Chapter 8 Bonding – General Concepts

Electronegativity: The ability of an atom in a molecule to attract shared electrons to itself.

- below 1.0
- 1.0–1.4
- 1.5–1.9
- 2.0–2.4
- 2.5–2.9
- 3.0–4.0

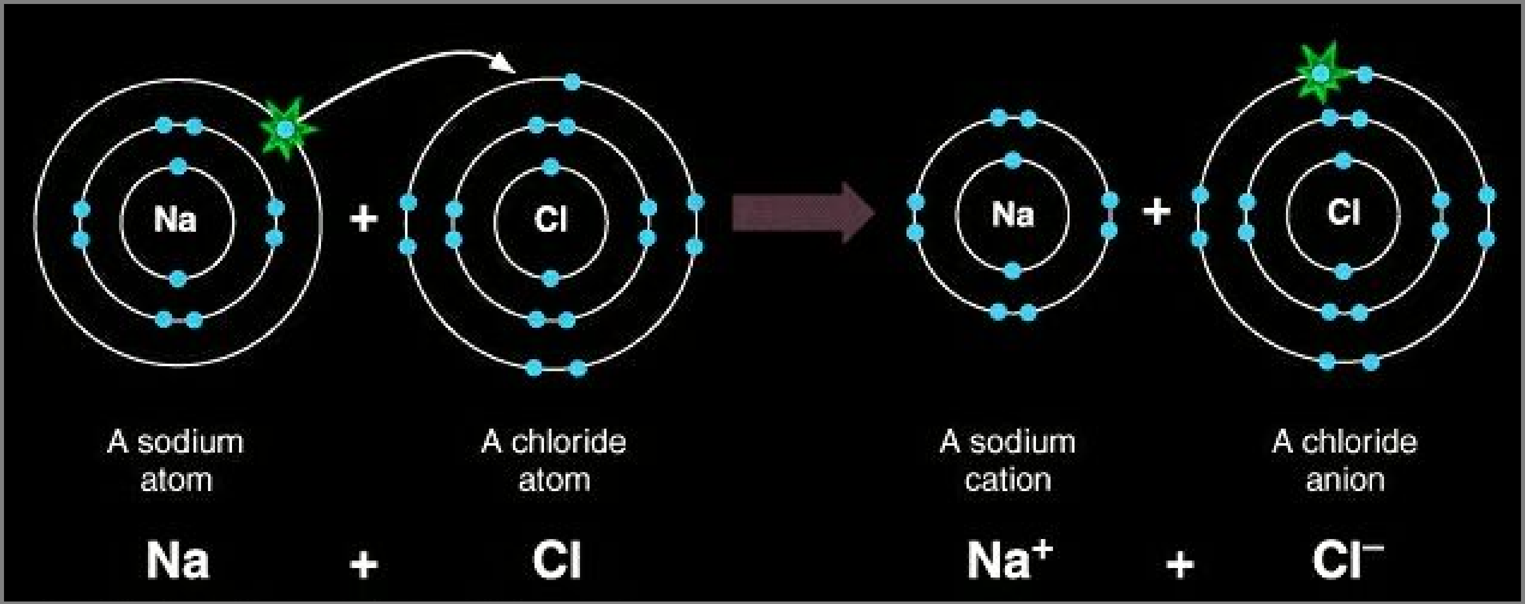
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
H 2.1																
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 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 0.8	Ba 0.9	La* 1.1	Hf 1.3	Ta 1.5	W 2.4	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
Fr 0.7	Ra 0.9	Ac† 1.1														

* Lanthanides: 1.1–1.3

† Actinides: 1.3–1.5

Ionic Bonds

- Electrons are transferred

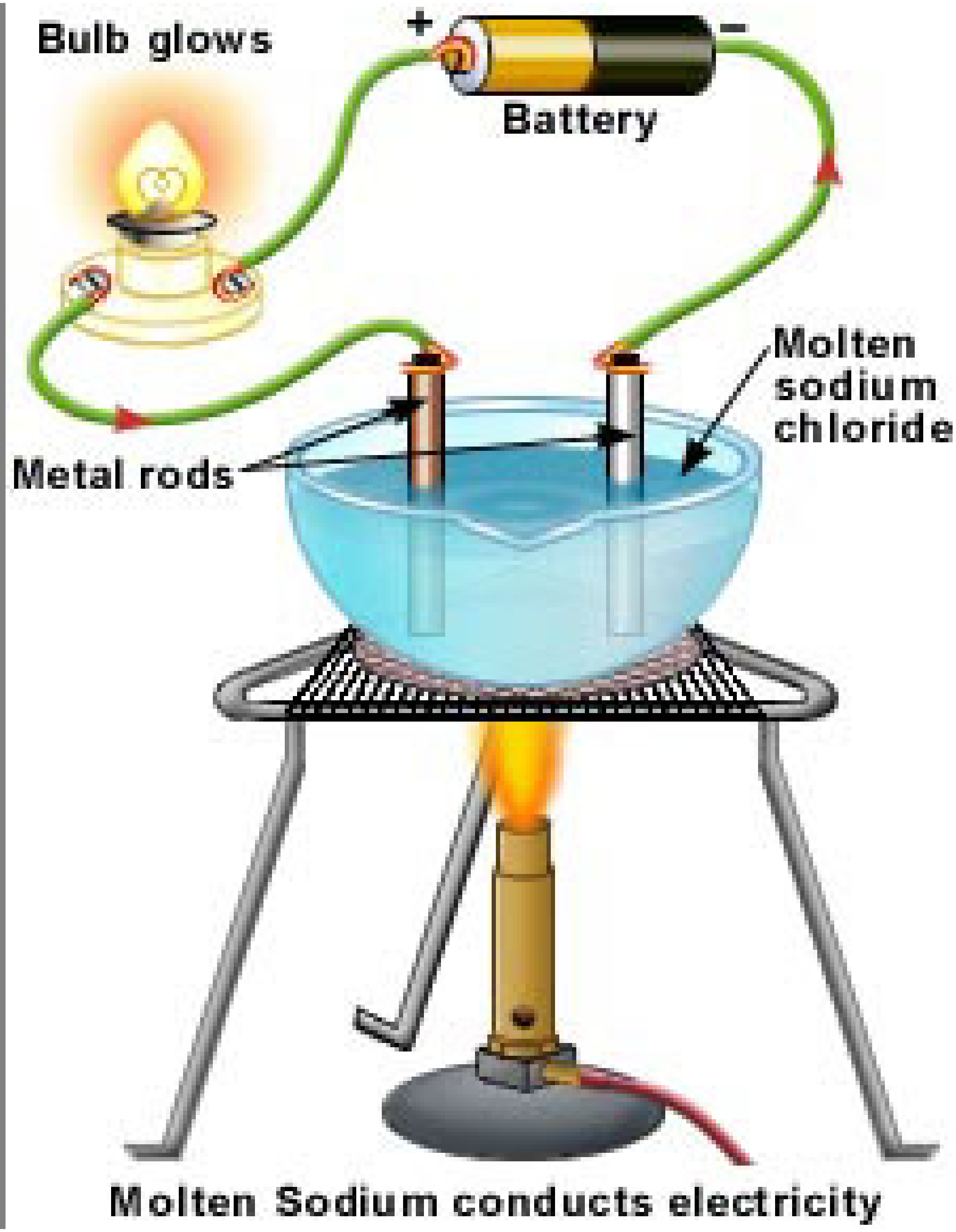


- Electronegativity differences are generally greater than 1.7
- The formation of ionic bonds is always exothermic!

