Chemical Bonding

Chemical Bonds

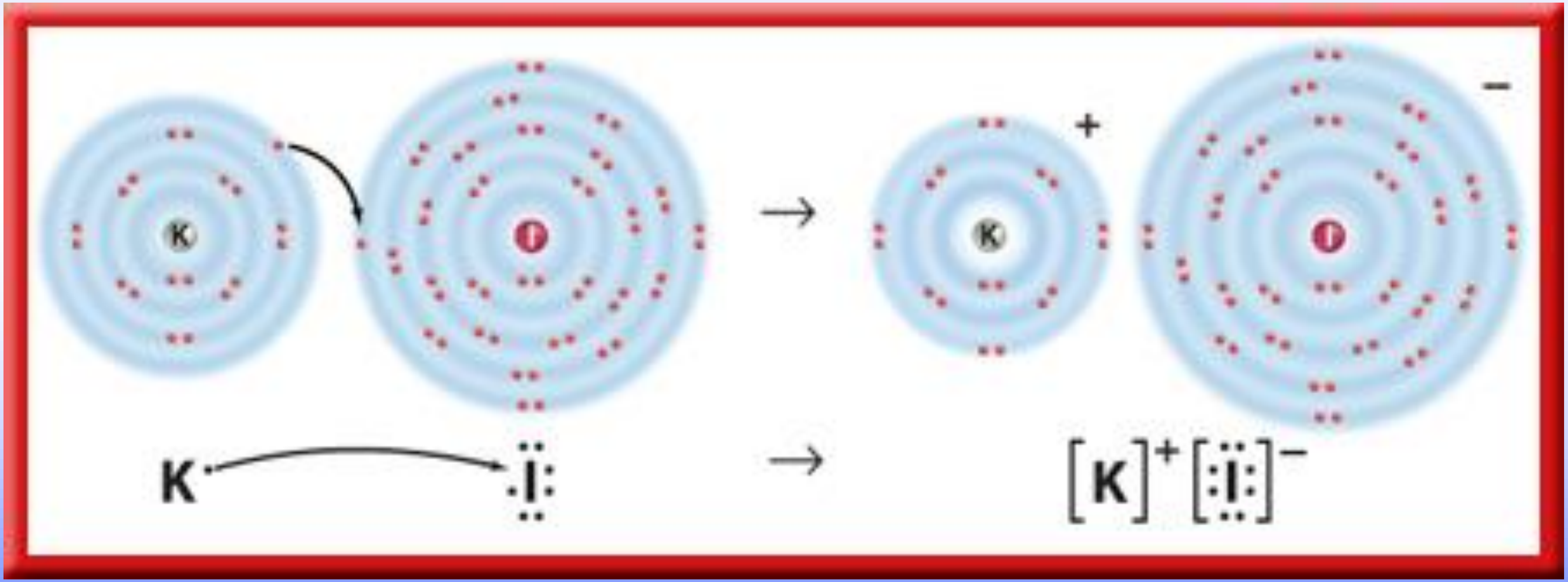
- Forces that hold atoms together
- **Ionic bonds** are the forces of attraction between ions
  - ions formed by electron transfer
  - electrostatic forces
- **Covalent bonds** are the forces of attraction between two atoms which are sharing electrons

Ionic Bonds

- Results from reaction between Metal and Nonmetal
- Metal loses electrons to form cation, Nonmetal gains electrons to form anion
- Ionic bond is the attraction between a positive ion and negative ion
- Larger Charge = Stronger Attraction
- Smaller Ion = Stronger Attraction
- ***No bond is 100% ionic!!***
- Electrostatic attraction nondirectional
  - no direct anion-cation pair, **No ionic molecule**
    - chemical formula is empirical formula, simply giving the ratio of ions based on charge balance
- Ions arranged in a pattern called a **crystal lattice**
    - maximizes attractions between + and - ions

