MODULE 4-COMPOUNDS

CHAPTER-5 (OF TEXTBOOK)

CHEMISTRY 1405

IONIC AND COVALENT COMPOUNDS

TOPICS COVERED ARE:

- ✓TYPES OF CHEMICAL BONDS
- ✓VALENCE ELECTRONS AND LEWIS SYMBOLS
- ✓THE OCTET RULE
- ✓THE IONIC BOND
- ✓THE SIGN AND MAGNITUDE OF THE IONIC CHARGE
- ✓LEWIS STRUCTURE FOR IONIC COMPOUNDS
- ✓CHEMICAL FORMULAS FOR IONIC COMPOUNDS
- ✓POLYATOMIC IONS

CHEMICAL BONDS

- ✓THE COVALENT BOND MODEL
- ✓LEWIS STRUCTURE FOR MOLECULAR COMPOUNDS
- ✓SINGLE BOND, DOUBLE BOND AND TRIPLE COVALENT BONDS
- ✓VALENCE ELECTRON COUNT AND NUMBER OF COVALENT BONDS FORMED
- ✓SYSTEMATIC PROCEDURES FOR DRAWING LEWIS STRUCTURE
- ✓MOLECULAR GEOMETRY
- ✓ELECTRONEGATIVITY
- ✓BOND POLARITY
- ✓MOLECULAR POLARITY

CHEMICAL BONDS

- CHEMICAL COMPOUNDS ARE DIVIDED INTO TWO BROAD CLASSES CALLED *IONIC COMPOUNDS* AND *MOLECULAR COMPOUNDS.*
- IONIC COMPOUNDS AND MOLECULAR COMPOUNDS CAN BE DISTINGUISHED FROM EACH OTHER ON THE BASIS OF GENERAL PHYSICAL PROPERTIES.
- INTERACTION BETWEEN TWO ELEMENTS PRODUCE CHEMICAL OR IONIC COMPOUND DEPENDS ON THE NATURE OF A CHEMICAL BOND.
- THE ATTRACTIVE FORCES THAT HOLD ATOMS TOGETHER IN A COMPLEX UNIT ARE CALLED CHEMICAL BONDS.

CHEMICAL BONDS

TWO TYPES OF CHEMICAL BONDS:

- IONIC BONDS: IONIC BOND IS A CHEMICAL BOND FORMED THROUGH THE TRANSFER OF ONE OR MORE ELECTRONS FROM ONE ATOM OR GROUP OF ATOMS TO ANOTHER.
  - CHEMICAL FORMULA IS CALLED A FORMULA UNIT.
  - NO DISCRETE MOLECULE.
  - HIGH MELTING POINTS
  - GOOD ELECTRICAL CONDUCTORS IN A MOLTEN STATE.
  - MOST ARE SOLUBLE IN POLAR SOLVENTS, NOT SOLUBLE IN NONPOLAR SOLVENTS

CHEMICAL BONDS

TWO TYPES OF CHEMICAL BONDS (CONT.):

- COVALENT BONDS: A COVALENT BOND IS A CHEMICAL BOND FORMED THROUGH THE SHARING OF ONE OR MORE ELECTRON PAIRS BETWEEN TWO ATOMS.
  - CHEMICAL FORMULA IS CALLED A MOLECULAR FORMULA.
  - FORM DISCRETE MOLECULES.
  - LOWER MELTING THAN IONIC COMPOUNDS
  - GASES, LIQUIDS AND LOW MELTING SOLIDS.
  - DO NOT CONDUCT ELECTRICITY
  - SOLUBLE IN NONPOLAR SOLVENTS AND SOME POLAR SOLVENTS

CHEMICAL BONDS

CHEMICAL BONDS CAN BE STRONGLY IONIC OR STRONGLY COVALENT BUT MOST WILL HAVE SOME CHARACTER OF BOTH TYPES OF BONDING.

- GOAL OF BONDING IS TO CREATE A MORE STABLE, "HAPPY" ATOM OR MOLECULE.

- DO ALL ELECTRONS PARTICIPATE IN BONDING?
  - NO. ONLY THE VALENCE ELECTRONS PARTICIPATE.

CHEMICAL BONDS

ATOMS BOND THROUGH THEIR VALENCE ELECTRONS.

REMEMBER, VALENCE ELECTRONS ARE THE ELECTRONS IN THE *OUTERMOST SHELL* (NOT JUST SUBSHELL) OF AN ATOM.

- THIS IS ALWAYS TRUE FOR REPRESENTATIVE OR NOBLE GAS ELEMENTS. (DETERMINING VALENCE ELECTRONS IN TRANSITION ELEMENTS IS A LITTLE MORE COMPLEX.)
- THE NUMBER OF VALENCE ELECTRONS FOR MANY ELEMENTS CAN BE FOUND USING ELECTRON CONFIGURATIONS OR PERIODIC TABLE PLACEMENT.

CHEMICAL BONDS

- REMEMBER VALENCE ELECTRONS ARE THE ONES IN THE *s* AND *p* SUBSHELL OF THE OUTER MOST ELECTRON SHELL.

ELEMENT	Z	ELECTRON CONFIGURATION
SODIUM	11	$1s^2 2s^2 2p^6 3s^1$
POTASSIUM	19	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
BROMINE	35	[AR] $4s^2\ 3d^{10}\ 4p^5$

Na AND K HAVE 1 ELECTRON IN THE OUTERMOST ELECTRON SHELL SO THEY HAVE 1 VALENCE ELECTRON; Br HAS 7 VALENCE ELECTRONS.

CHEMICAL BONDS

- SODIUM HAS FULL FIRST AND SECOND SHELLS.
- POTASSIUM HAS FULL FIRST, SECOND AND THIRD SHELLS.
- BROMINE HAS FULL FIRST, SECOND AND THIRD SHELLS
  - **ELECTRONS IN FULL SHELLS DO NOT PARTICIPATE IN BONDING**

CHEMICAL BONDS

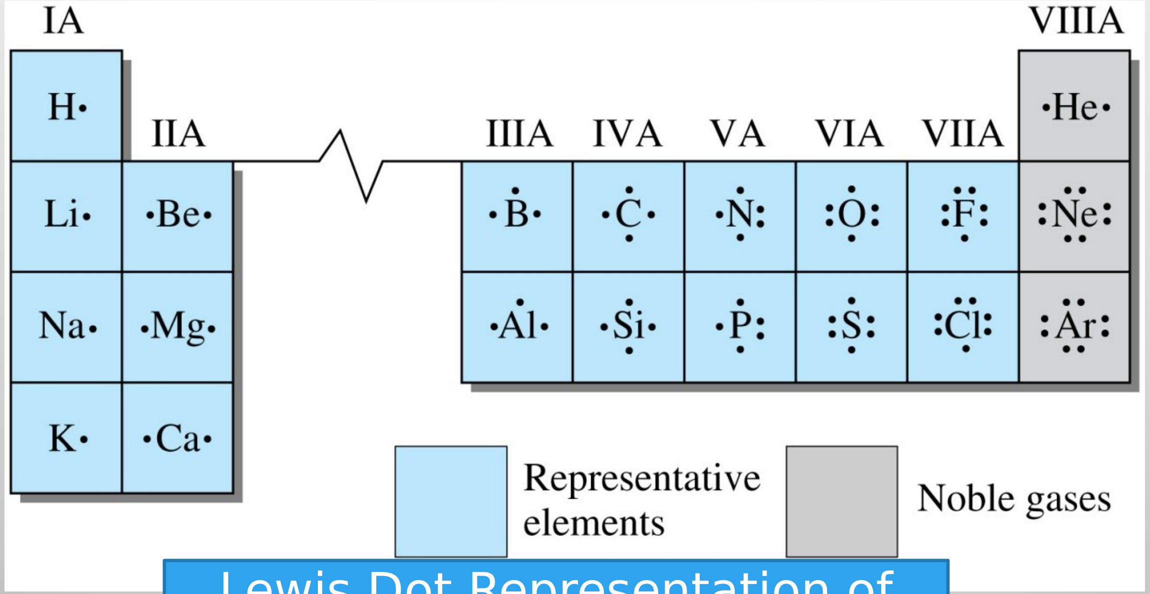
- A "HAPPY" ATOM IS ONE THAT HAS ALL OUTER ELECTRON SHELLS FULL.
  - THE ELECTRON CONFIGURATION OF A FULL OUTER SHELL IS THE SAME ELECTRON CONFIGURATION AS A NOBLE GAS. THIS CONFIGURATION IS THE MOST STABLE.
  - EACH ATOM IN A COMPOUND WANTS A TOTAL OF 8 ELECTRONS IN THE *S* AND *P* SUBSHELLS. (EXCEPT HYDROGEN – WHY?)
    - HYDROGEN HAS NO P ORBITALS; ONLY HOLDS 2 ELECTRONS.

CHEMICAL BONDS

- A NOBLE GAS CONFIGURATION OF ELECTRONS IS OFTEN REFERRED TO AS THE OCTET RULE:
  - IN FORMING COMPOUNDS, ATOMS OF ELEMENTS **LOSE**, **GAIN** OR **SHARE** ELECTRONS IN SUCH A WAY AS TO PRODUCE A NOBLE GAS ELECTRON CONFIGURATION FOR EACH OF THE ATOMS INVOLVED.

CHEMICAL BONDS

- LEWIS DOT SYMBOLS HELP VISUALIZE THE VALENCE ELECTRONS AND THE OCTET RULE.
- THE SYMBOL IS A CHEMICAL SYMBOL OF AN ELEMENT SURROUNDED BY DOTS EQUAL TO THE NUMBER OF VALENCE ELECTRONS.

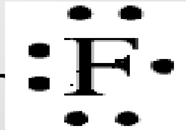


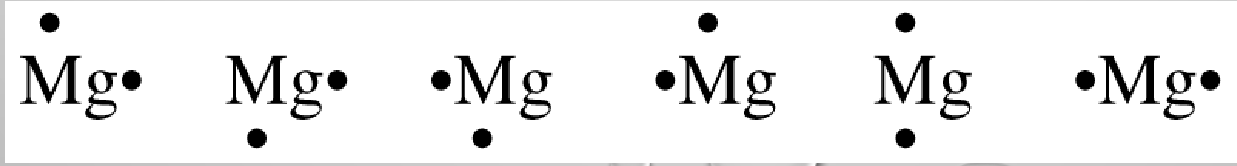
Lewis Dot Representation of Element

ELECTRON DOT STRUCTURES (LEWIS SYMBOLS): A WAY OF DEPICTING VALENCE ELECTRONS

EXAMPLE: Mg	EXAMPLE: F
$1S^2 2S^2 2P^6 3S^2$	$1S^2 2S^2 2P^5$
2 VALENCE ELECTRONS	7 VALENCE ELECTRONS

- **AN ELECTRON DOT STRUCTURE CONSISTS OF AN ELEMENT'S SYMBOL SURROUNDED BY ONE DOT FOR EACH VALENCE ELECTRON.**
- **THE CHOICE OF WHERE TO PLACE T OTS IS NOT CRUCIAL:**





CHEMICAL BONDING

- DOTS ARE NOT PAIRED UNTIL THERE ARE MORE THAN 4.
  - REPRESENTATIVE ELEMENTS IN THE SAME GROUP OF THE PERIODIC TABLE HAVE THE SAME NUMBER OF VALENCE ELECTRONS.
  - THE NUMBER OF VALENCE ELECTRONS FOR REPRESENTATIVE ELEMENTS IN A GROUP IS THE SAME AS THE PERIODIC TABLE GROUP NUMBER.
  - THE MAXIMUM NUMBER OF VALENCE ELECTRONS FOR ANY ELEMENT IS 8.

