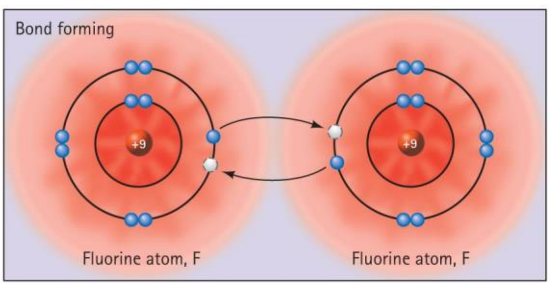


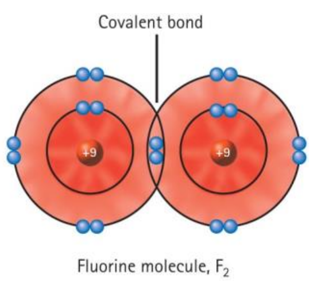
Note that elements within the same group have the same electron-dot structure.

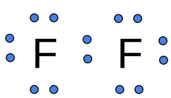
7

Covalent Bonds (sharing of *e-*)

- The type of electrical attraction in which atoms are held together by their mutual attraction for shared electrons.







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Covalent Bonds

- The type of electrical attraction in which atoms are held together by their mutual attraction for shared electrons.
- There are two electrons within a single covalent bond.
- The covalent bond is represented using a straight line.

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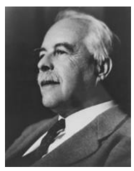
Electron Dot Formulas of Molecules

- *electron dot formulas,*
- also called *Lewis dot structures, Lewis structures*



Gilbert. N. Lewis
1875 - 1946

- We will now draw electron dot formulas for molecules
- A ***Lewis structure*** shows the bonds between atoms and helps us visualize the arrangement of atoms in a molecule.

10

Rules for Writing Lewis Structures

1) **Count the total number of valence e^-**
   Notes: Add one more electron for each negative charge in the composition. Subtract one electron for each positive charge in the composition.
2) **Write the skeleton structure**
   Notes: -Element that needs the most e^- go in the center
   -H are terminal atoms
   -Least electronegative atom go on the center
3) **Use two electrons to connect elements**
4) **Complete octets by distributing the remaining e^-**
5) **Make double or triple bonds if octets not complete**

11

Lewis Structures for Water, H_2O

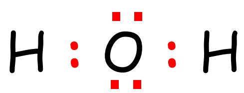
1. Count the total number of valence electrons:

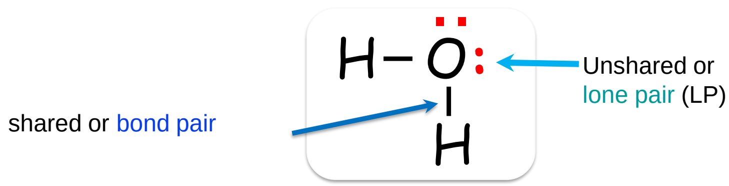
   Oxygen = 1(6 e)
   hydrogen = <u>2(1e)</u>
   total = 8 e^-

2. Draw a skeleton of the structure

   H O H

3-4. Place eight electrons around the central oxygen atom.





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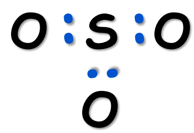
Electron Dot Formula for Sulfur Trioxide, SO_3