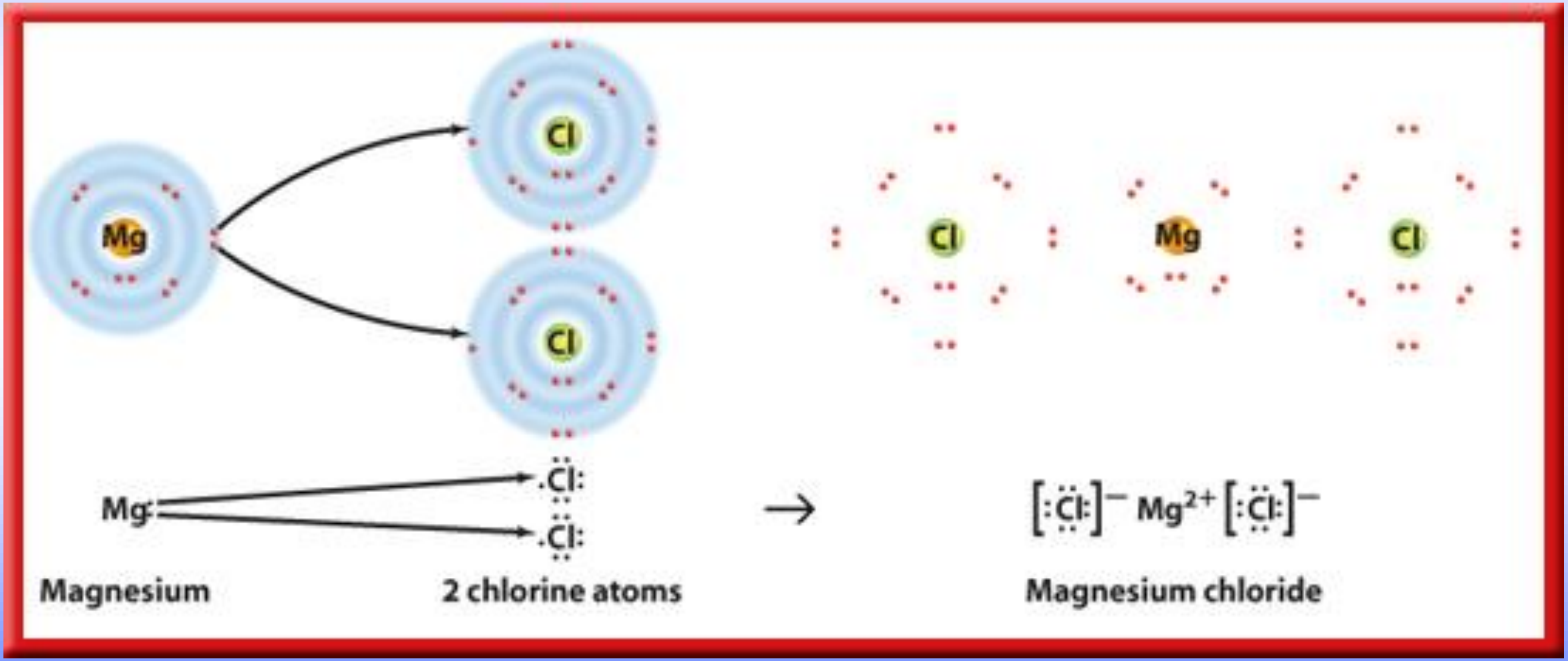
Ionic Bonds

- Ionic bonds usually are formed by bonding between metals and nonmetals.



Ionic Bonds

- One cation can bond to multiple (more than one) anion



IONic Bonding

- electrons are transferred between valence shells of atoms
- ionic compounds are made of ions

NOT MOLECULES

- ionic compounds are called Salts or Crystals

IONic bonding

- **Always** formed between metals and non-metals

[METALS]$^{+}$ [NON-METALS]$^{-}$

Lost e^{-}

Gained e^{-}

Properties of Ionic Compounds

- hard solid @ 22^{o}C
- high mp temperatures
- **good** conductors in liquid phase or dissolved in water (aq)

Covalent Bonds

- Typical of molecular substances
- Atoms bond together to form molecules
  - strong attraction
- **Sharing pairs of electrons**
- Molecules attracted to each other weakly
- Often found between nonmetal atoms