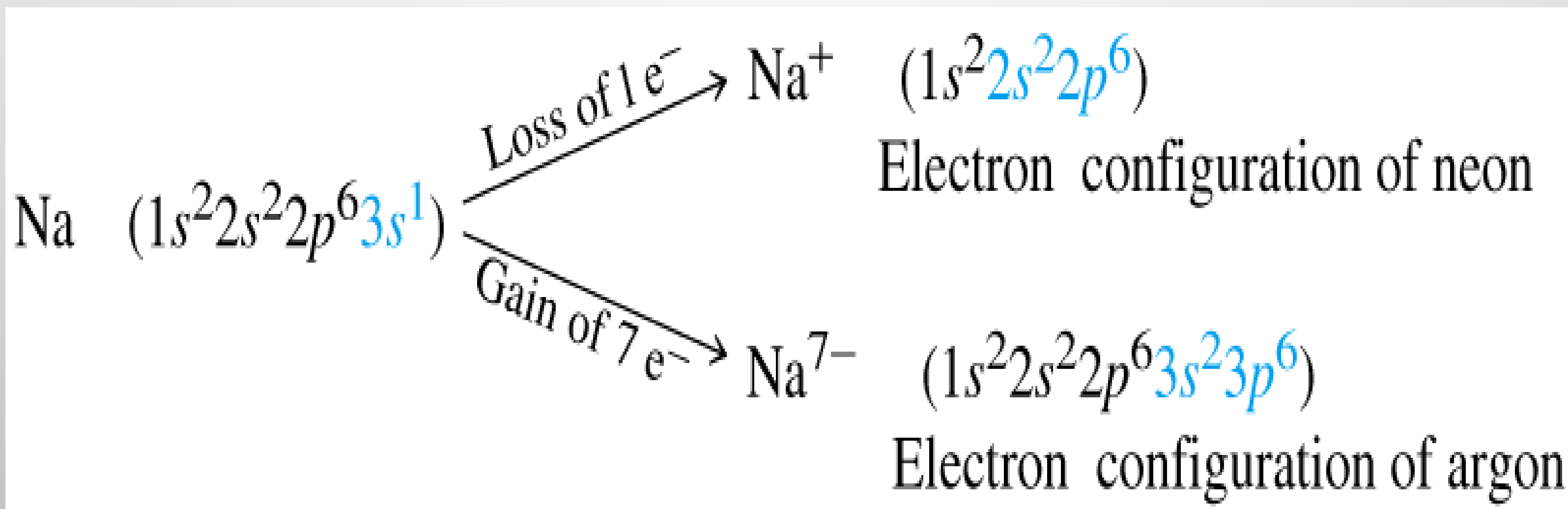
IONIC BONDS

- AN **ION** IS AN ATOM (OR GROUP OF ATOMS) THAT IS ELECTRICALLY CHARGED AS THE RESULT OF LOSS OR GAIN OF ELECTRONS.
  - AN **ION** IS CREATED BY THE **LOSS** OR **GAIN** OF ELECTRONS. THE NUCLEUS OF THE ATOM DOES NOT CHANGE.
- ANION IS A NEGATIVELY CHARGED ION, MAINLY NONMETALS. Cl^{-}, O^{2-}, N^{3-}
- CATION IS A POSITIVELY CHARGES ION, MAINLY METALS. Na^{+}, Mg^{2+}, Al^{3+}

IONIC BONDS

DOES THE ELEMENT WANT TO LOSE ELECTRONS OR GAIN ELECTRONS?

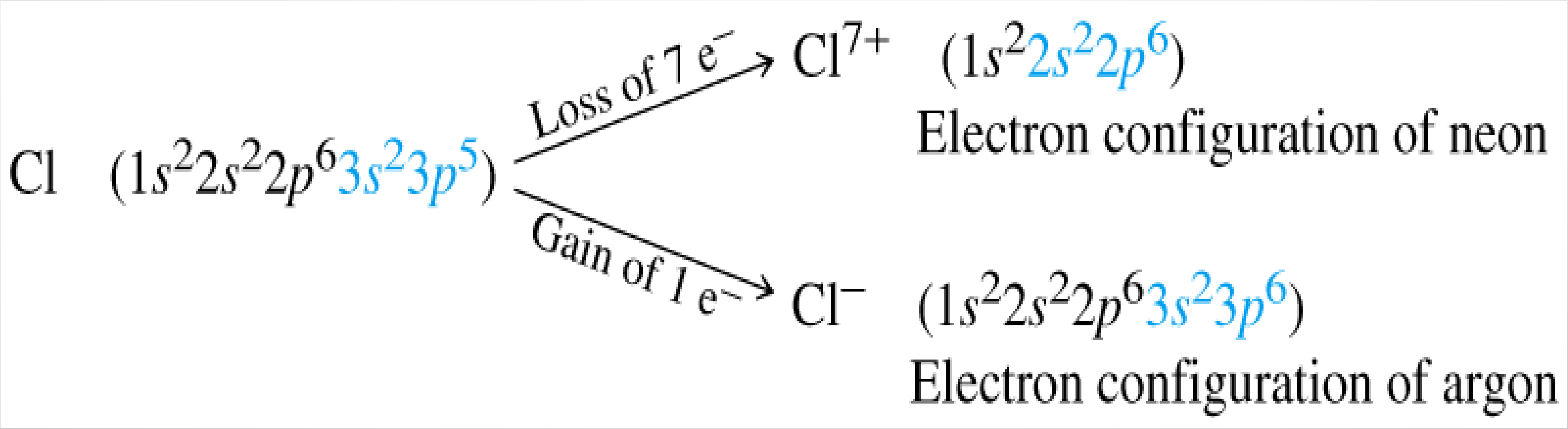
LOOK AT THE METAL SODIUM. IT IS EASIER TO LOSE ONE ELECTRON THAN TO GAIN 7.



IONIC BONDS

Does the element want to lose electrons or gain electrons?

Look at the non-metal chlorine. It is easier to gain one electron than to lose 7.



IONIC BONDS

- METAL ATOMS TEND TO LOSE ELECTRONS TO ACQUIRE NOBLE GAS CONFIGURATION.
  - HOW MANY DO THEY *LOSE*?
- NONMETAL ATOMS TO GAIN ELECTRONS TO ACQUIRE A NOBLE GAS CONFIGURATION.
  - HOW MANY DO THEY *GAIN*?
- MANY IONS CAN HAVE THE SAME NOBLE GAS CONFIGURATION.

IONIC BONDS

- HOW MANY ELECTRONS ARE PRESENT IN EACH OF THE FOLLOWING IONS?
  - Ca^{2+}
  - K^{+}
  - Cl^{-}
  - S^{2-}
  - Sc^{3+}
- DO YOU SEE A PATTERN?

$1s^2 2s^2 2p^6 3s^2 3p^6$ 18 electrons

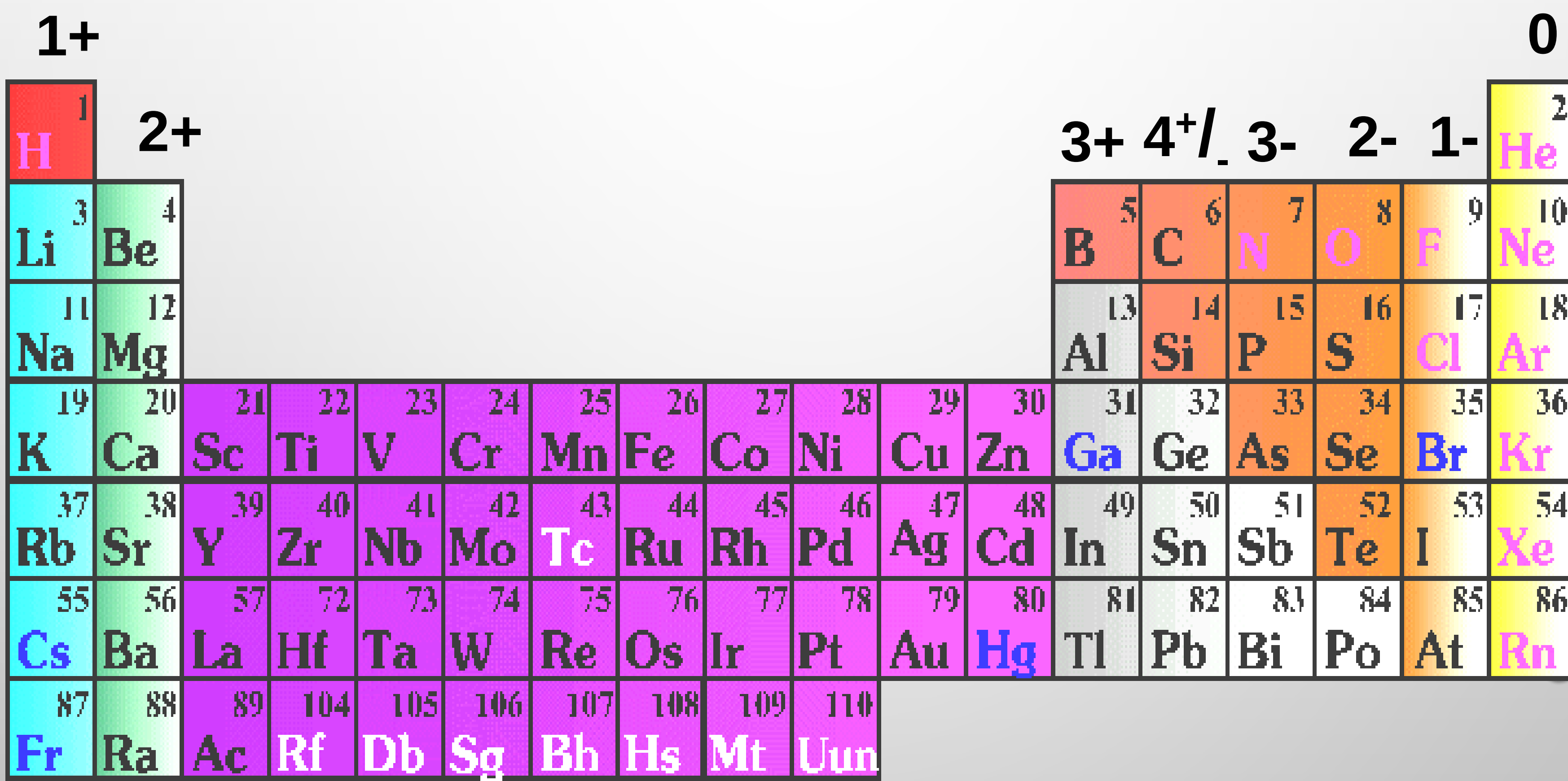
IONIC BONDS

- IONS WITH THE SAME ELECTRONIC CONFIGURATION AS A NOBLE GAS ARE SAID TO BE ISOELECTRONIC WITH THE NOBLE GAS.
- ISOELECTRONIC SPECIES ARE IONS OR AN ATOM AND IONS, HAVING THE SAME NUMBER AND CONFIGURATION OF ELECTRONS.

Ions Isoelectronic with Selected Noble Gases

Electron Configuration	Anions			Noble Gas	Cations		
$1s^2$			H^-	He	Li^+	Be^{2+}	
$1s^22s^22p^6$	N^{3-}	O^{2-}	F^-	Ne	Na^+	Mg^{2+}	Al^{3+}
$1s^22s^22p^63s^23p^6$	P^{3-}	S^{2-}	Cl^-	Ar	K^+	Ca^{2+}	Sc^{3+}

COMMON ION CHARGES



IONIC COMPOUND FORMULAS

- THE NET CHARGE FOR THE COMPOUND MUST BE EQUAL TO ZERO.
- THE SYMBOL FOR THE *POSITIVE* ION MUST ALWAYS BE WRITTEN FIRST.
- THE CHARGES ON THE IONS PRESENT ARE **NOT** SHOWN IN THE FORMULA.
- THE SUBSCRIPT NUMBERS IN THE FORMULA GIVE THE *COMBINING RATIO* OF THE IONS.