Determination of Ionic Character

Electronegativity difference is **not** the final determination of ionic character

Compounds are ionic if they conduct electricity in their molten state



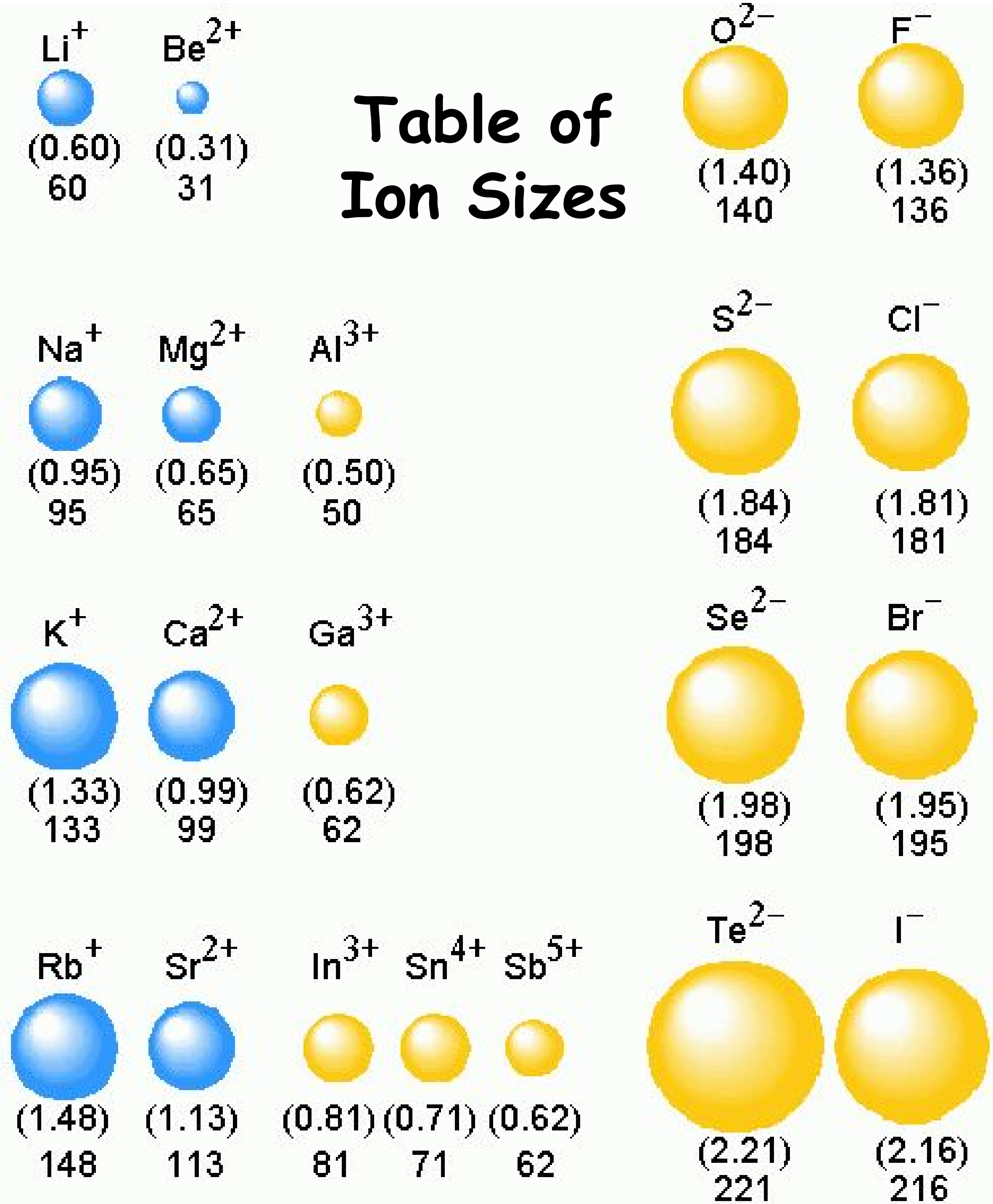
Coulomb's Law

"The energy of interaction between a pair of ions is proportional to the product of their charges, divided by the distance between their centers"

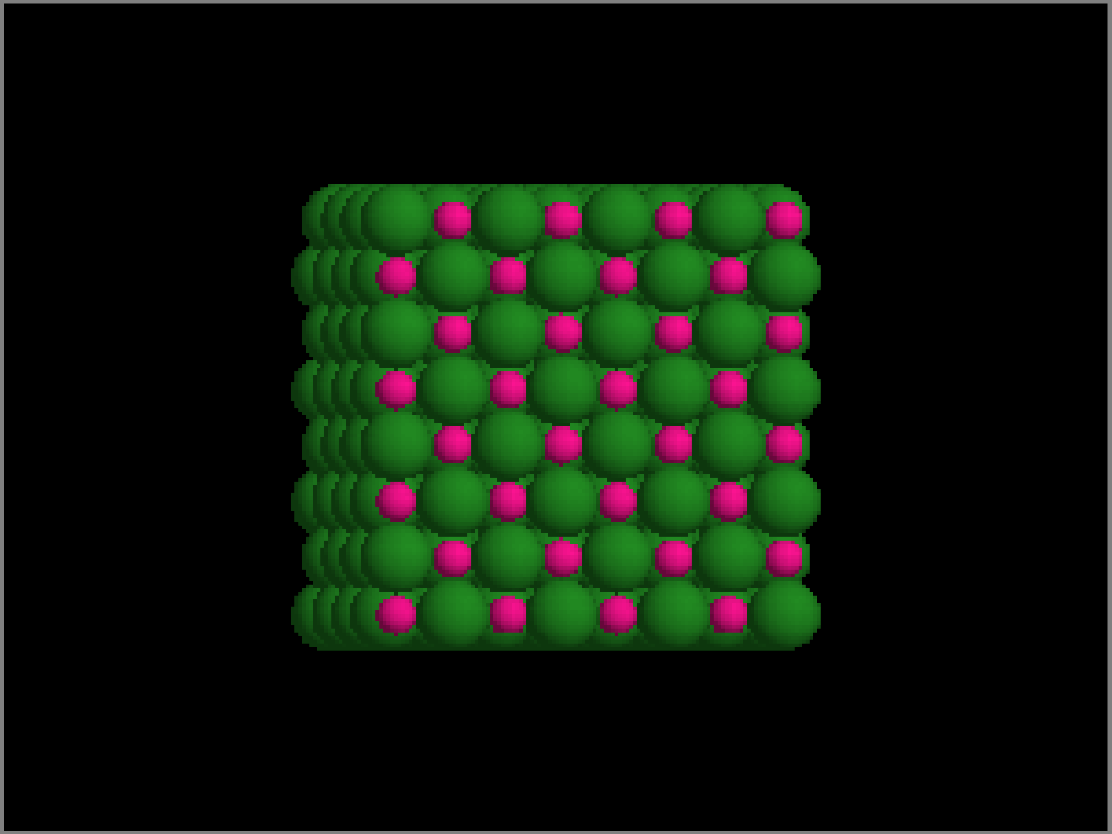
$$E = (2.31x10^{-19}\, J \cdot nm)\left(\frac{Q_1 Q_2}{r}\right)$$

$$E \propto \left(\frac{Q_1 Q_2}{r}\right)$$

Table of Ion Sizes



Sodium Chloride Crystal Lattice



Ionic compounds form solids at ordinary temperatures.