1. Count the total number of valence electrons:

   oxygen = 3(6e)
   sulfur = 1(6e)
   total = **24 e^-**

2. Write the skeleton structure

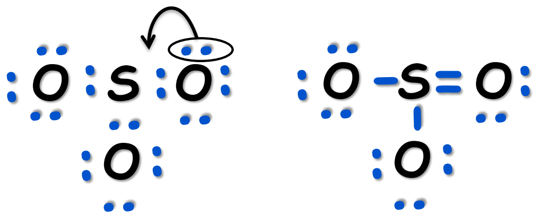


3. Use two electrons to connect elements

   24-6= 18 e^- left

4. Complete octets by distributing the remaining e^-

5. Make double triple bonds if octets not complete



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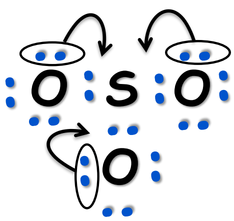
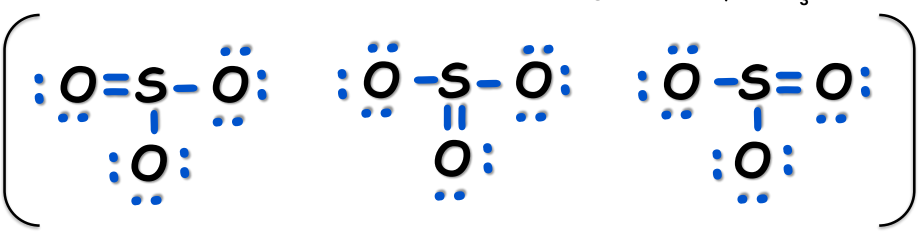
Resonance

On the LDS of SO_3, the double bond can be placed between the sulfur and any of the three oxygen atoms. This phenomenon is called ***resonance.***



Resonance Structures for SO_3



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Electron Dot Formula for NH_4^+

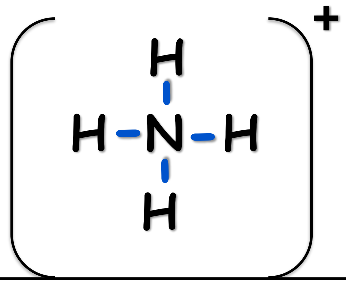
1. Count the total number of valence electrons:

N → 1(5e) = 5
H → 4(1e) = 4
(+) → -1e = -1
total = 8e

We must subtract one electron for the positive charge.

2. Write the skeleton structure

3. Use two electrons to connect elements



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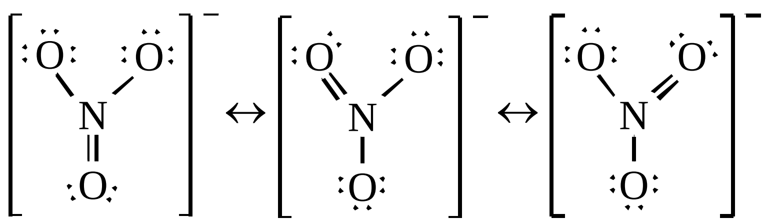
Practice

- Write the LDS for NO_3^-

$NO_3^- = 24e^-$



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Electron Dot Formula for:

1) CH_2O

2) CO_2

2) NH_3

3) O_2

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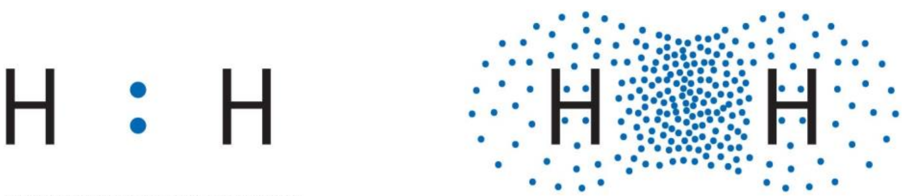
Polar Covalent Bonds

- Electrons within a covalent bond are shared evenly when the two atoms are the same.



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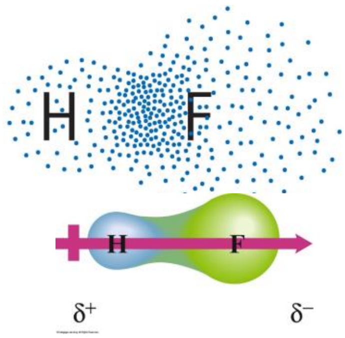
Polar Covalent Bonds

- Electrons within a covalent bond are shared evenly when the two atoms are the same.
- They may be shared *unevenly*, however, when the bonded atoms are different.