IONIC COMPOUND FORMULAS

- USE THE NUMBER OF ELECTRONS LOST/GAINED TO HELP DETERMINE THE RATIO OF ATOMS IN THE FORMULA UNIT:
  - Na IS +1
  - Cl IS -1
  - TO MAKE A NEUTRAL FORMULA UNIT YOU NEED ONE ATOM OF EACH.

NaCl

Na: 1 X (+1) = +1

Cl: <u>1 X (-1) = -1</u>

NET CHARGE = 0

IONIC COMPOUND FORMULAS

- USE THE NUMBER OF ELECTRONS LOST/GAINED TO HELP DETERMINE THE RATIO OF ATOMS IN THE FORMULA UNIT:
  - Al IS +3
  - O IS -2
  - TO MAKE A NEUTRAL FORMULA UNIT YOU NEED TWO ALUMINUM ATOMS AND 3 OXYGEN ATOMS.

    2 X (+3) = +6

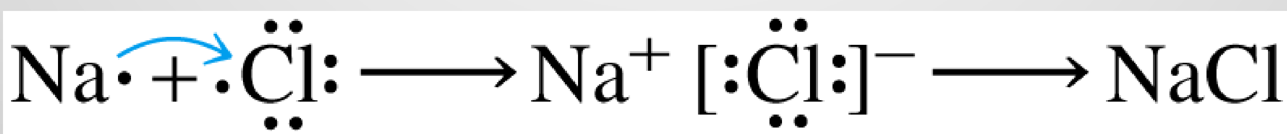
    <u>3 X (-2) = -6</u>

NET CHARGE = 0

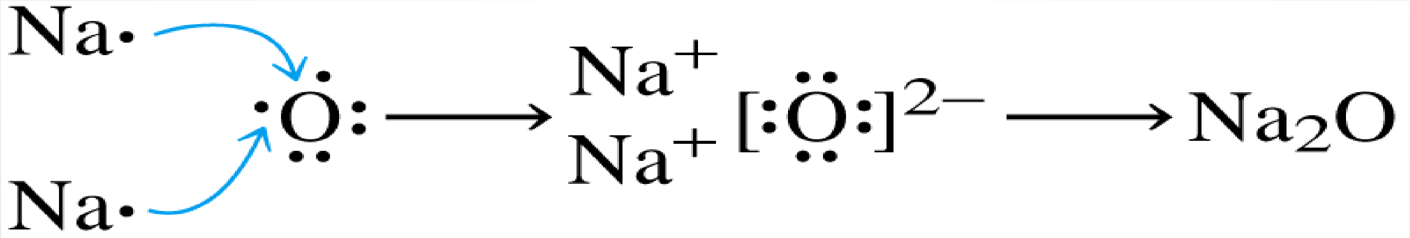
Al_2O_3

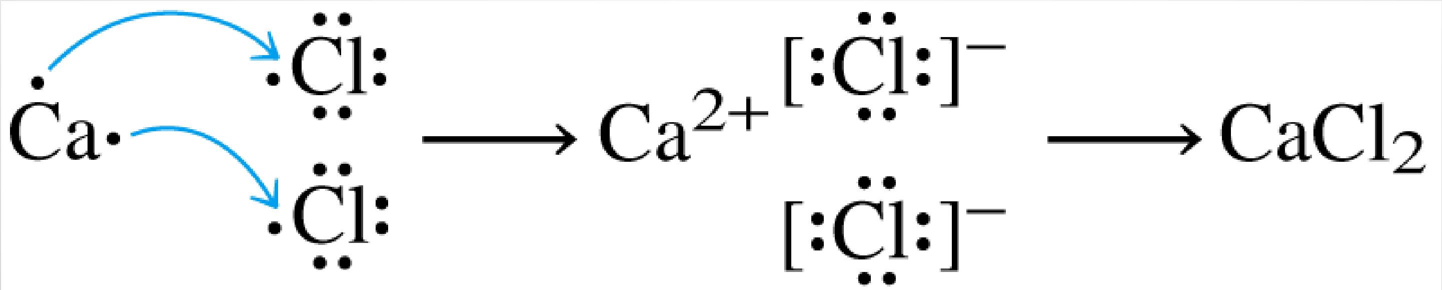
IONIC COMPOUND FORMATION

TO HELP VISUALIZE IONIC COMPOUND FORMATION USE THE LEWIS SYMBOLS TO FORM **LEWIS STRUCTURES**. THESE ARE A GROUPING OF LEWIS SYMBOLS THAT SHOWS EITHER THE TRANSFER OF ELECTRONS OR THE SHARING OF ELECTRONS IN CHEMICAL BONDS.



IONIC COMPOUND FORMATION FROM LEWIS STRUCTURE





IONIC COMPOUND FORMATION

- IONIC LEWIS STRUCTURE PRACTICE:
  - Ca_3P_2
  - Li_2O
  - $BeCl_2$

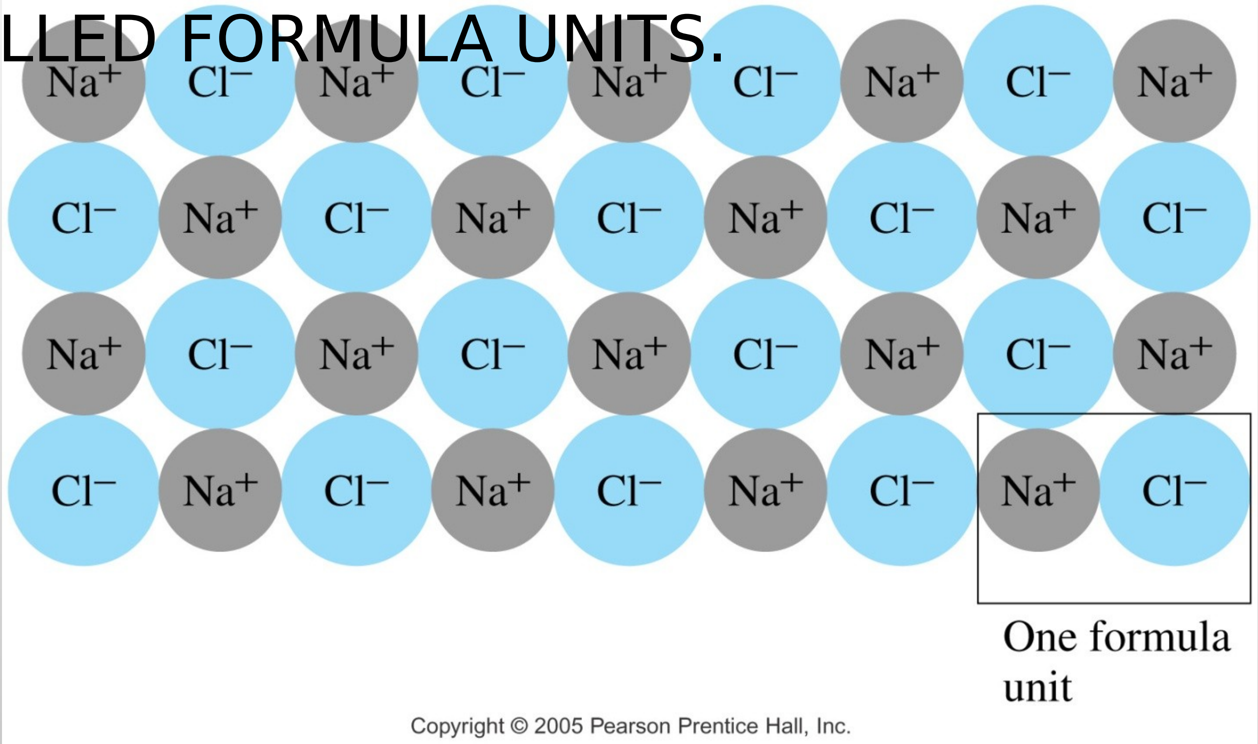
Can you do this ?

IONIC COMPOUNDS

- IONIC COMPOUNDS USUALLY CONTAIN A METAL AND A NONMETAL (OR A *POLYATOMIC* ION).
- THE METALLIC ELEMENT ATOMS LOSE ELECTRONS TO PRODUCE POSITIVE IONS WHILE THE NONMETAL ELEMENT ATOMS GAIN ELECTRONS TO PRODUCE NEGATIVE IONS.
- THE ELECTRONS LOST BY THE METAL ATOMS ARE THE SAME ONES THAT ARE GAINED BY THE NONMETAL ATOMS. ELECTRON LOSS MUST ALWAYS EQUAL ELECTRON GAIN.
- THE RATIO IN WHICH THE IONS COMBINE IS THE LOWEST POSSIBLE RATIO AND HAS CHARGE NEUTRALITY FOR THE COMPOUND.

IONIC COMPOUNDS

- THE RATIO IN WHICH THE IONS COMBINE IS THE LOWEST POSSIBLE RATIO AND HAS CHARGE NEUTRALITY FOR THE COMPOUND. THESE ARE CALLED FORMULA UNITS.



IONIC COMPOUNDS

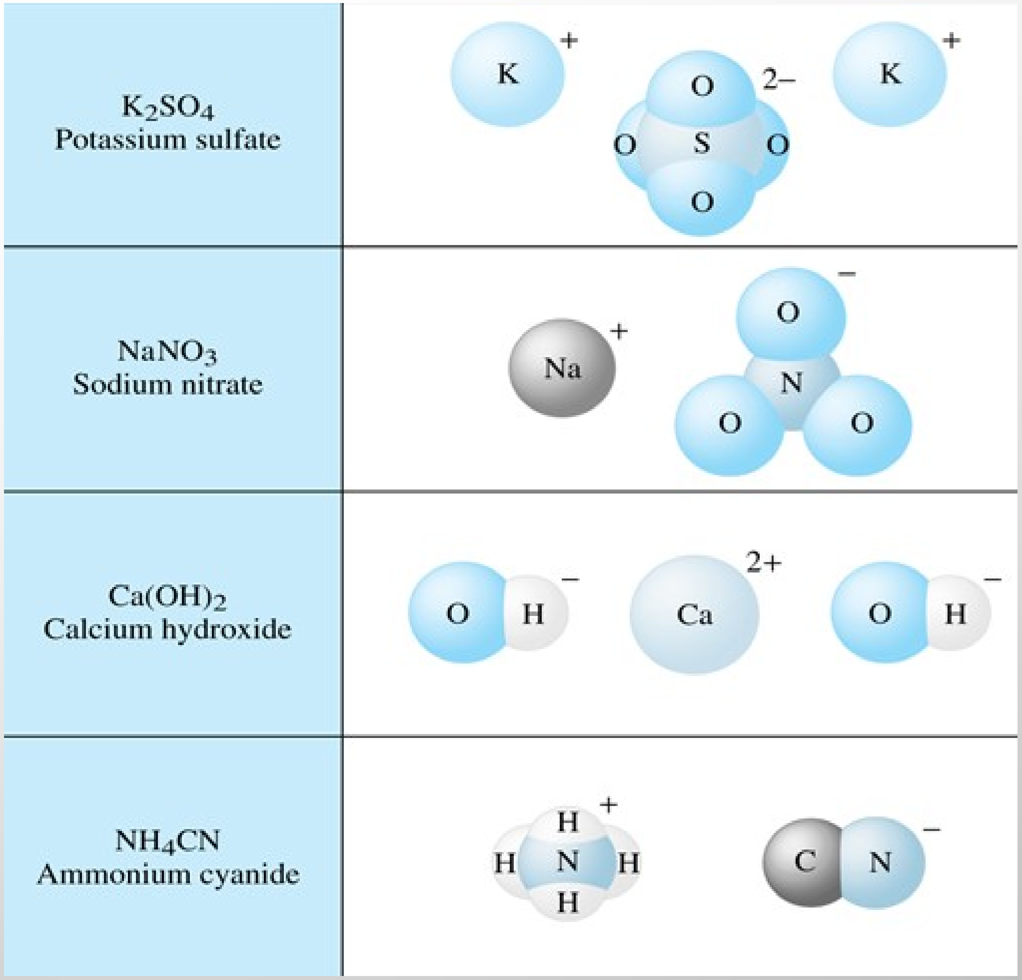
- METALS FROM GROUPS IA, IIA, AND IIIA OF THE PERIODIC TABLE FORM IONS WITH 1+, 2+, AND 3+ RESPECTIVELY.
- NONMETALS FROM GROUPS VA, VIA, AND VIIA OF THE PERIODIC TABLE FORM IONS WITH 3-, 2-, AND 1- RESPECTIVELY