Covalent Bonds

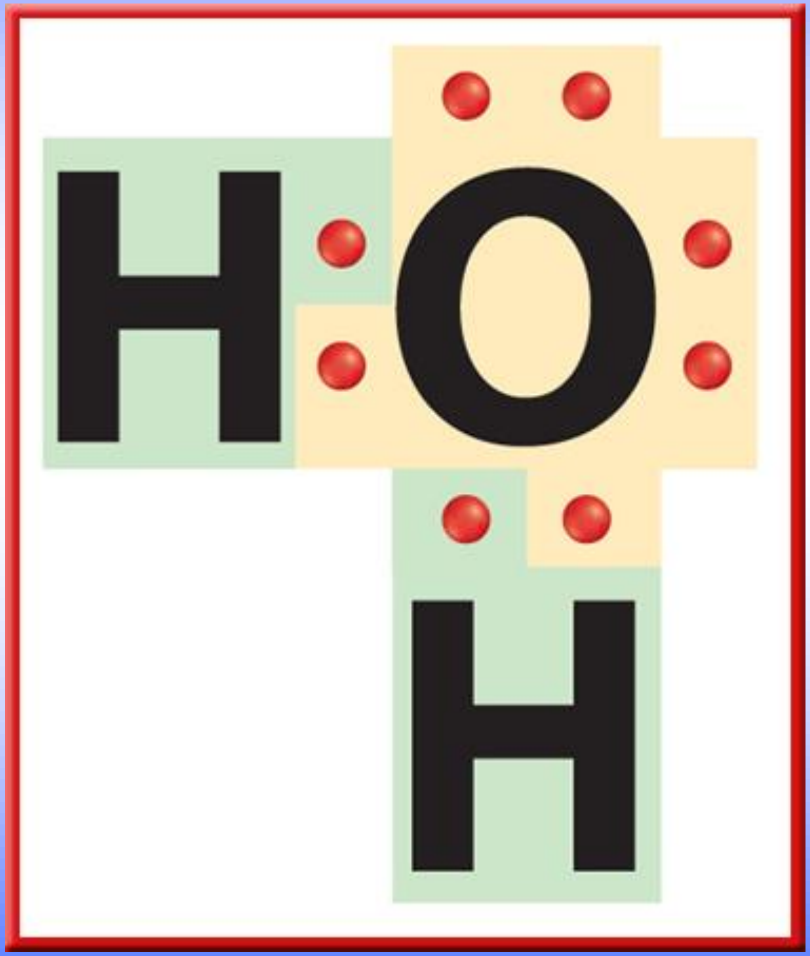
- Each shared pair represented as a line in a structural formula

→ Example: H - H

*this is a single covalent bond

**Goal of bonding is to fill the outer energy level and become stable

Covalent Bonds – Electron dot diagrams



- Each hydrogen shares one pair of electrons with the oxygen atom

Covalent Bonding

- **Pairs** of e- are **shared** between **non-metal** ator

molecules

- electronegativity *difference* **< 2.0**
- forms polyatomic ions

Properties of Molecular Substances

Covalent bonding

- **Low m.p. temp and b.p. temps**
- relatively **soft solids** as compared to ionic compounds
- **nonconductors** of electricity in any phase

Electronegativity

- Measure of the ability of an atom to attract shared electrons
  - Larger electronegativity means atom attracts more strongly
  - Values 0.7 to 4.0
- Increases across period (left to right) on Periodic Table
- Decreases down group (top to bottom) on Periodic Table
- Larger difference in electronegativities means more polar bond