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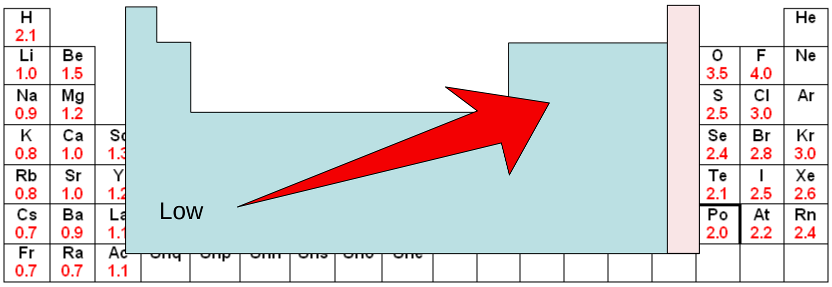
Polar Covalent Bonds

- They may be shared *unevenly*, however, when the bonded atoms are different and have different *electronegativity* -- "electron pulling power."
- **Electronegativity:** The ability of a bonded atom to pull on shared electrons. Greater electronegativity means greater "pulling power."

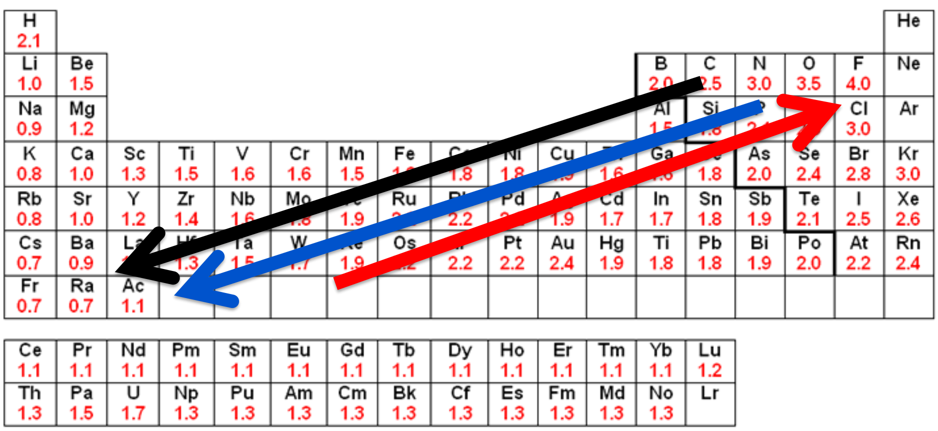
20

Polar Covalent Bonds

- **Electronegativity:** The ability of a bonded atom to pull on shared electrons. Greater electronegativity means greater "pulling power."



Atomic Radius, Metallic Character, and Electronegativity



Increasing electronegativity →

Decreasing electronegativity ↓

H 2.1

Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.9	Ni 1.9	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
Cs 0.7	Ba 0.9	La–Lu 1.0–1.2	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.9	Bi 1.9	Po 2.0	At 2.2
Fr 0.7	Ra 0.9	Ac 1.1	Th 1.3	Pa 1.4	U 1.4	Np–No 1.4–1.3										

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Polar Bonds

If EN |difference| is:

EN < 0.5 the bond is considered to be nonpolar

C–C 2.5-2.5=0

C–S 2.5-2.5=0

Br–Br 2.8-2.8=0

I–H 2.5-2.1=0.4

2.0 > EN ≥ 0.5 the bond is considered to be polar

C–O 2.5-3.5=1

F–H 4.0-2.1=1.9

N–C 3.0-2.5=0.5

Si–O 1.8-3.5=1.7

EN ≥ 2.0 the bond is considered to be ionic

Al :F 1.5-4.0=2.5

Ca :O 1.0-3.5=2.5

Na :Cl 0.9-3.0=2.1

Rb :N 0.8-3.0=2.2

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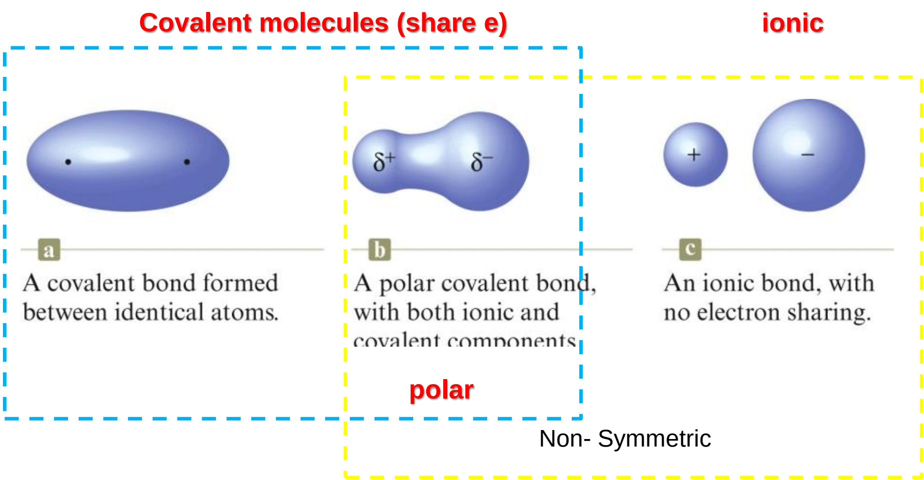
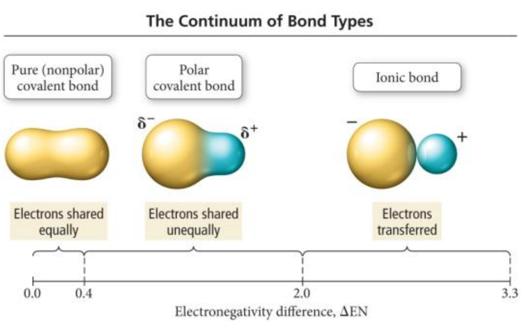
The polarity of a bond depends on the difference between the electronegativity (EN) values and asymmetry of the molecule.



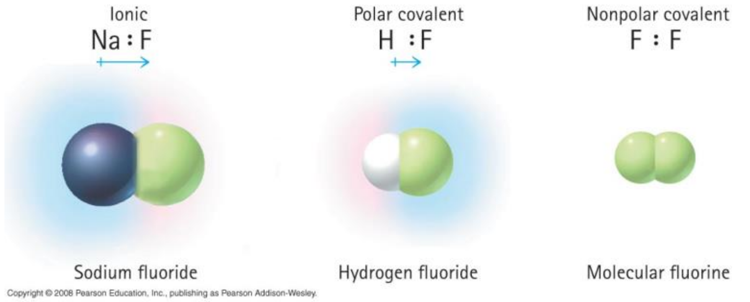
Polarity and Electronegativity

Electronegativity Difference (ΔEN)	Bond Type	Example
Small (0–0.4)	Covalent	Cl_2
Intermediate (0.4–2.0)	Polar covalent	HCl
Large (2.0+)	Ionic	NaCl



Polar Covalent Bonds

- *Electronegativity*: The ability of a bonded atom to pull on shared electrons. Greater electronegativity means greater "pulling power".



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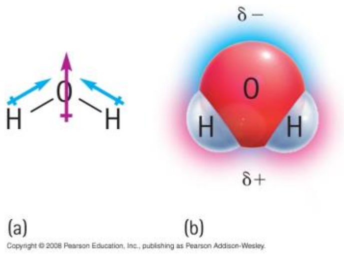
Molecular Polarity

- But if polar bonds within a molecule are facing in equal and opposite directions…

  …then the polarity may cancel itself out.



…or not!

Hence 3D structure is important when determining molecular polarity

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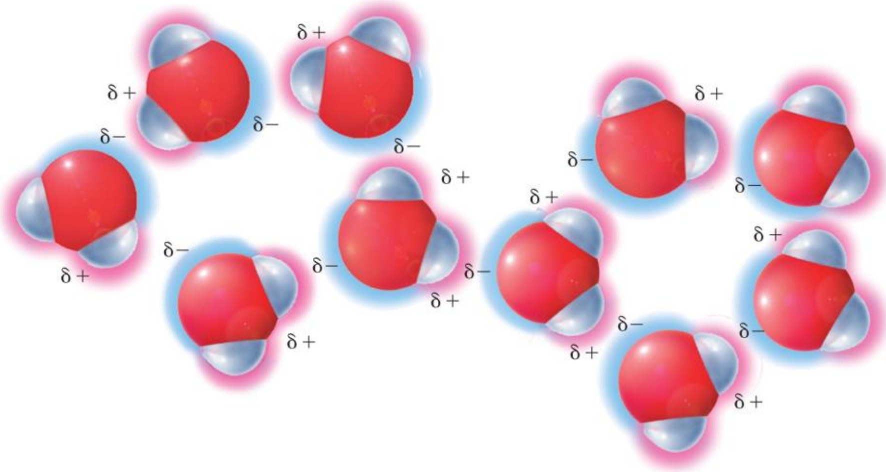
Molecular Polarity