General Formulas for Ionic Compounds as a Function of Periodic Table Position of the Metal and Nonmetal

	Nonmetals (X)		
Metals (M)	VIIA (−1 ions)	VIA (−2 ions)	VA (−3 ions)
IA (+1 ions)	MX	M_2X	M_3X
IIA (+2 ions)	MX_2	MX	M_3X_2
IIIA (+3 ions)	MX_3	M_2X_3	MX

POLYATOMIC IONS

- A POLYATOMIC ION IS AN ION FORMED FROM A GROUP OF ATOMS, HELD TOGETHER WITH COVALENT BONDS, THAT LOSE OR GAIN ELECTRONS AS A GROUP.



COVALENT BONDING

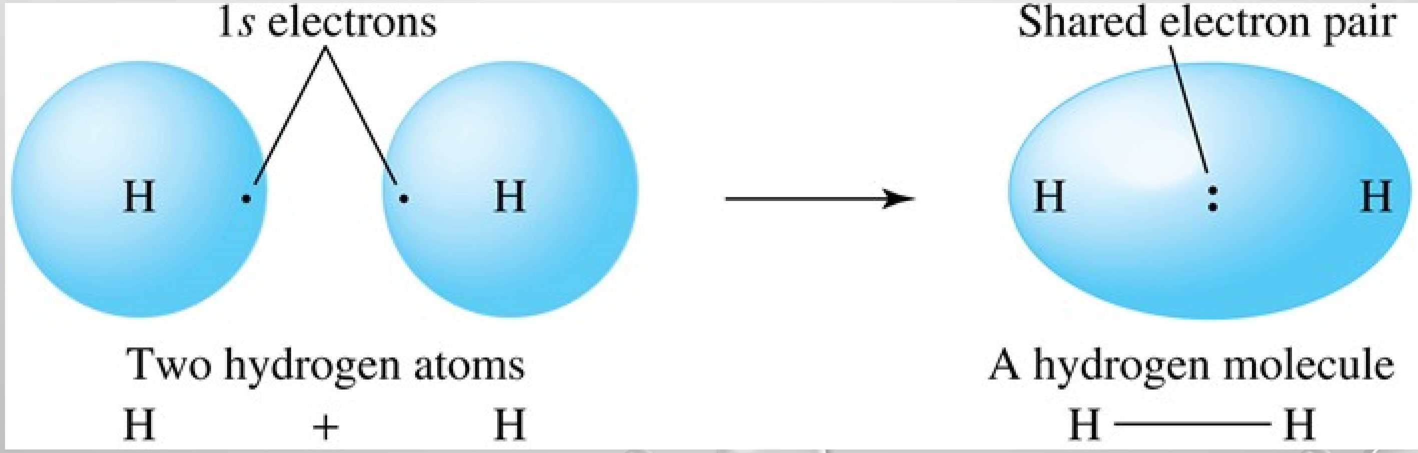
- COVALENT BONDS FORM BETWEEN TWO NONMETAL ATOMS (CAN BE THE SAME NONMETAL).
- COVALENT BONDS SHARE VALENCE ELECTRONS.
- THE **MOLECULE** IS THE BASIC STRUCTURAL UNIT OF COVALENT COMPOUNDS.
- **MOLECULAR COMPOUNDS** MAY BE SOLIDS, LIQUIDS OR GASES.
- **MOLECULAR COMPOUNDS** WHICH ARE WATER SOLUBLE GENERALLY DO NOT CONDUCT ELECTRICITY.
  - REMEMBER FROM LAB, SUGAR DID NOT CONDUCT ELECTRICITY.

COVALENT BONDING

COVALENT BOND IS A CHEMICAL BOND RESULTING FROM TWO NUCLEI ATTRACTING THE SAME SHARED ELECTRONS.

AS ATOMS COME TOGETHER, ORBITALS OVERLAP TO GIVE A COMMON ORBITAL.

ELECTRONS LIKE TO HANG OUT IN THE MIDDLE.



DRAWING LEWIS STRUCTURES FOR COVALENTLY BONDED SPECIES

1. DETERMINE THE TOTAL NUMBER OF VALENCE ELECTRONS IN THE MOLECULE OR ION. IF THE SPECIES IS CATION SUBTRACT APPROPRIATE NUMBER OF ELECTRONS, IF SPECIES IS ANION THEN ADD AN APPROPRIATE NUMBER OF ELECTRONS.
2. DETERMINE THE ARRANGEMENT OF ATOMS. (H IS ALWAYS A TERMINAL ATOM).
3. DIVIDE THE TOTAL VALENCE ELECTRONS BY 2 TO FIND THE NUMBER OF ELECTRON PAIRS IN THE MOLECULE.
4. SURROUND THE CENTRAL ATOM WITH 4 ELECTRON PAIRS. PLACE THE REMAINING ELECTRON PAIRS TO COMPLETE THE OCTET AROUND THE OTHER ATOMS, **(EXCEPT H).**

DRAWING LEWIS STRUCTURES FOR COVALENTLY BONDED SPECIES

5. PLACE REMAINING ELECTRON PAIRS ON TERMINAL ATOMS UNTIL EACH ONE HAS AN OCTET. SUBTRACT WHAT YOU USE FROM THE TOTAL.

6. ELECTRON PAIRS THAT ARE SHARED BY ATOMS ARE CALLED ***BONDING ELECTRONS***. THE OTHER ELECTRONS COMPLETE OCTETS AND ARE CALLED ***NONBONDING ELECTRONS***, OR LONE PAIRS.

7. IF THERE ARE NOT ENOUGH ELECTRON PAIRS TO PROVIDE EACH ATOM WITH AN OCTET, MOVE A NONBONDING ELECTRON PAIR BETWEEN TWO ATOMS THAT ALREADY SHARE AN ELECTRON PAIR.

COVALENT BONDING

ATOMS CAN HAVE **BONDING ELECTRONS** AND **NONBONDING ELECTRONS**.

BONDING ELECTRONS ARE PAIRS OF VALENCE ELECTRONS THAT ARE SHARED BETWEEN ATOMS.

NONBONDING ELECTRONS ARE THOSE THAT DO NOT PARTICIPATE IN BONDING.

COVALENT BONDING

USING LEWIS STRUCTURES:

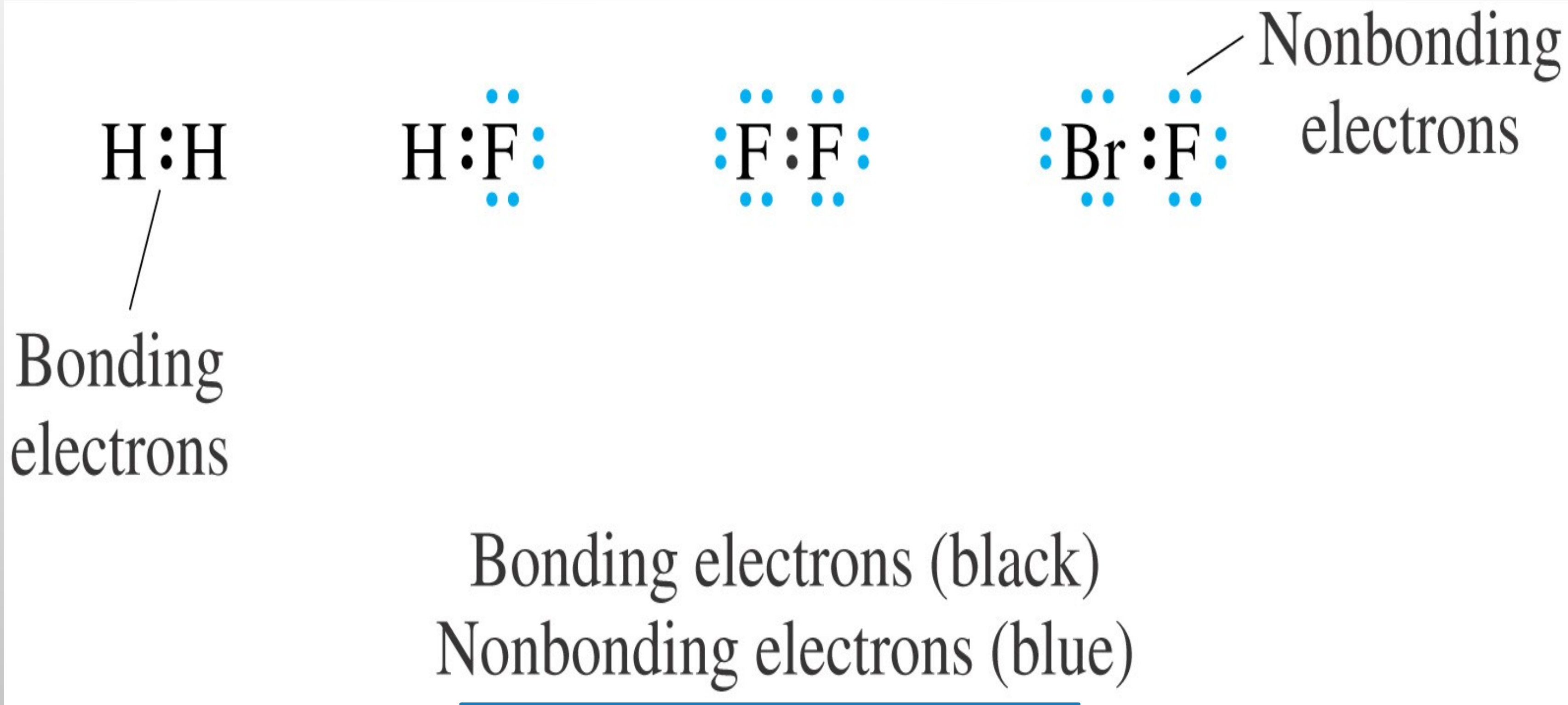
HYDROGEN H

CHLORINE Cl

EACH HAS ONE BONDING ELECTRON.