Increasing electronegativity

Decreasing electronegativity

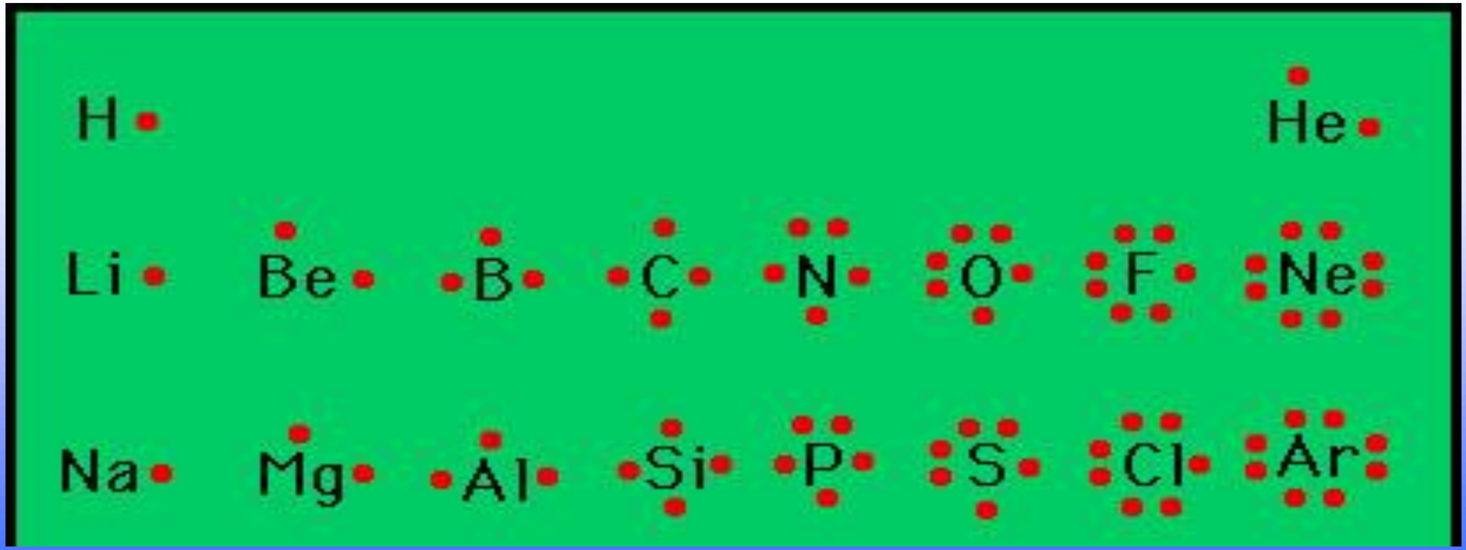
				H 2.1												
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.9	Ni 1.9	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	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										

Key

- < 1.5
- 1.5–1.9
- 2.0–2.9
- 3.0–4.0

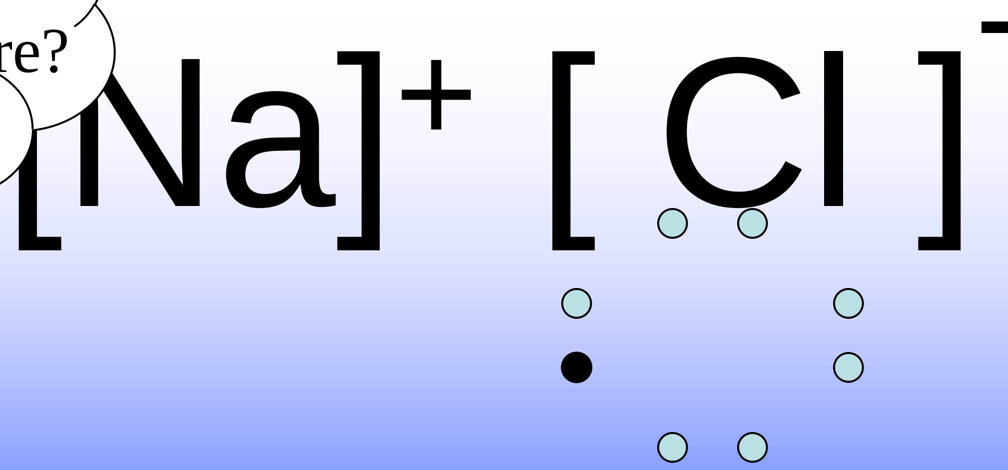
Drawing ionic compounds using Lewis Dot Structures

- Symbol represents the KERNEL of the atom (nucleus and inner e-)
- dots represent valence e^-