Ionic compounds organize in a characteristic crystal lattice of alternating positive and negative ions.

Estimate ΔH_f for Sodium Chloride

$Na(s) + \frac{1}{2}\ Cl_2(g) \rightarrow NaCl(s)$

Lattice Energy	-786 kJ/mol
Ionization Energy for Na	495 kJ/mol
Electron Affinity for Cl	-349 kJ/mol
Bond energy of Cl_2	239 kJ/mol
Enthalpy of sublimation for Na	109 kJ/mol

$Na(s) \rightarrow Na(g)$	+ 109 kJ
$Na(g) \rightarrow Na^+(g) + e^-$	+ 495 kJ
$\frac{1}{2}\ Cl_2(g) \rightarrow Cl(g)$	+ $\frac{1}{2}$(239 kJ)
$Cl(g) + e^- \rightarrow Cl^-(g)$	- 349 kJ
$Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$	-786 kJ
$Na(s) + \frac{1}{2}\ Cl_2(g) \rightarrow NaCl(s)$	**-412 kJ/mol**

Covalent Bonds

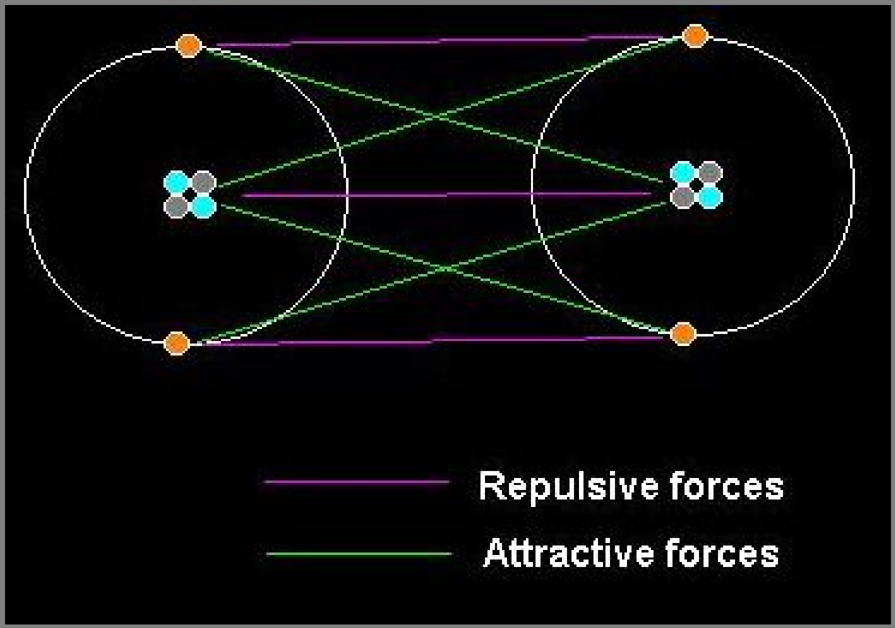
Polar-Covalent bonds

- Electrons are unequally shared
- Electronegativity difference between .3 and 1.7

Nonpolar-Covalent bonds

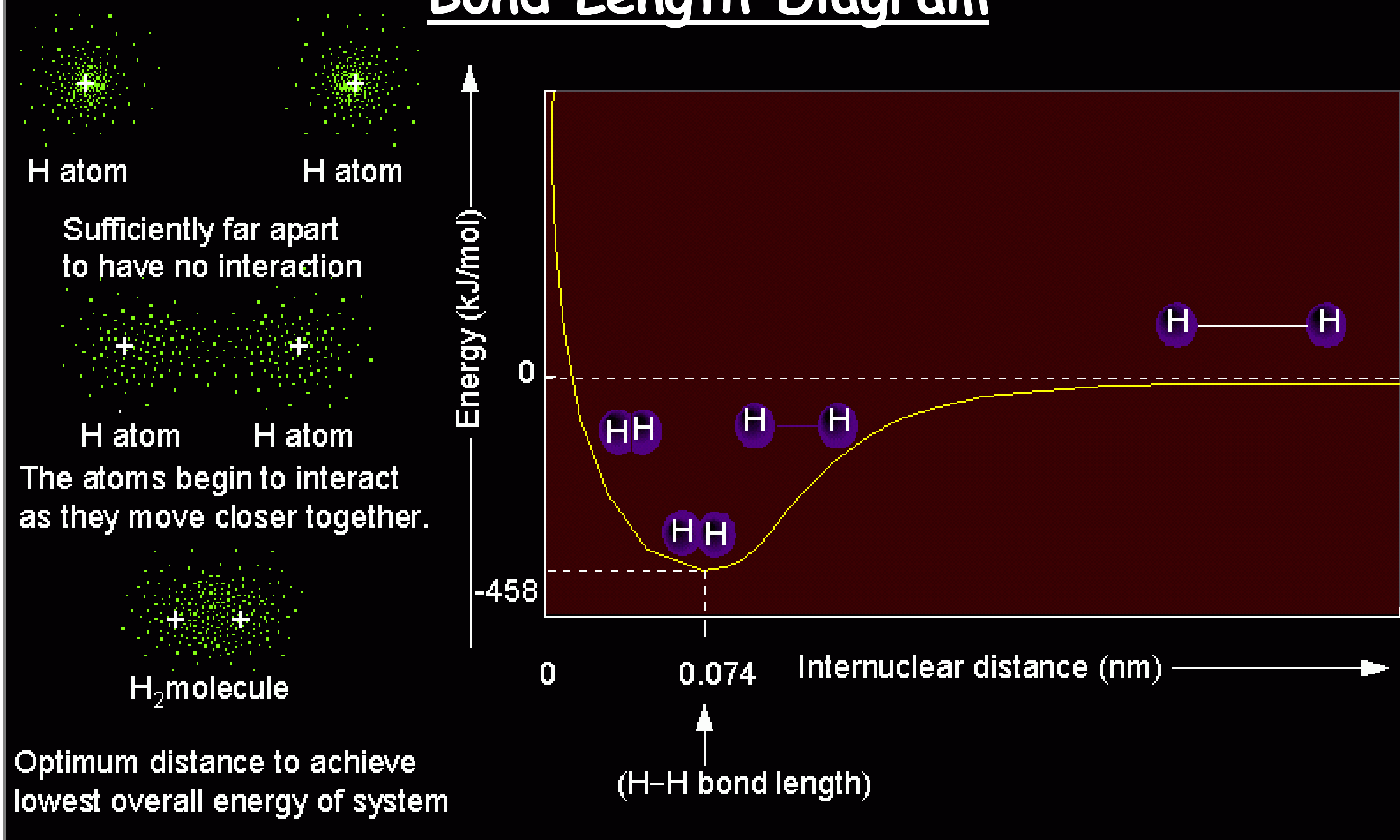
- Electrons are equally shared
- Electronegativity difference of 0 to 0.3