CHLORINE HAS 3 NONBONDING ELECTRON PAIRS

COVALENT BONDING

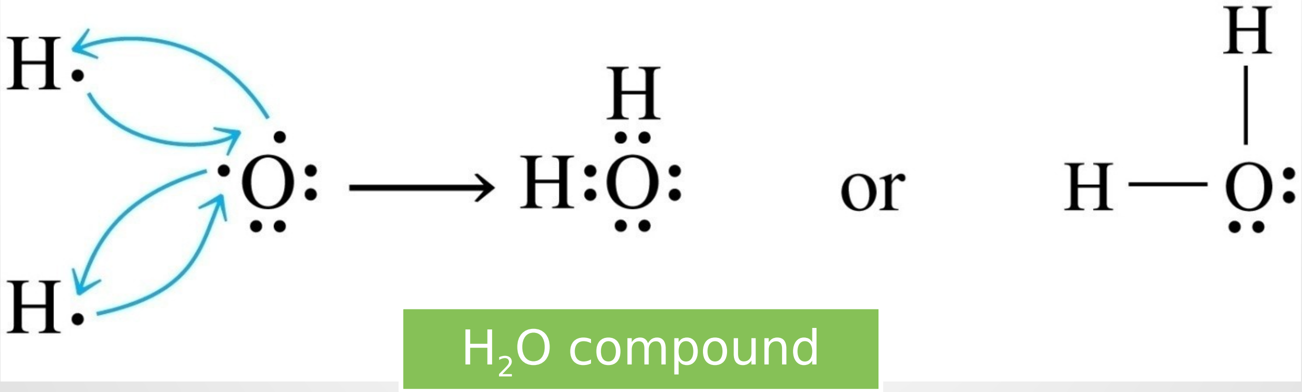


EXAMPLE

COVALENT BONDING

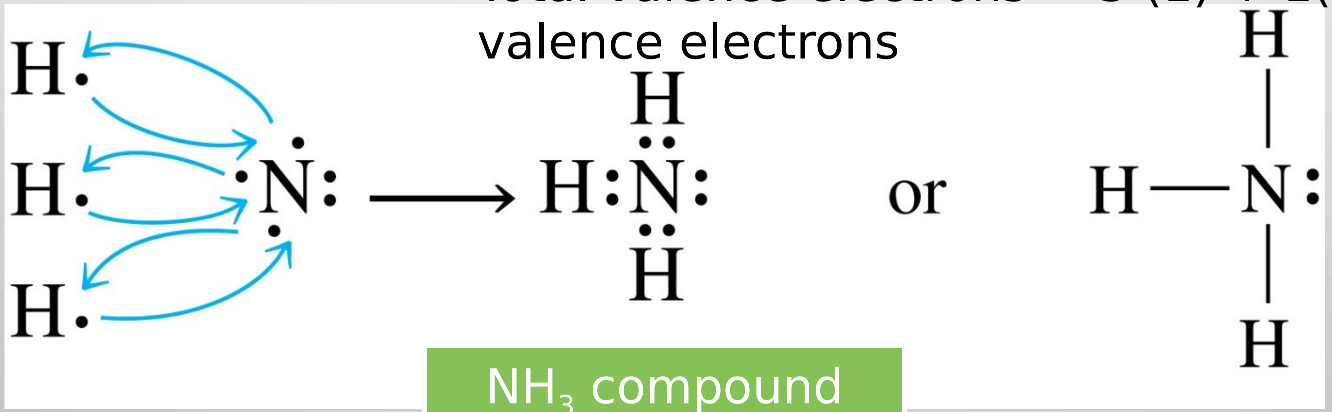
CREATING LEWIS STRUCTURES WITH LEWIS SYMBOLS:

Total valence electrons 2 (1) + 1 (6) = 8 valence electrons



H_2O compound

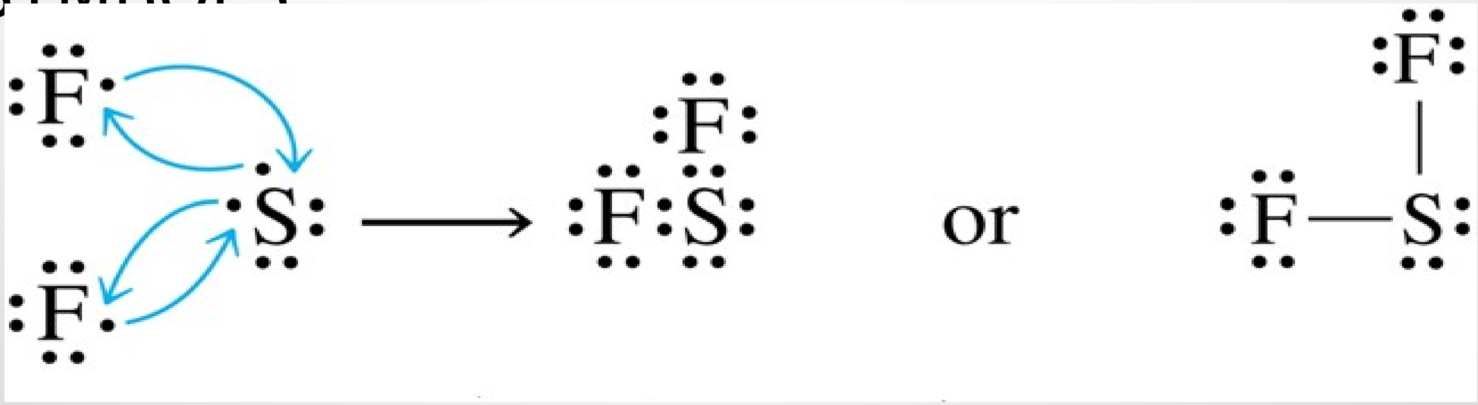
Total valence electrons = 3 (1) + 1(5) = 8 valence electrons



NH_3 compound

COVALENT BONDING

CREATING LEWIS STRUCTURES WITH LEWIS SYMBOLS:

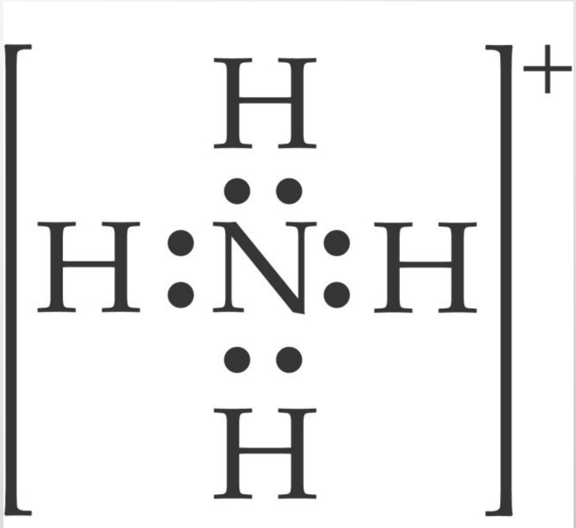


- NOTICE THAT THE **BONDING PAIR** CAN BE REPRESENTED USING DOTS OR A DASH. **NONBONDING PAIRS** REMAIN DOTS.

ELECTRON DOT FORMULA FOR NH_4^+

1. THE TOTAL NUMBER OF VALENCE ELECTRONS IS 5 + 4(1) – 1 = 8 e^-. WE MUST SUBTRACT ONE ELECTRON FOR THE POSITIVE CHARGE. WE HAVE 4 PAIRS OF ELECTRONS.

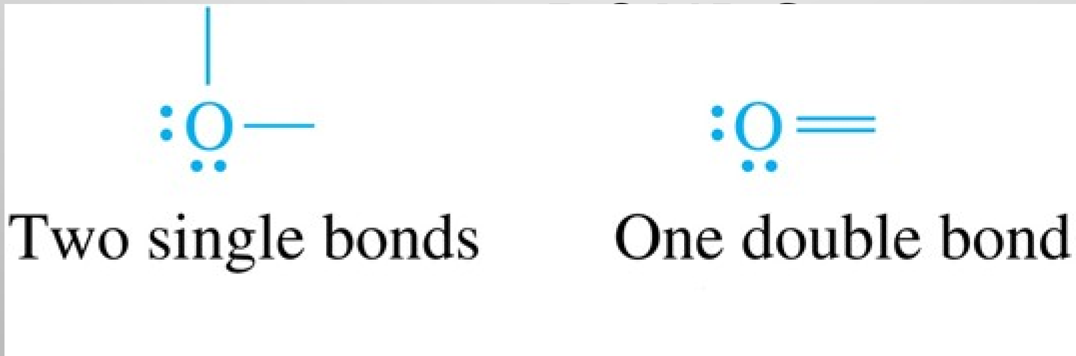
2. Place 4 electron pairs around the central nitrogen atom and attach the four hydrogens.
3. Enclose the polyatomic ion in brackets and indicate the charge outside the brackets.



COVALENT BONDING – MULTIPLE BONDS

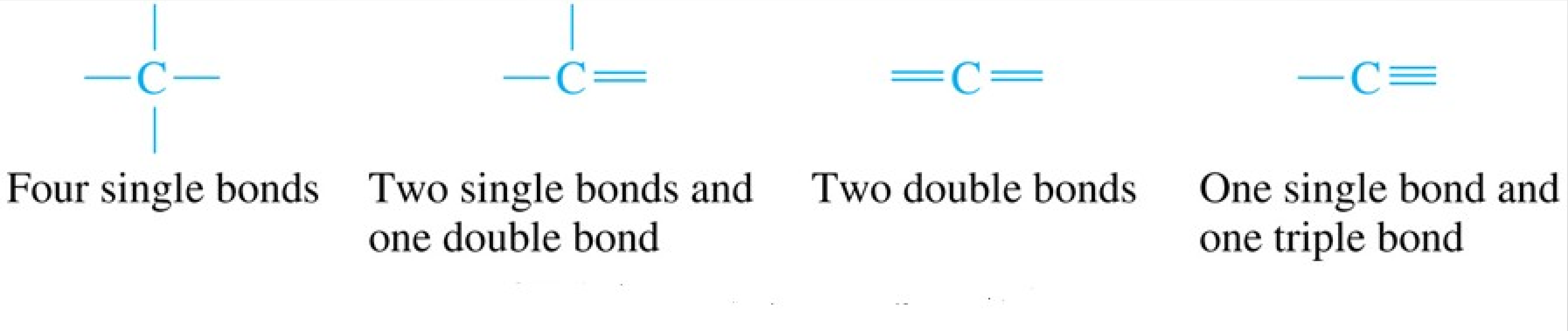
COVALENT COMPOUNDS CAN FORM SINGLE, DOUBLE OR TRIPLE BONDS BY SHARING 1, 2 OR 3 PAIRS OF ELECTRONS. HOW MANY IS DETERMINED BY THE VALENCE ELECTRONS.