NaCl

- This is the finished Lewis Dot Structure



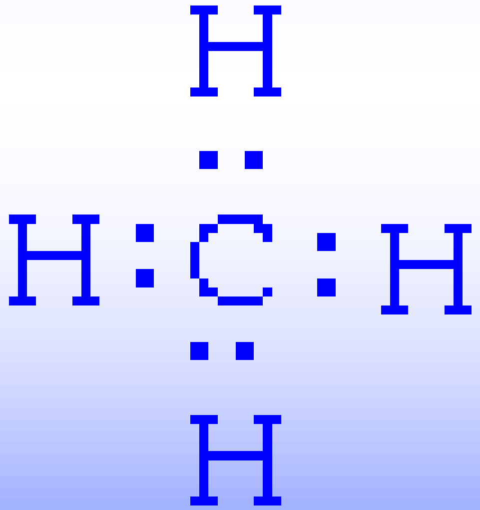
- Step 1 **after** checking that it is IONIC
  - Determine which atom will be the $^{+}$ion
  - Determine which atom will be the $^{-}$ ion
- Step 2
  - Write the symbol for the + ion first.
    - NO DOTS
  - Draw the e- dot diagram for the $^{-}$ ion
    - COMPLETE outer shell
- Step 3
  - Enclose both in brackets and **show each charge**

Draw the Lewis Diagrams

- LiF
- MgO
- $CaCl_2$
- K_2S

Methane CH_4

- This is the finished Lewis dot structure



- **Step 1**
  - **count total valence e^- involved**
- **Step 2**
  - **connect the central atom (usually the first in the formula) to the others with single bonds**
- **Step 3**
  - **complete valence shells of outer atoms**
- **Step 4**
  - **add any extra e^- to central atom**

IF the central atom has 8 valence e^- surrounding it . . YOU'RE DONE!

Electron Arrangements And Ion Charge

- We know
  - Group 1A metals form ions with +1 charge
  - Group 2A metals form ions with +2 charge
  - Group 7A nonmetals form ions with -1 charge
  - Group 6A nonmetals form ions with -2 charge
  - Group 8A nonmetals do not form ions, in fact they are extremely unreactive

Electron Arrangements and Ion Charge

- Representative Metals form cations by losing enough electrons to get the same electron configuration as the previous noble gas
- Nonmetals form anions by gaining enough electrons to get the same electron configuration as the next noble gas

Atom	Atoms Electron Config	Ion	Ions Electron Config
Na	[Ne]$3s^1$	Na^{+1}	[Ne]
Mg	[Ne]$3s^2$	Mg^{+2}	[Ne]
Al	[Ne]$3s^2 3p^1$	Al^{+3}	[Ne]
O	[He]$2s^2 2p^4$	O^{-2}	[Ne]
F	[He]$2s^2 2p^5$	F^{-1}	[Ne]

Electron Arrangements and Ionic Bonding

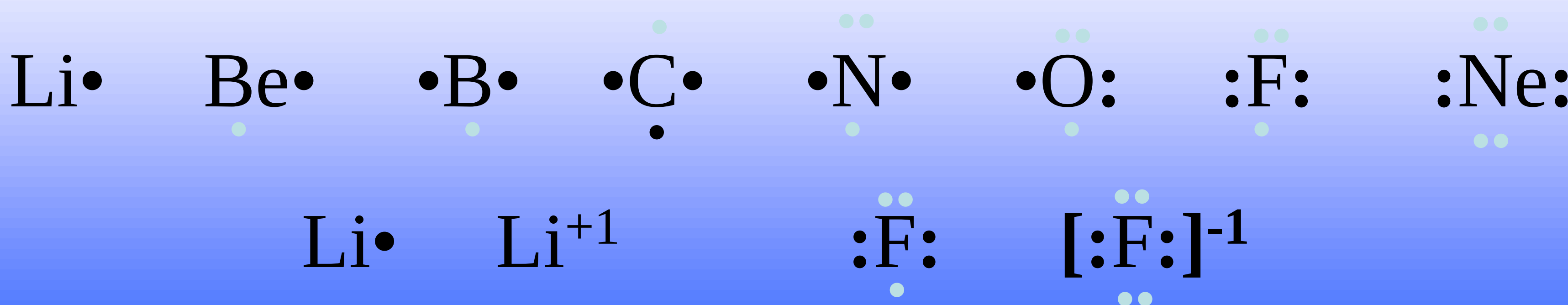
- Representative metals lose their valence electrons to form cations
- Nonmetals gain electrons so their valence shell has the same electron arrangement as the next noble gas
- There have to be enough electrons from the metals atoms to supply the needed electrons for the nonmetal atoms
  - Allows us to predict the formulas of ionic compounds
- In Polyatomic ions, the atoms in the ion are connected with covalent bonds. The ions are attracted to oppositely charged ions to form an ionic compound