Covalent Bonding Forces

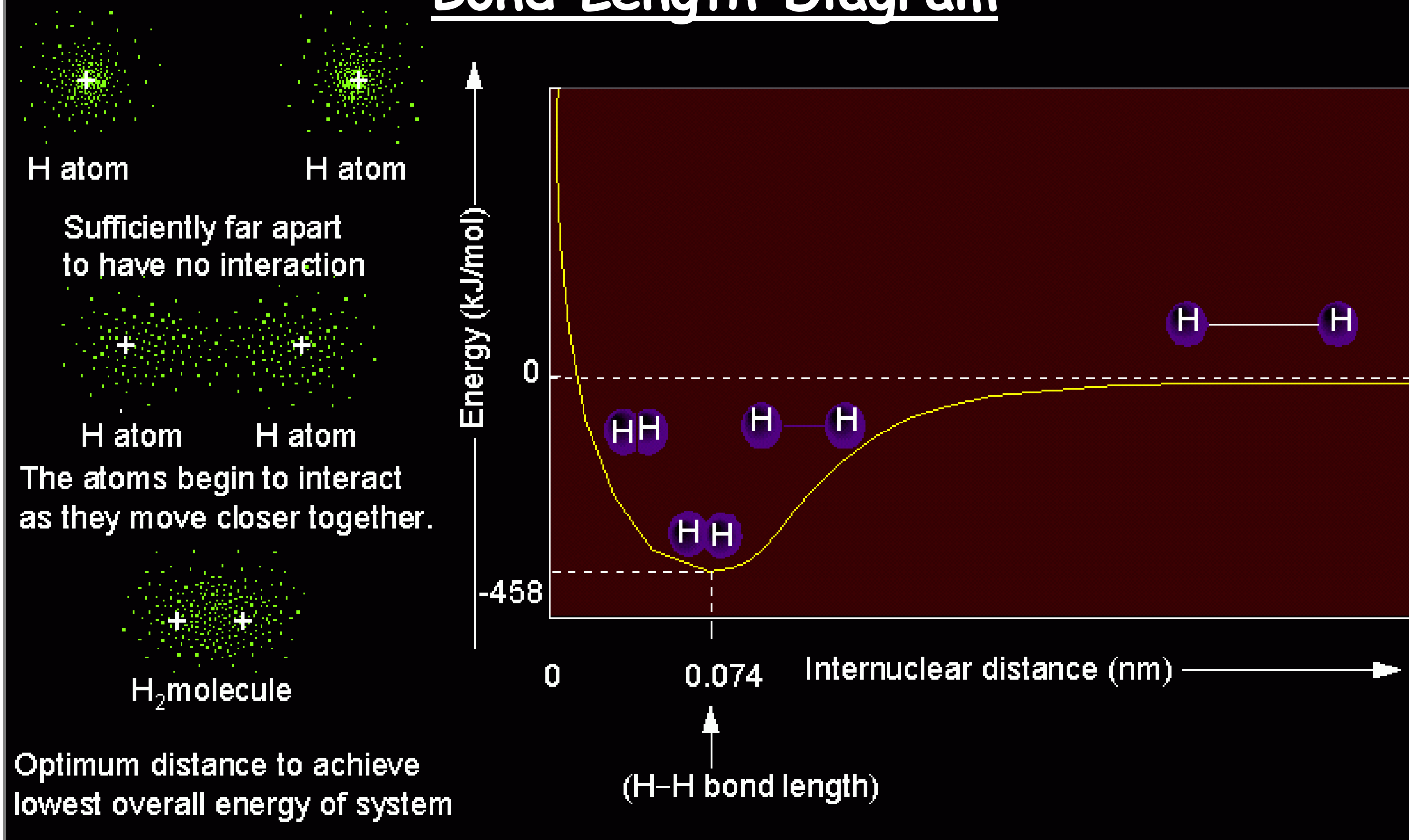


- Electron – electron repulsive forces
- Proton – proton repulsive forces
- Electron – proton attractive forces