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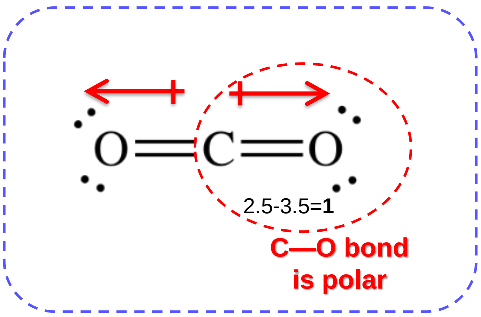
Polar Bonds and molecules



CO_2 molecule is nonpolar

- The bond between the C atom and O atoms in CO_2 molecule is polar.
- The bonding electrons are pulled toward the O ends of the molecule equally because O is more electronegative (EN) than the C atom.
  - The net result is a nonpolar molecule.

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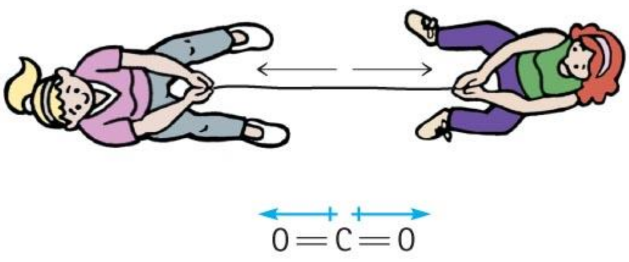
Molecular Polarity

- But if polar bonds within a molecule are facing in equal and opposite directions…

  …then the polarity may cancel itself out.



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Draw LDS for: Which are polar molecules?

1) HCl
2) CH_4
3) PCl_3

32

Shapes of Molecules, 3D

- Electron pairs surrounding an atom repel each other. This is referred to as **V**alence **S**hell **E**lectron **P**air **R**epulsion (VSEPR) theory.
- The ***molecular shape*** indicates the arrangement of **atoms** around the central atom as a result of electron repulsion.

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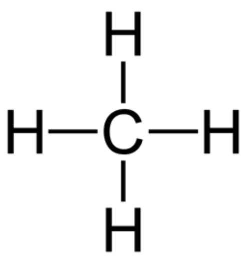
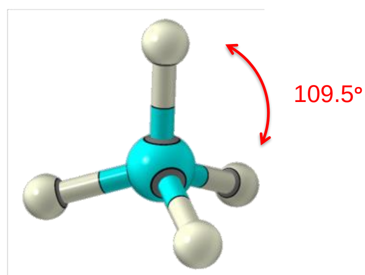
Tetrahedral

- In methane, CH_4, the central C atom has four atoms attached (4 hydrogen atoms) and has no lone pair.

The molecular shape: ***tetrahedral***.

Bond angle: **109.5°**





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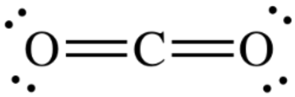
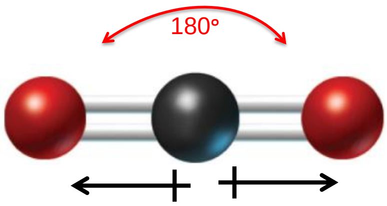
Linear Molecules

- In carbon dioxide, CO_2, the central C atom is bonded to each oxygen by two electron pairs (4 bonding e^-).
- The molecular shape (M.S.): *linear*.