Properties of Ionic Compounds

- All solids at room temperature
  - Melting points greater than 300°C
- Liquid state conducts electricity, solid state does not
  - Liquid = molten
- Brittle and Hard
- Often soluble in water, and when dissolved the solution becomes an electrical conductor
  - When ionic compounds containing polyatomic ions dissolve, the covalent bonds holding the polyatomic ion do not break, the ion stays together even though it separates from the other ion
  - All strong electrolytes

Lewis Symbols of Atoms and Ions

- Also known as electron dot symbols
- Use symbol of element to represent nucleus and inner electrons
- Use dots around the symbol to represent valence electrons
  - put one electron on each side first, then pair
- Elements in the same group have the same Lewis symbol
  - Because they have the same number of valence electrons
- Cations have Lewis symbols without valence electrons
- Anions have Lewis symbols with 8 valence electrons



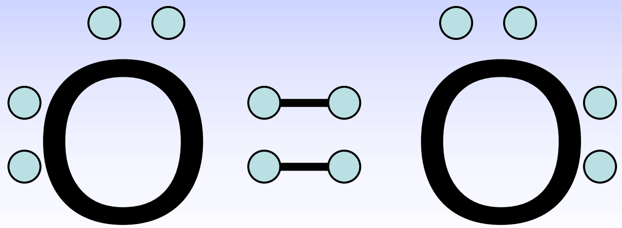
Writing Lewis Structures of Molecules

- Count the ***total*** number of valence electrons from all the atoms
- Attach the atoms together with one pair of electrons
  - A line is often used as shorthand for a pair of electrons that attach atoms together
- Arrange the remaining electrons in pairs so that all hydrogen atoms have 2 electrons (1 bond) and other atoms have 8 electrons (combination of bonding and nonbonding)
- Occasionally atoms may violate this rule
  - Nonbonding pairs of electrons are also know as Lone Pairs

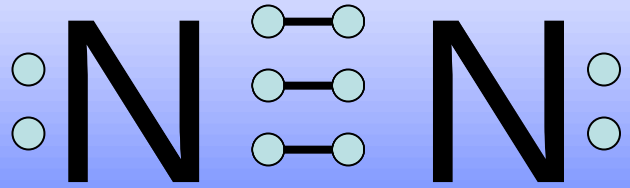
Covalent Bonds

- Single Covalent Bond the atoms share 2 electrons,
  - (1 pair)
- Double Covalent Bond the atoms share 4 electrons,
  - (2 pairs)
- Triple Covalent Bond the atoms share 6 electrons,
  - (3 pairs)
- Bond Strength = Triple > Double > Single
  - For bonds between same atoms, C≡N > C=N > C—N
  - Though Double not 2x the strength of Single and Triple not 3x the strength of Single
- Bond Length = Single > Double > Triple
  - For bonds between same atoms, C—N > C=N > C≡N

- DOUBLE bond
  - atoms that share two e- pairs (4 e-)



- TRIPLE bond
  - atoms that share three e- pairs (6 e-)



Draw Lewis Dot Structures

You may represent valence electrons from different atoms with the following symbols x, ,

● ○

CO_2

NH_3

Draw the Lewis Dot Diagram for polyatomic ions

- Count all valence e- needed for covalent bonding
- Add or subtract other electrons based on the charge

REMEMBER!

A *positive* charge means it *LOST* electrons!!!!!