Bond Length Diagram



Bond Length Diagram



Bond Energy and Enthalpy

$$\Delta H = \sum D_{bonds\,broken} - \sum D_{bonds\ formed}$$

Energy required Energy released

D = Bond energy per mole of bonds

Breaking bonds always requires energy

Breaking = endothermic

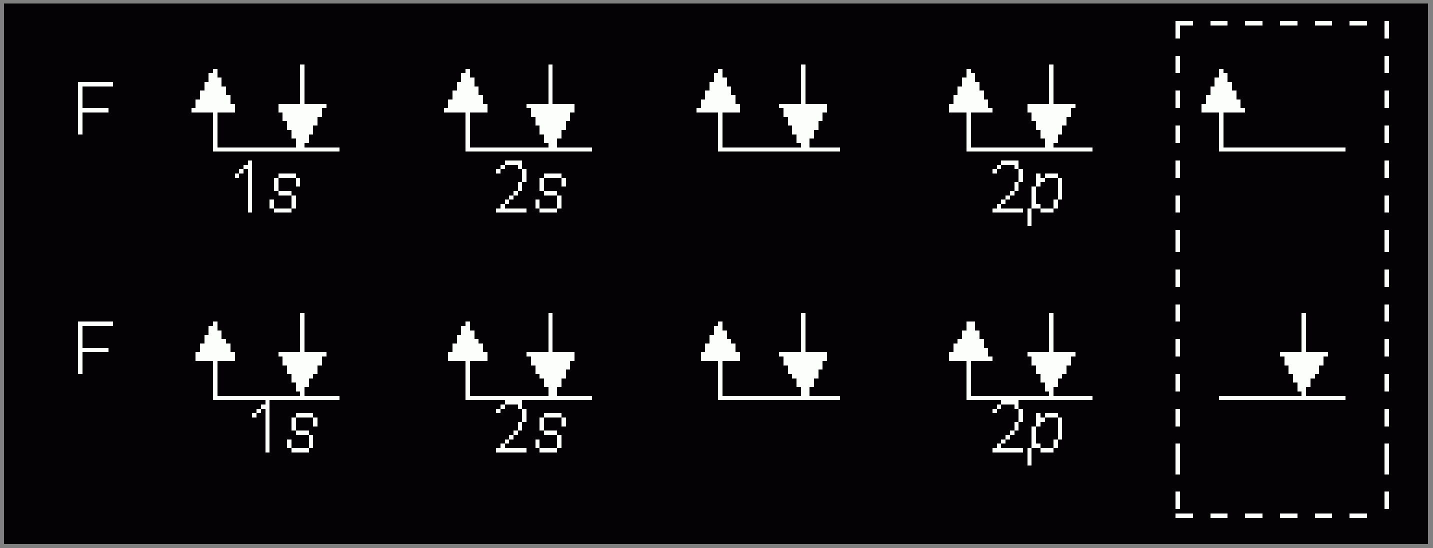
Forming bonds always releases energy

Forming = exothermic

The Octet Rule

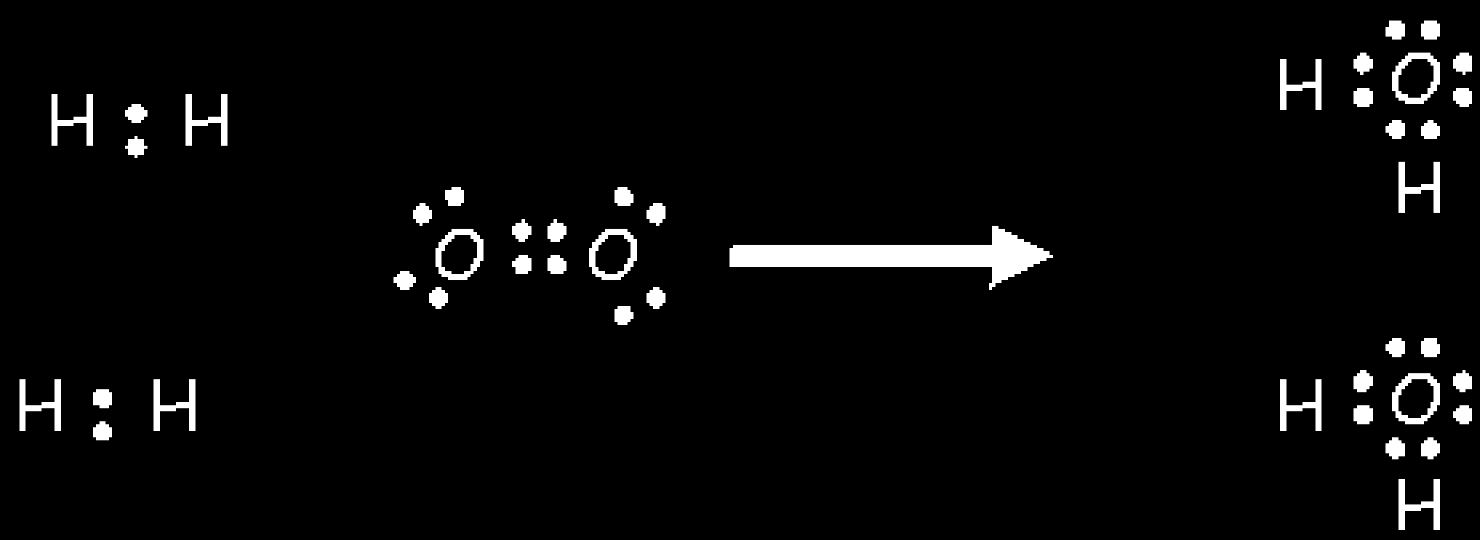
Combinations of elements tend to form so that each atom, by gaining, losing, or sharing electrons, has an octet of electrons in its highest occupied energy level.

Diatomic Fluorine



Formation of Water by the Octet Rule

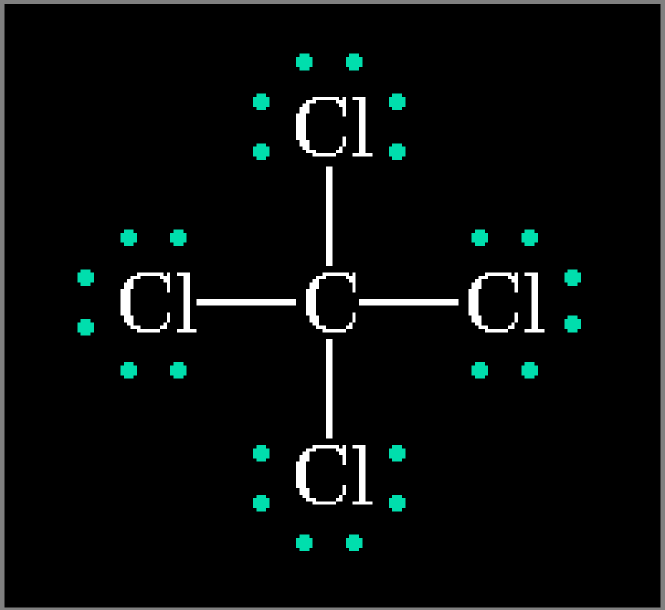
$$2H_2 + O_2 \rightarrow 2H_2O$$



Comments About the Octet Rule

- 2nd row elements C, N, O, F observe the octet rule (HONC rule as well).
- 2nd row elements B and Be often have fewer than 8 electrons around themselves - they are very reactive.
- 3rd row and heavier elements CAN exceed the octet rule using empty valence *d* orbitals.
- When writing Lewis structures, satisfy octets first, then place electrons around elements having available *d* orbitals.

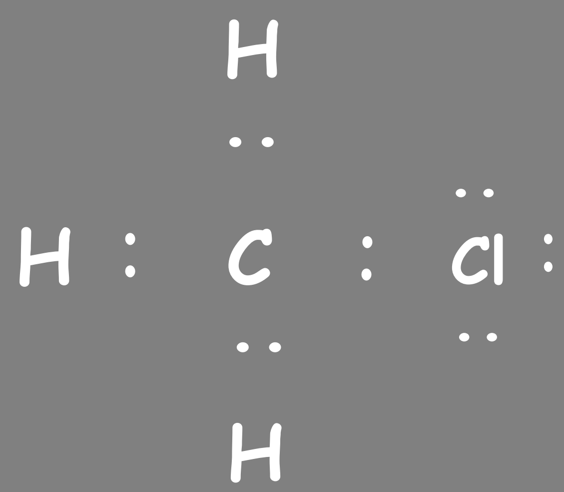
Lewis Structures



- Shows how valence electrons are arranged among atoms in a molecule.
- Reflects central idea that stability of a compound relates to noble gas electron configuration.

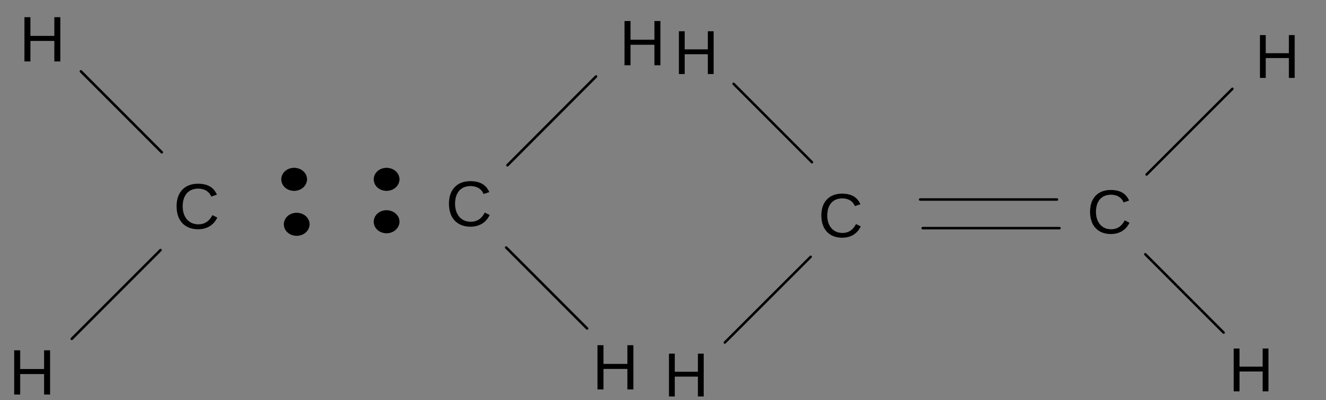
Completing a Lewis Structure -CH_3Cl

- Make carbon the central atom
- Add up available valence electrons:
  - C = 4, H = (3)(1), Cl = 7 Total = 14
- Join peripheral atoms to the central atom with electron pairs.
- Complete octets on atoms other than hydrogen with remaining electrons