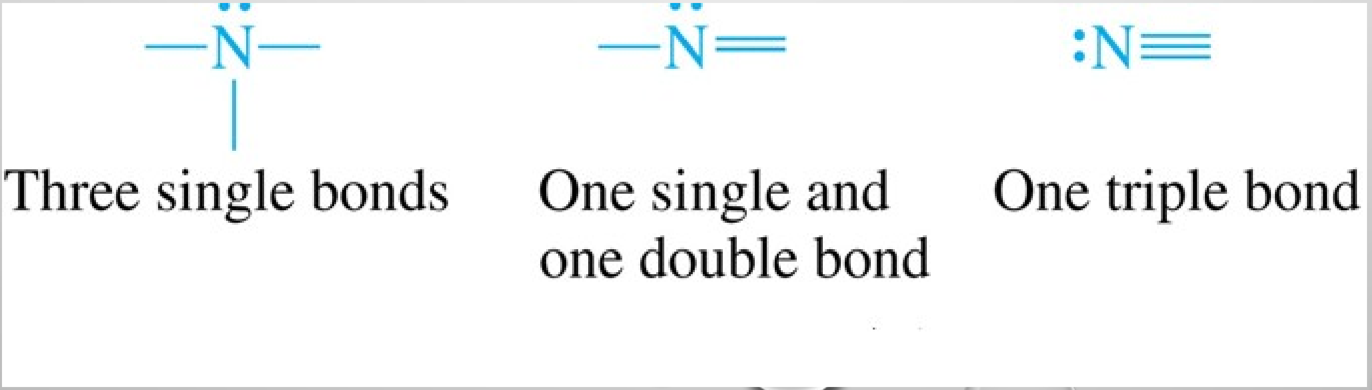
OXYGEN CAN MAKE SINGLE OR DOUBLE



COVALENT BONDING – MULTIPLE BONDS

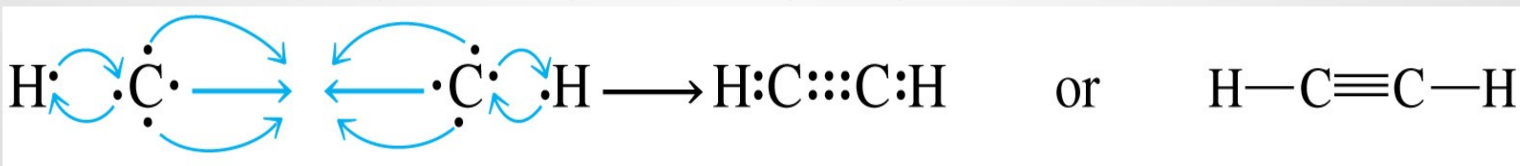
CARBON AND NITROGEN CAN MAKE ALL THREE TYPES OF BONDS





COVALENT BONDING – MULTIPLE BONDS

- ACETYLENE HAS A TRIPLE BOND BETWEEN THE TWO CARBON ATOMS:



Rearrangement of electrons to form double or triple bonds

- HYDROGEN CYANIDE HAS A TRIPLE BOND BETWEEN CARBON AND NITROGEN.

$$\mathrm{H{:}C{:}{:}{:}N{:}} \quad \text{or} \quad \mathrm{H{-}C{\equiv}N{:}}$$

COVALENT LEWIS STRUCTURE PRACTICE

- CH_4
- C_2H_4
- N_2H_4
- HCN

Can you do these ?

MOLECULAR GEOMETRY AND VSEPR

NOW THAT YOU CAN WRITE A LEWIS STRUCTURE, WHAT **SHAPE** DOES THE MOLECULE HAVE?

- MOLECULAR GEOMETRY IS A DESCRIPTION OF THE THREE-DIMENSIONAL ARRANGEMENT OF ATOMS WITHIN A MOLECULE.
- MOLECULAR GEOMETRY PLAYS AN IMPORTANT ROLE IN DETERMINING THE PHYSICAL AND CHEMICAL PROPERTIES OF SUBSTANCES.

MOLECULAR GEOMETRY AND VSEPR

- VSEPR – VALENCE SHELL ELECTRON PAIR REPULSION THEORY IS A SET OF PROCEDURES FOR PREDICTING THE GEOMETRY OF A MOLECULE FROM THE INFORMATION IN THE MOLECULES LEWIS STRUCTURE.
- NONBONDING ELECTRON PAIRS AND THE NUMBER OF ATOMS BONDED TO AN ATOM DETERMINE THE GEOMETRY OF THE MOLECULE AROUND THAT ATOM.
- NEED TO KNOW THE NUMBER OF ELECTRON GROUPS.

MOLECULAR GEOMETRY AND VSEPR

BASICALLY, ALL ELECTRON GROUPS WANT TO BE AS FAR AWAY FROM EACH OTHER AS POSSIBLE.

- THE ELECTRONS ALL CARRY A NEGATIVE CHARGE AND LIKE CHARGES REPEL EACH OTHER.
- THINK ABOUT THIS IN TERMS OF PUTTING TWO NORTH POLES OF A MAGNET NEXT TO EACH OTHER.

MOLECULAR GEOMETRY AND VSEPR

- A VSEPR ELECTRON GROUP IS A GROUP OF VALENCE ELECTRONS PRESENT IN A LOCALIZED REGION ABOUT AN ATOM OR MOLECULE.
  - THIS IS SLIGHTLY DIFFERENT THAN AN ELECTRON PAIR.

:N N· O : CENTRAL ATOM HAS TWO VSEPR ELECTRON GROUP (SINGLE BOND AND TRIPLE BOND)

:O S O: CENTRAL ATOM HAS THREE VSEPR ELECTRON GROUPS (SINGLE BOND, DOUBLE BOND AND NON-BONDING ELECTRON PAIR)

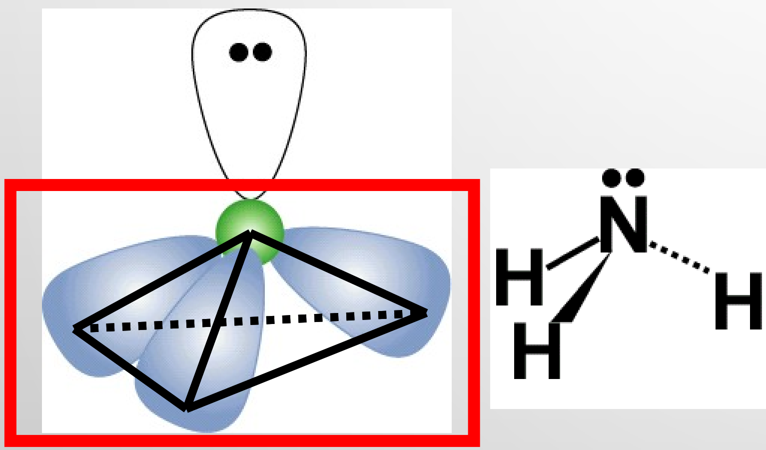
H O H CENTRAL ATOM HAS 4 VSEPR ELECTRON GROUP(2 SINGLE & 2NB)

MOLECULAR GEOMETRY AND VSEPR

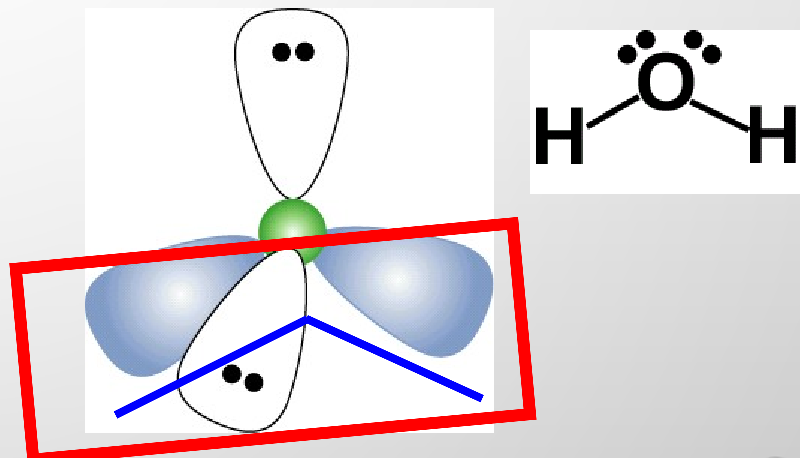
1. ATOMS ARRANGE THEMSELVES TO MINIMIZE ELECTRON PAIR REPULSION (GET THE PAIRS AS FAR APART AS POSSIBLE)
2. NO DISTINCTION IS MADE BETWEEN BONDING ELECTRONS (SHARED) AND NON-BONDING ELECTRONS (LONE PAIRS)
3. SINGLE, DOUBLE AND TRIPLE BONDS ARE ALL COUNTED EQUALLY AS ONE “PAIR” – ONE THING ATTACHED TO THE CENTRAL ATOM.

MOLECULAR GEOMETRY AND VSEPR

- **NON-BONDING ELECTRONS CONTRIBUTE TO THE SHAPE OF THE MOLECULE BUT ARE INVISIBLE.**



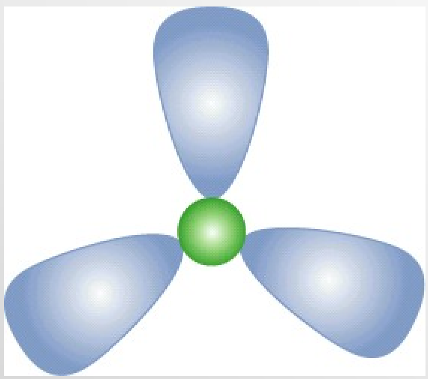
Trigonal Pyramidal

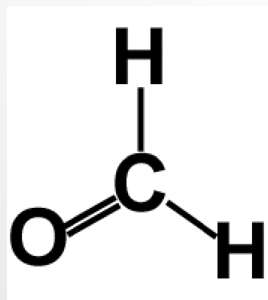


Bent (or Angular)

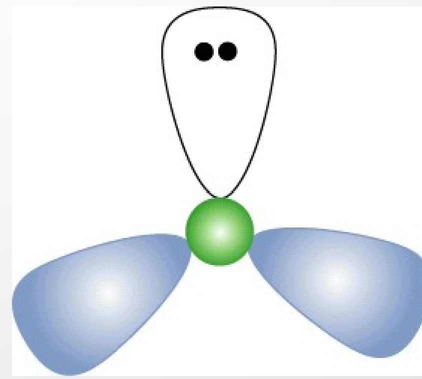
MOLECULAR GEOMETRY

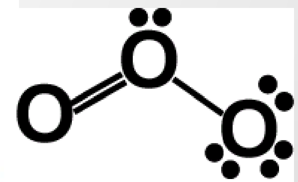
- Molecules with 2 or 3 VSEPR pairs are planar.