Draw Polyatomics

- Ammonium
- Sulfate

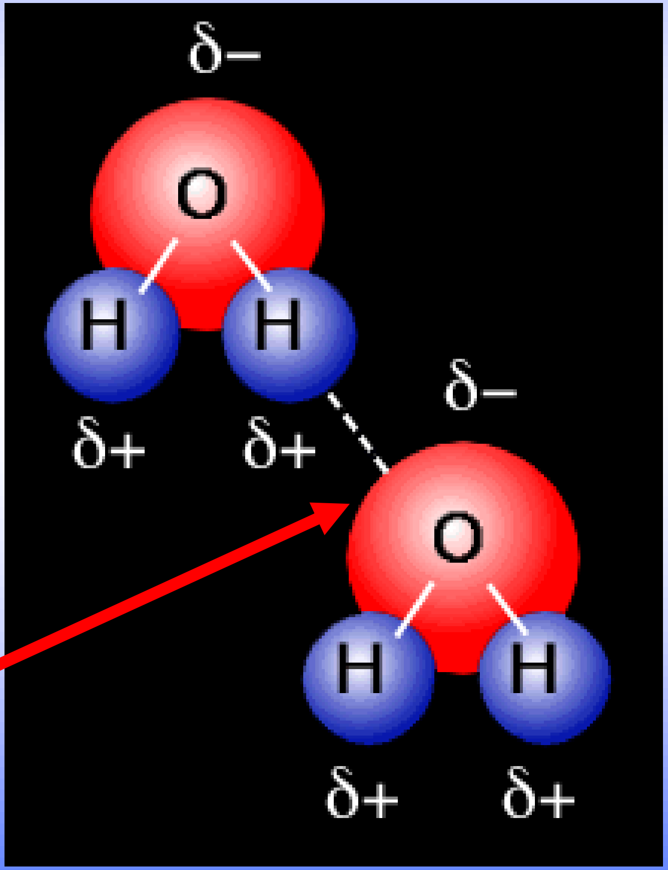
Problems with Lewis Structures

- Some atoms do not tend to follow the octet rule
  - B and Be often found octet deficient
  - Elements in the 3rd Period or below often have expanded octets
- Some molecules have an odd number of electrons
- Impossible to accurately draw Lewis structure of molecules that exhibit resonance
- Sometimes the Lewis Structure does not accurately describe a structure that explains all the observed properties of the molecule
- The paramagnetic behavior of O_2

Hydrogen "Bonding"

- Strong polar attraction
  - Like magnets
- Occurs *ONLY* between H of one molecule and N, O, F of another

H "bond"



H is shared between

2 atoms of OXYGEN or

2 atoms of NITROGEN or

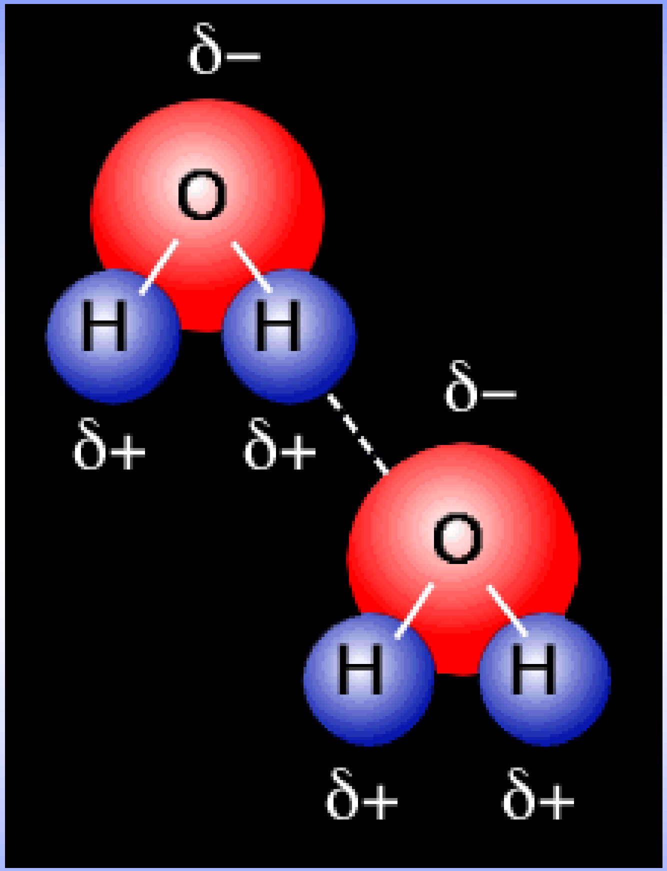
2 atoms of FLUORINE

Of

2

different

molecules



Why does H “bonding” occur?