Multiple Covalent Bonds:

Double bonds

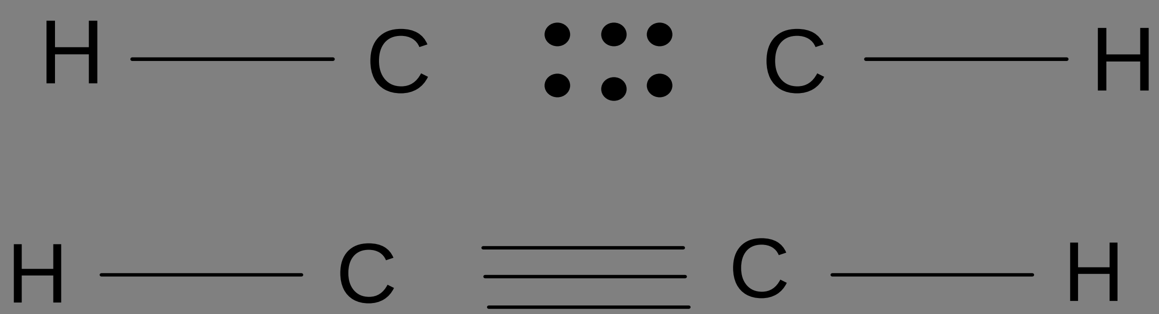


Ethene

Two pairs of shared electrons

Multiple Covalent Bonds:

Triple bonds



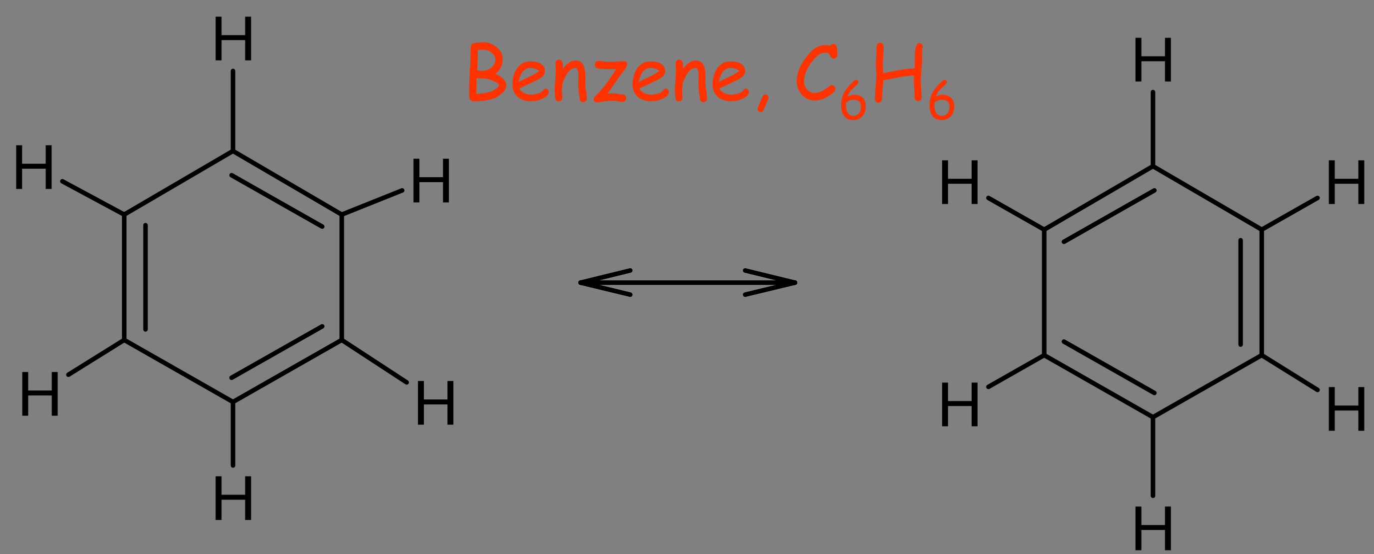
Ethyne

Three pairs of shared electrons

Resonance

- Resonance is invoked when more than one valid Lewis structure can be written for a particular molecule.

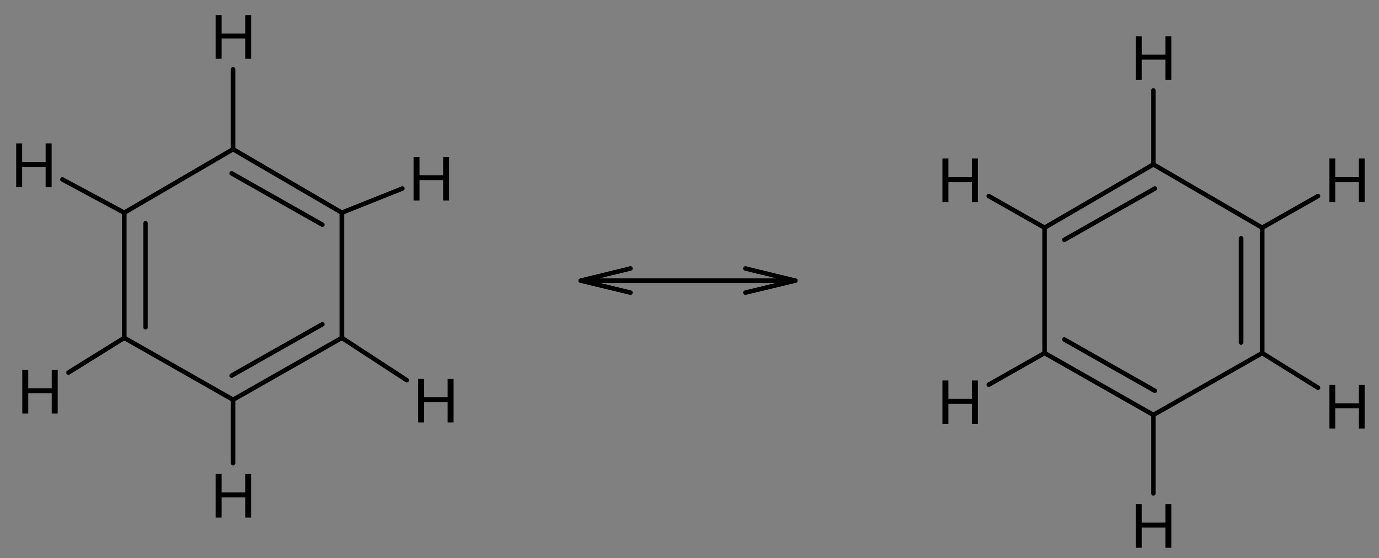
Benzene, C_6H_6



- The actual structure is an average of the resonance structures.
- The bond lengths in the ring are identical, and between those of single and double bonds.