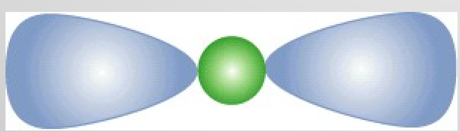


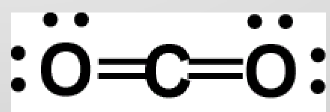
Trigonal Planar





Bent



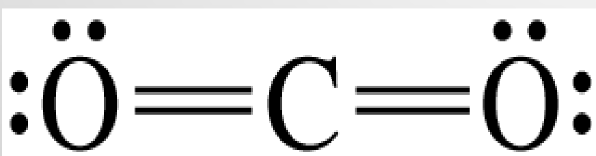


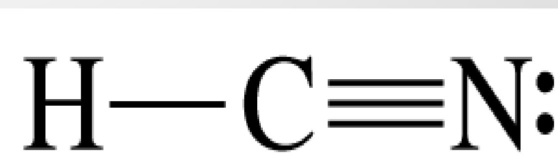
Linear

VSEPR

WHEN THE ELECTRON PAIRS ARE 180° APART,

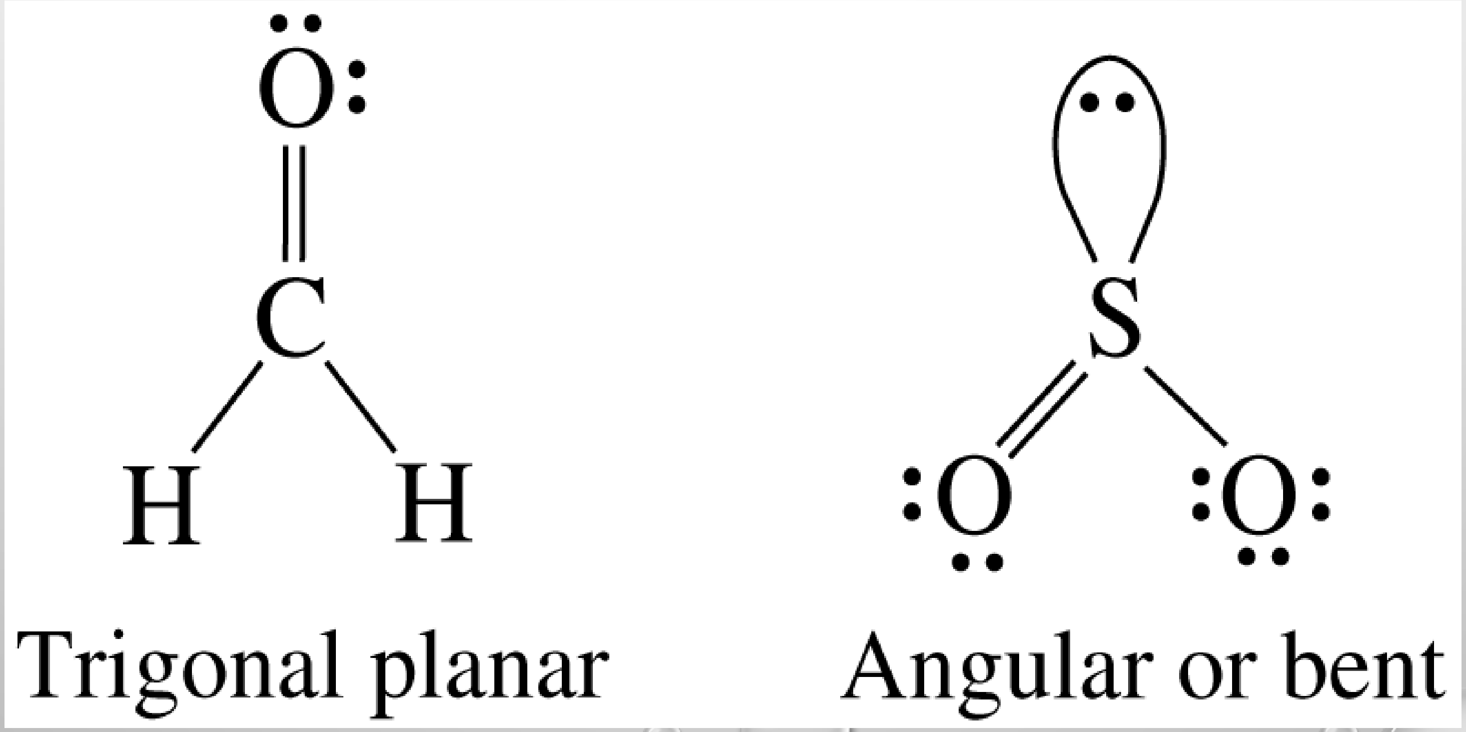
THE MOLECULAR GEOMETRY WILL BE LINEAR.





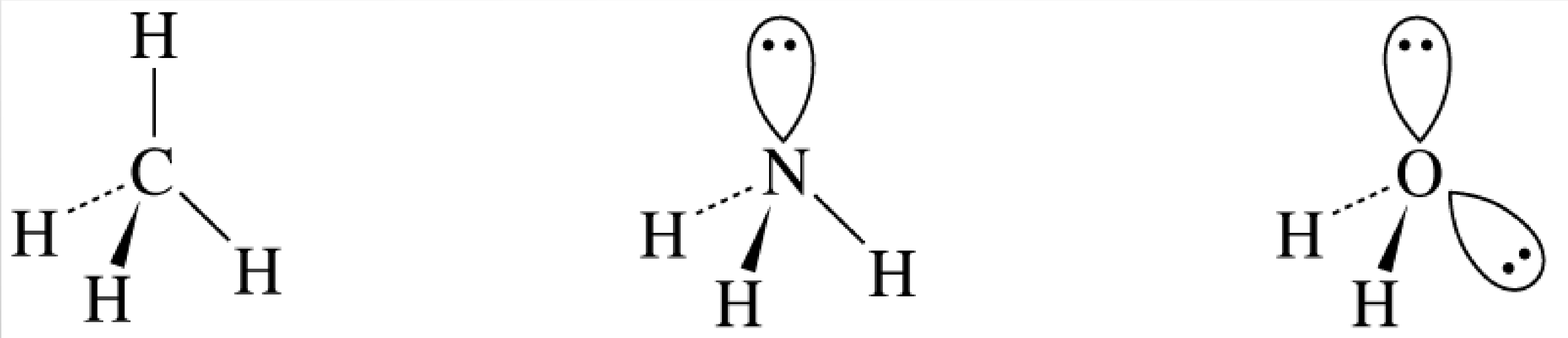
VSEPR

- When the electron pairs are 120° apart, the molecular geometry will be either trigonal planar or angular (bent).



VSEPR

WHEN THE ELECTRON PAIRS ARE 109.5° APART, THE MOLECULAR GEOMETRY WILL BE ONE OF THREE POSSIBILITIES…



Tetrahedral **Trigonal Pyramidal** **Bent**

Formula	VESPR Groups	Shape
XB_2	2	Linear
XB_3	3	Trigonal planar
XB_2N_1	3	Bent
XB_4	4	Tetrahedral
XB_3N_1	4	Trigonal pyramidal
XB_2N_2	4	bent

X = central atom; B = bonding electron groups
N = nonbonding electron groups

ELECTRONEGATIVITY

- MEASURE OF THE **RELATIVE ATTRACTION** THAT AN ATOM HAS FOR THE *SHARED ELECTRONS* IN A BOND.
- THE *GREATER* THE ELECTRONEGATIVITY THE *GREATER* THE ELECTRON ATTRACTION.
- <u>FLUORINE</u> IS THE MOST ELECTRONEGATIVE ELEMENT AND WAS ASSIGNED A VALUE OF 4.0.
- ALL OTHER ELEMENTS ARE GIVEN ELECTRONEGATIVITY VALUES BASED ON HOW ELECTRONEGATIVE THEY ARE COMPARED TO FLUORINE.

ELECTRONEGATIVITY

Electronegativity Increases

H 2.1																	He –
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne –
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Ar –
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 1.8	Ni 1.8	Cu 1.8	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8	Kr –
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	Xe –
Cs 0.7	Ba 0.9	57–71 1.1–1.2	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 1.8	Bi 1.9	Po 2.0	At 2.2	Rn –
Fr 0.7	Ra 0.9																

BOND POLARITY

IF ATOMS HAVE DIFFERENT ELECTRONEGATIVITY, IT FOLLOWS THAT THE BONDS THEY MAKE MAY NOT ALL BE EQUAL.

BOND POLARITY IS THE MEASURE OF THIS DEGREE OF INEQUALITY IN THE SHARING OF ELECTRONS IN A CHEMICAL BOND.

BOND POLARITY

- SOME BONDS DO *HAVE EQUAL SHARING* OF ELECTRONS – THESE ARE CALLED **NONPOLAR COVALENT BONDS.**

- WHERE THE ATOMS DO NOT *HAVE EQUAL SHARING* OF ELECTRONS – ELECTRONEGATIVITY DIFFERENCES CREATE A **POLAR COVALENT BOND**. THE POLARITY IS REPRESENTED WITH A “D-” OR “D+” FOR NEGATIVE AND POSITIVE RESPECTIVELY.

  THIS **POLAR COVALENT BOND** CREATES A POLARITY IN THE RESULTING *MOLECULE* AND INFLUENCES THE RESULTING PROPERTIES OF THE MOLECULE.

BOND POLARITY

- REMEMBER THE ELECTRONEGATIVITY TABLE –
  - IT CAN BE USED TO CALCULATE A ROUGH MEASURE OF THE BOND POLARITY.

H = 2.1

Cl = 3.0

DIFFERENCE: 0.9; A POLAR COVALENT BOND

HCl

Δ+ Δ–

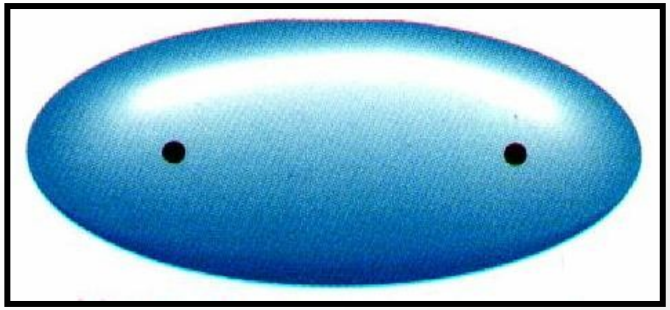
  - THE GREATER THE DIFFERENCE, THE MORE POLAR THE BOND.

BOND POLARITY

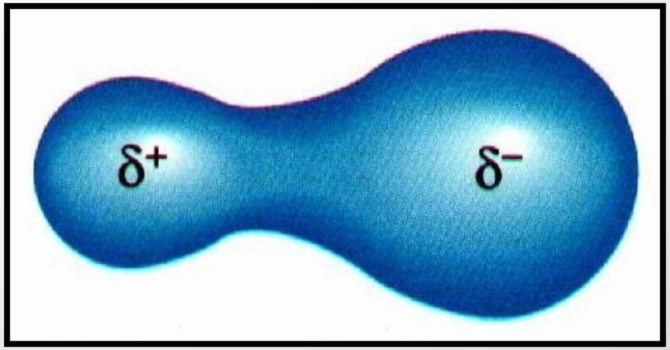
- IF THE ELECTRONEGATIVITY DIFFERENCE IS LESS THAN 0.4, THE BOND IS NONPOLAR COVALENT.
- IF THE ELECTRONEGATIVITY DIFFERENCE IS GREATER THAN 0.4 BUT LESS THAN 2 THE BOND IS POLAR COVALENT.
- IF THE ELECTRONEGATIVITY DIFFERENCE IS 2.0 OR MORE THAN 2.0 THE BOND IS CONSIDERED IONIC.

BOND POLARITY

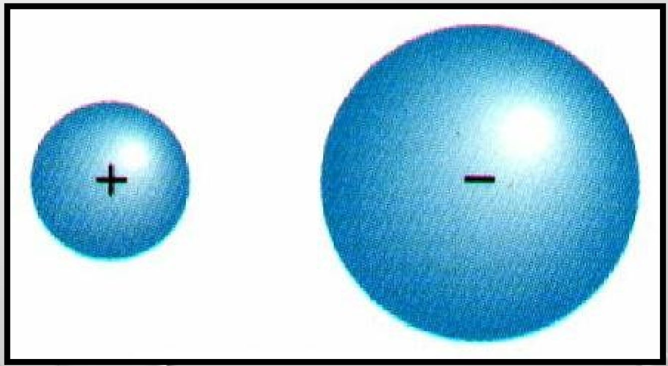
- **Nonpolar Covalent**



- **Polar Covalent**

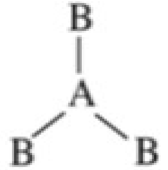
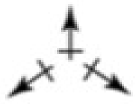
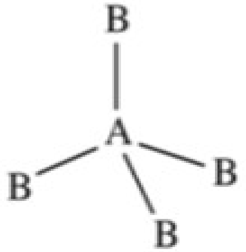