Bond angle: **180º**





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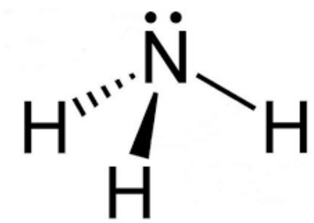
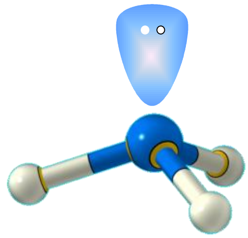
Trigonal pyramidal

- In ammonia, NH_3, the central N atom has three atoms attached (Bonding e^-) and has one lone pair (non bonding e^-).
- The molecular shape: *trigonal pyramidal.*
- Bond angle: ~109.5º (~107º actually)





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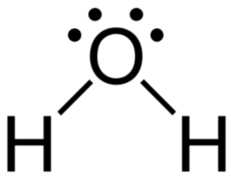
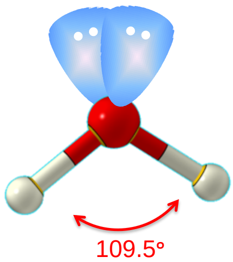
Bent

- In water, H_2O, the central O atom has two atoms attached (2 hydrogen atoms) and has two lone pair.

The molecular shape: ***bent.***

Bond angle: **~109.5°**





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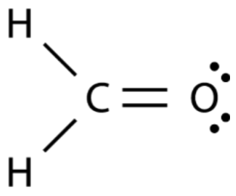
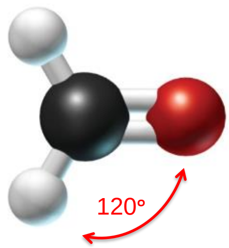
Trigonal Planar

- In formaldehyde, H_2CO, the central C atom has three atoms attached (2 hydrogen and 1 oxygen) and has no lone pair.

The molecular shape: ***trigonal planar.***

Bond angle: **120°**





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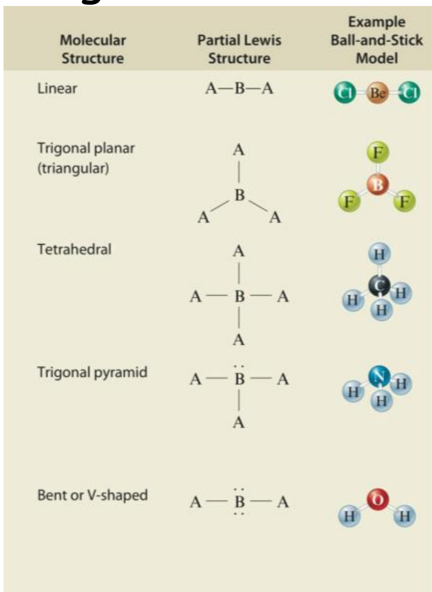
Arrangements of Electron Pairs and the Resulting Molecular Shape



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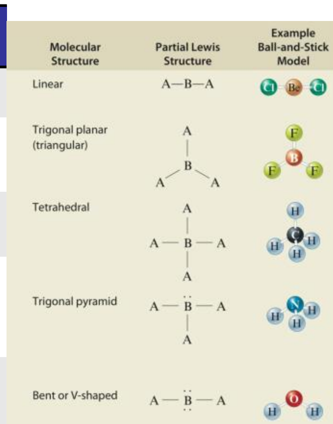
Steps for Predicting Molecular Shape Using the VSEPR Model

1. Draw the Lewis structure for the molecule.
2. Determine # of lone pair of electrons and bonded atoms

	Lone pair of electrons	Bonded atoms	Molecular Structure
Polar if asymmetric	0	2	Linear
	0	3	Trigonal Planar
	0	4	Tetrahedral
Polar	1	3	Trigonal pyramidal
	2 or 1	2	bent



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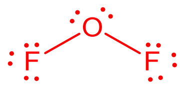
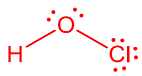
Predict the molecular shape, bond and molecular polarity for:

	LDS Structure	Molecular Shape	Bond Polarity	Molecular Polarity
1) C_2H_2		Linear	C-H 2.5-2.4=0.4, np	Symmetrical Non-Polar
3) OF_2		Bent	O-F 3.5-4=0.5, p	Asymmetrical Polar
4) HOCl		Bent	H-O 2.4-3.5=0.6, p O-Cl 3.5-3=0.5, p	Asymmetrical Polar

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