- Nitrogen, Oxygen and Fluorine
  - small atoms with strong nuclear charges
    - powerful atoms
  - **very high electronegativities**

Which substance has the highest boiling point?

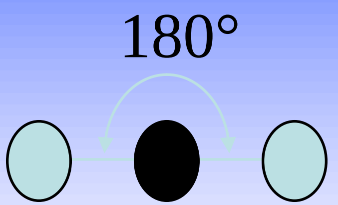
- HF
- NH_3
- H_2O

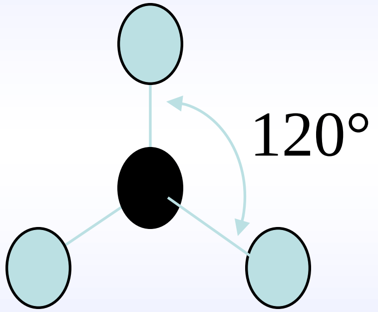
- WHY?

Fluorine has the highest e-neg, SO HF will experience the **strongest** H bonding and ∴ needs the most energy to weaken the i.m.f. and boil

Some Geometric Figures

- **Linear**
  - 2 atoms on opposite sides of central atom
  - 180° bond angles
- **Trigonal Planar**
  - 3 atoms form a triangle around the central atom
  - Planar
  - 120° bond angles
- Tetrahedral
  - 4 surrounding atoms form a tetrahedron around the central atom
  - 109.5° bond angles





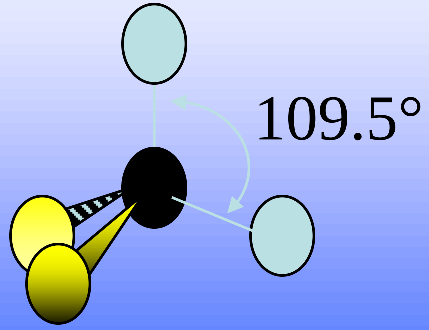
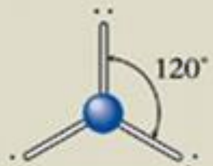
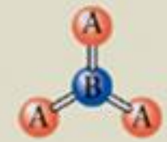
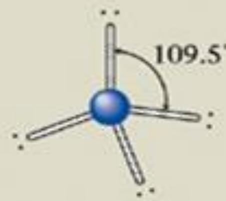
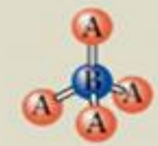
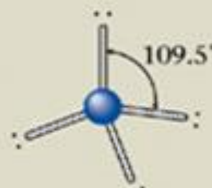
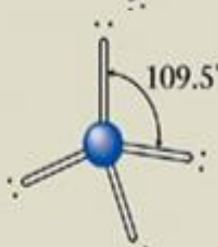
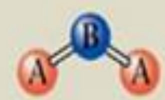


Table 11.4 Arrangements of Electron Pairs and the Resulting Molecular Structures for Two, Three, and Four Electron Pairs

Case	Number of Electron Pairs	Bonds	Electron Pair Arrangement	Ball-and-Stick Model	Angle Between Pairs	Molecular Structure	Partial Lewis Structure	Ball-and-Stick Model	Example
1	2	2	Linear		180°	Linear	A—B—A		BeF_2
2	3	3	Trigonal planar (triangular)		120°	Trigonal planar (triangular)	A | B A / \ A		
3	4	4	Tetrahedral		109.5°	Tetrahedral	A | A — B — A | A		CH_4
4	4	3	Tetrahedral		109.5°	Trigonal pyramid	A — B̈ — A | A		NH_3
5	4	2	Tetrahedral		109.5°	Bent or V-shaped	A — B — A (with lone pairs on B)		H_2O