- **Ionic**



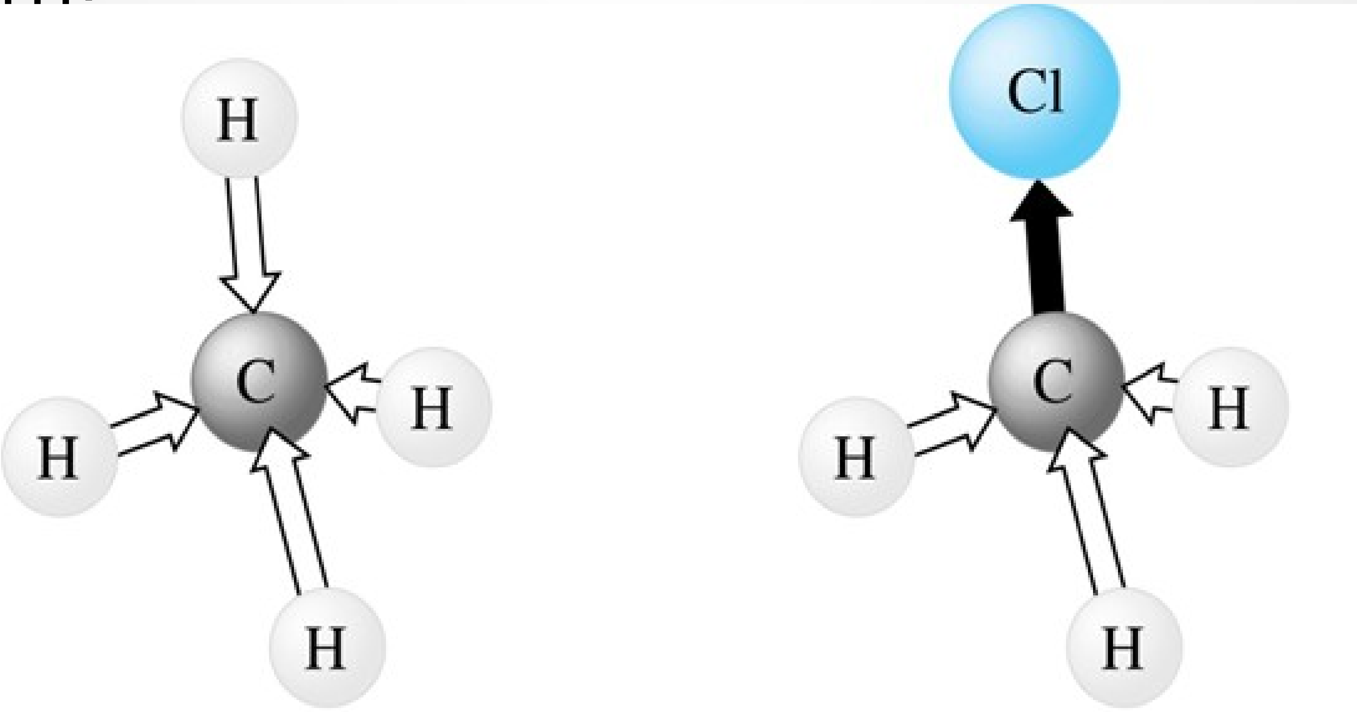
MOLECULAR POLARITY

IF THE BONDS HAVE POLARITY, ARE THE MOLECULE ALSO POLAR? ANS -SOMETIMES THE POLARITY “CANCELS” OUT:

Type		Cancellation of Polar Bonds	Example
Linear molecules with two identical bonds	B—A—B		CO_2
Trigonal planar molecules with three identical bonds			SO_3
Tetrahedral molecules with four identical bonds			CH_4

MOLECULAR POLARITY

- SOMETIMES THE POLARITY DOESN'T "CANCEL" OUT:



(a) CH_4, a nonpolar molecule (b) CH_3Cl, a polar molecule

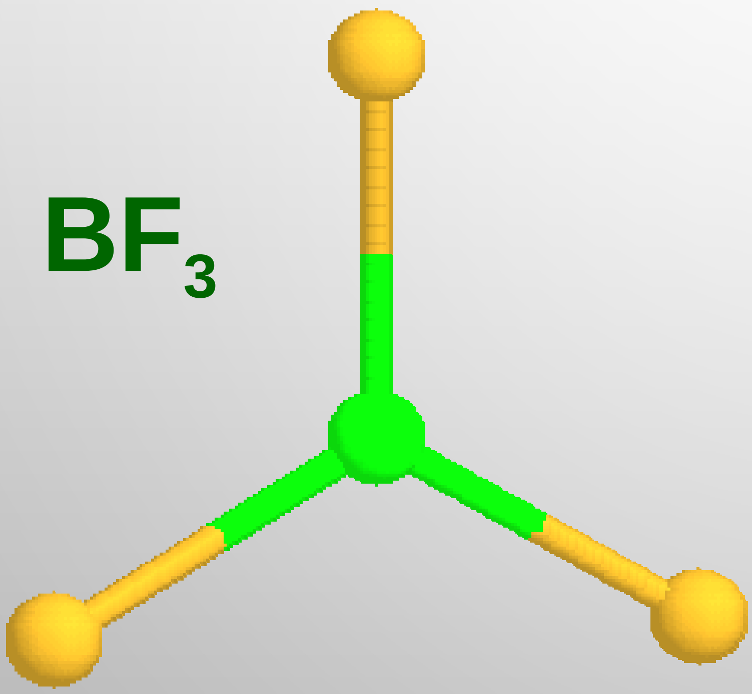
MOLECULAR POLARITY

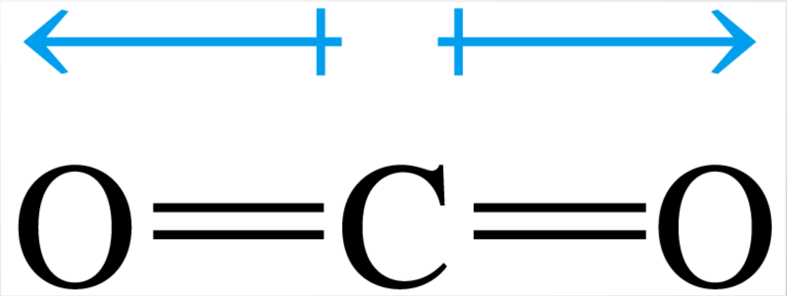
- MOLECULAR POLARITY IS A MEASURE OF THE DEGREE OF INEQUALITY IN THE ATTRACTION OF BONDING ELECTRONS TO VARIOUS LOCATIONS WITH A MOLECULE.
  - A **POLAR** MOLECULE HAS AN UNSYMMETRICAL CHARGE DISTRIBUTION.
  - A **NONPOLAR** MOLECULE HAS A SYMMETRICAL CHARGE DISTRIBUTION.
- MOLECULAR GEOMETRY AND BOND POLARITY DETERMINE MOLECULAR POLARITY.

DETERMINING MOLECULAR POLARITY

- **Nonpolar Molecules**
  - Dipole moments are symmetrical and cancel out.

BF_3



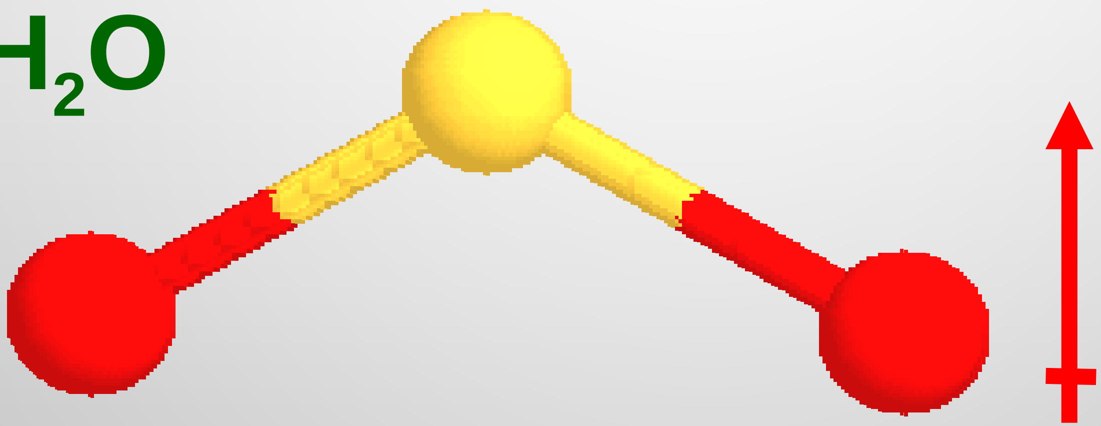


- + -

DETERMINING MOLECULAR POLARITY

- **Polar Molecules**
  - Dipole moments are asymmetrical and don’t cancel .

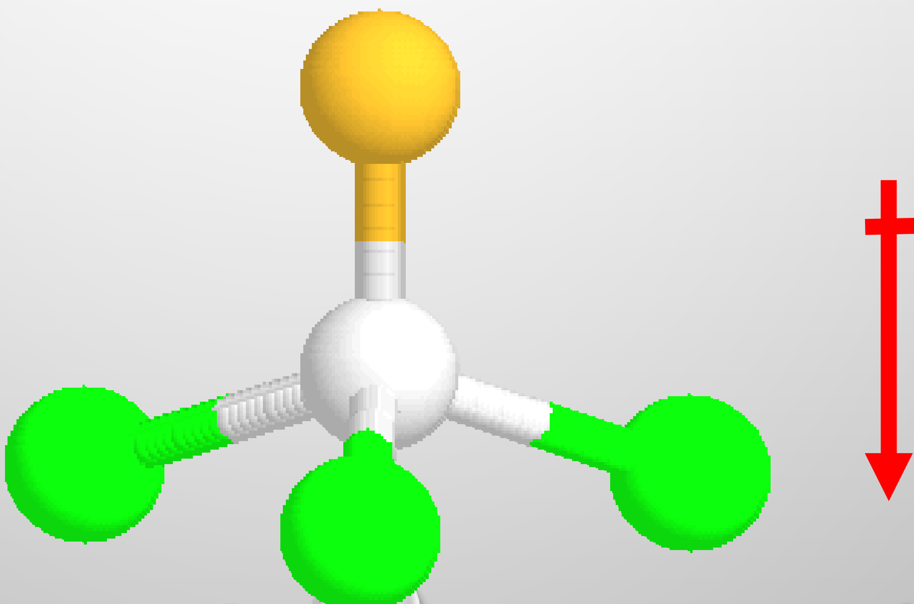
H_2O



DETERMINING MOLECULAR POLARITY

- **Therefore, polar molecules have...**
  - asymmetrical shape (lone pairs) or
  - asymmetrical atoms

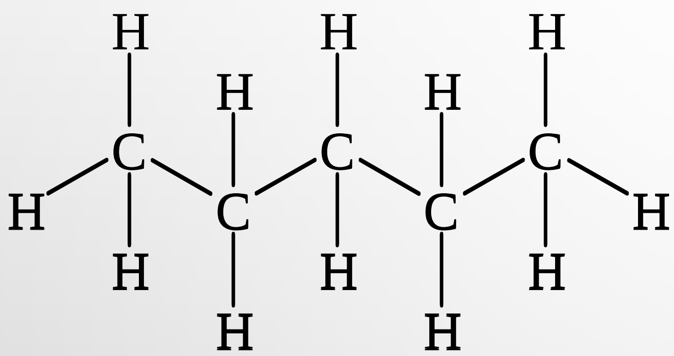
$CHCl_3$



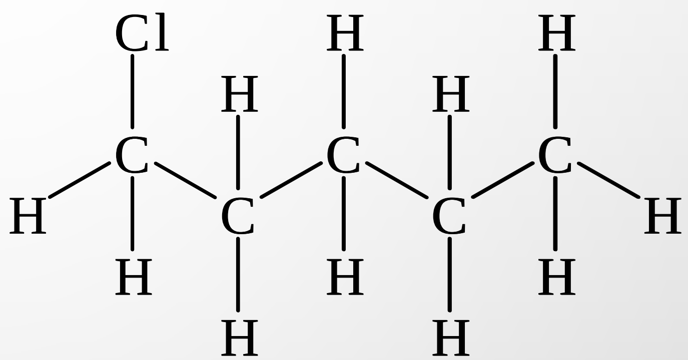
net dipole moment

POLARITY OF MORE COMPLEX MOLECULES

Pentane



1-chloropentane



Nonpolar - no distinctive polarity - C ~ H for Electronegativity

Polar - one of the carbons has a Cl group, so at least one end of the molecule has some polarity