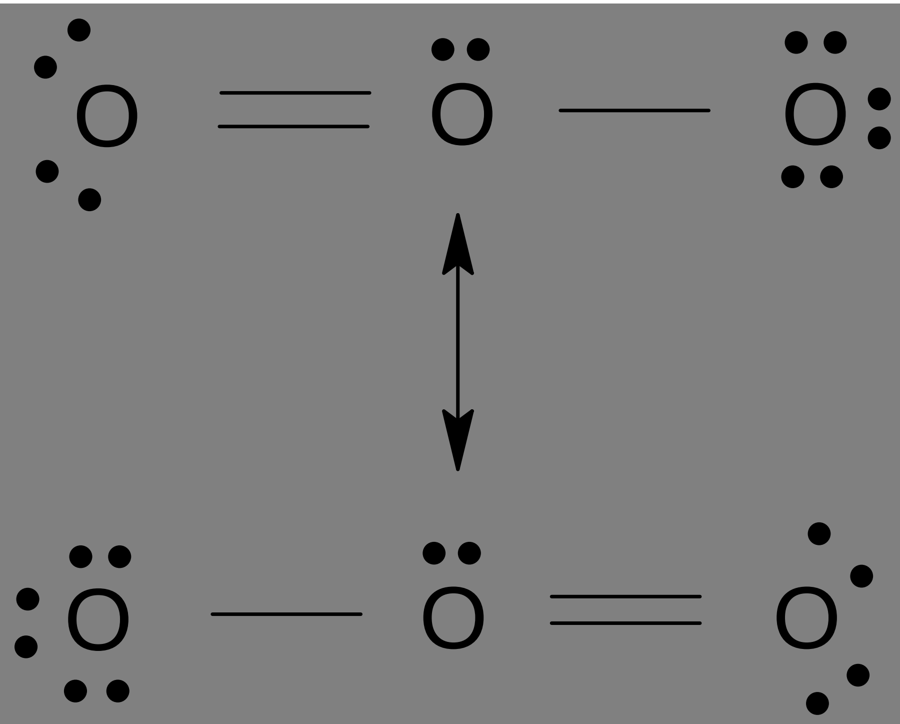
Resonance Bond Length and Bond Energy

- Resonance bonds are <u>shorter</u> and <u>stronger</u> than single bonds.



- Resonance bonds are <u>longer</u> and <u>weaker</u> than double bonds.

Resonance in Ozone, O_3

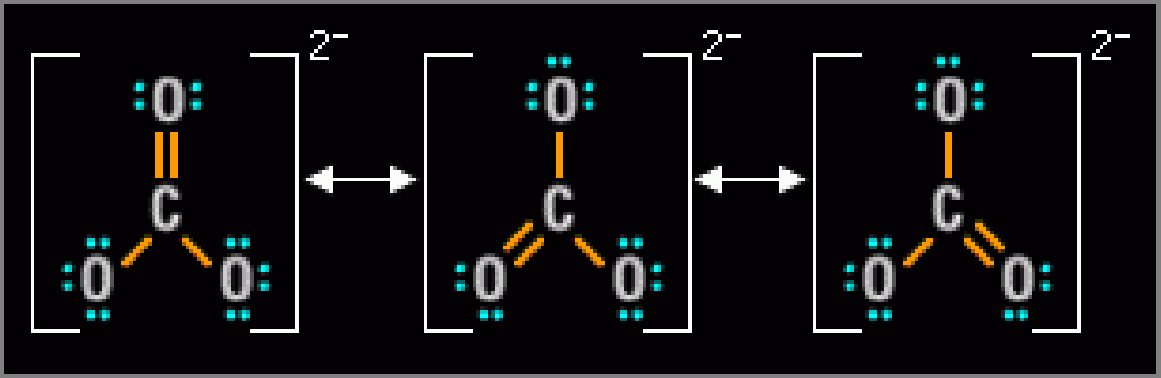


Neither structure is correct.

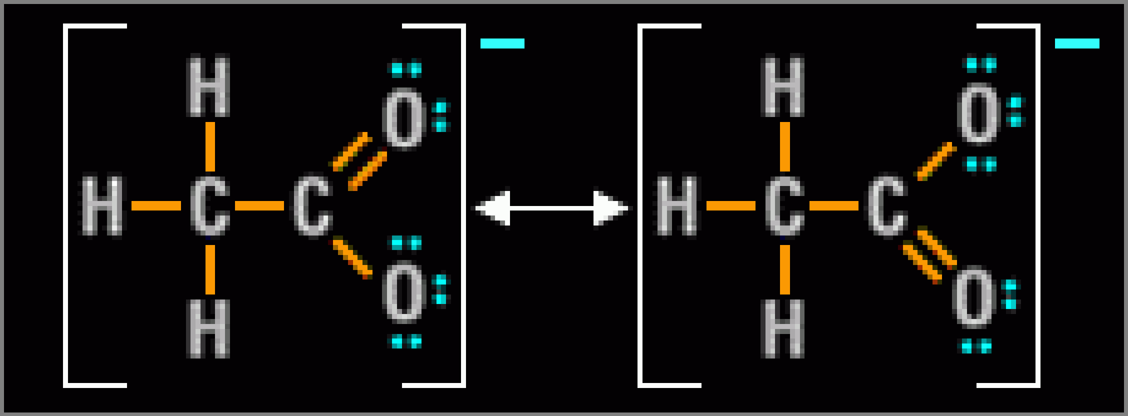
Oxygen bond lengths are identical, and intermediate to single and double bonds

Resonance in Polyatomic Ions

Resonance in a carbonate ion:



Resonance in an acetate ion:



Localized Electron Model

Lewis structures are an application of the "Localized Electron Model"

L.E.M. says: Electron pairs can be thought of as "belonging" to pairs of atoms when bonding

Resonance points out a weakness in the Localized Electron Model.

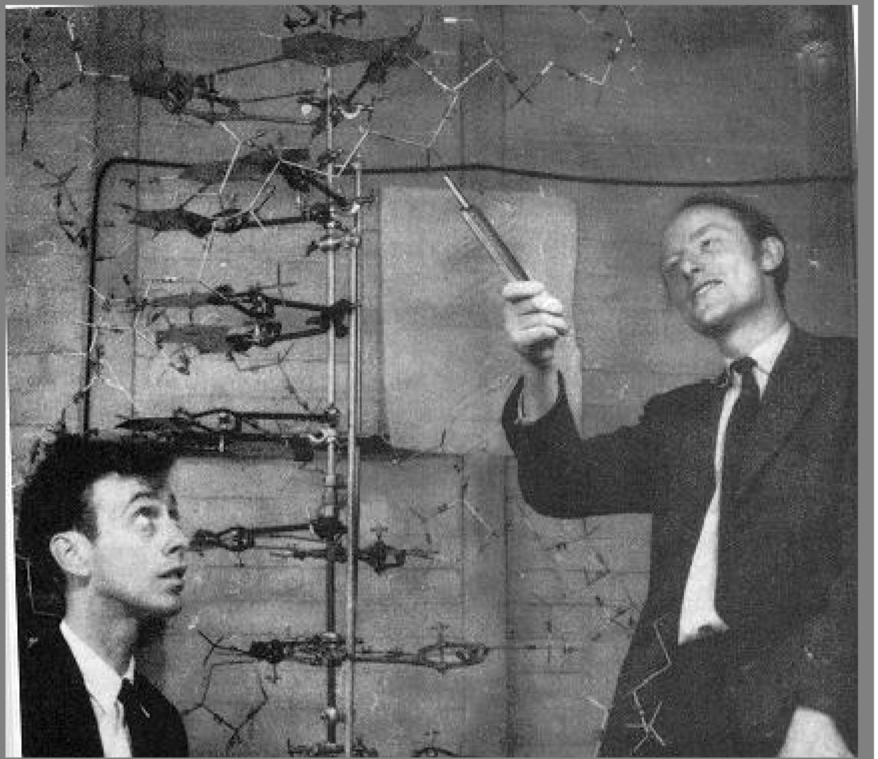
Models

Models are attempts to explain how nature operates on the microscopic level based on experiences in the macroscopic world.

Models can be **physical** as with this DNA model

Models can be **mathematical**

Models can be **theoretical** or **philosophical**



Fundamental Properties of Models

- A model does not equal reality.
- Models are oversimplifications, and are therefore often wrong.
- Models become more complicated as they age.
- We must understand the underlying assumptions in a model so that we don't misuse it.

VSEPR – Valence Shell Electron Pair Repulsion

X + E	Overall Structure	Forms
2	Linear	AX_2
3	Trigonal Planar	AX_3, AX_2E
4	Tetrahedral	AX_4, AX_3E, AX_2E_2
5	Trigonal bipyramidal	AX_5, AX_4E, AX_3E_2, AX_2E_3
6	Octahedral	AX_6, AX_5E, AX_4E_2

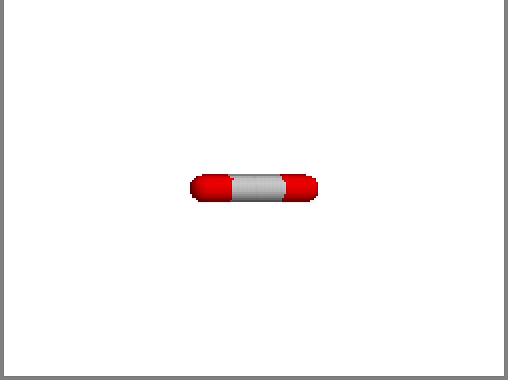
A = central atom

X = atoms bonded to A

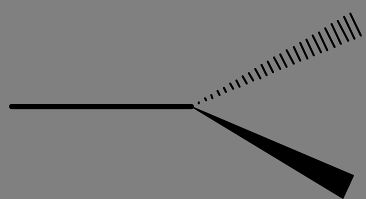
E = nonbonding electron pairs on A

VSEPR: Linear

__________ AX_2 CO_2

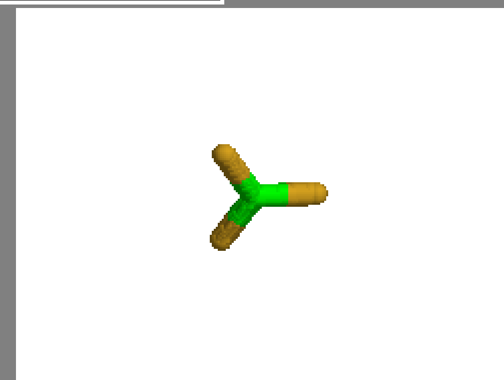


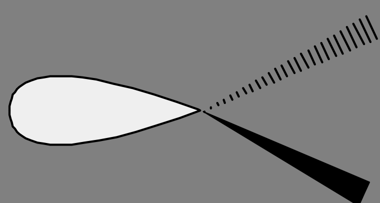
VSEPR: Trigonal Planar



AX_3

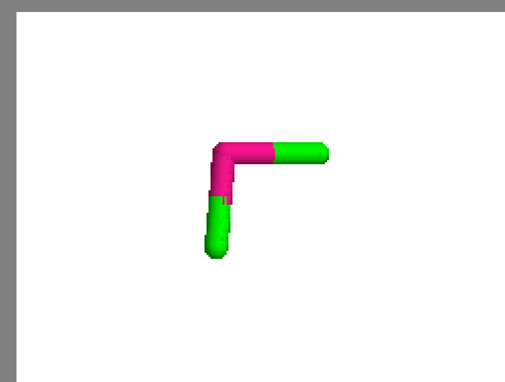
BF_3



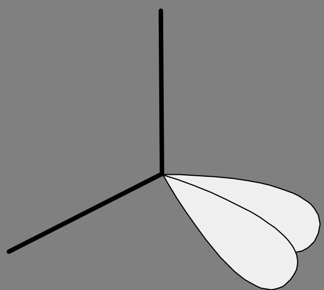


AX_2E

$SnCl_2$

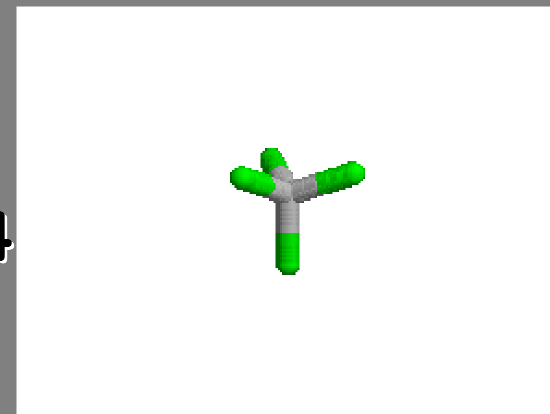


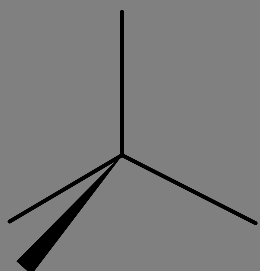
VSEPR: Tetrahedral



AX_4

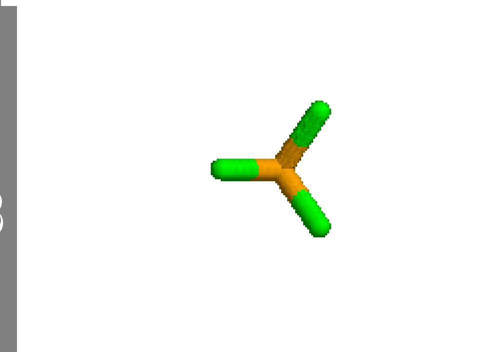
CCl_4

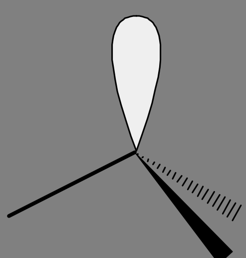




AX_3E

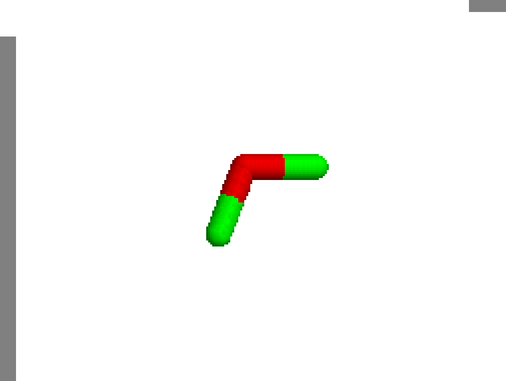
PCl_3



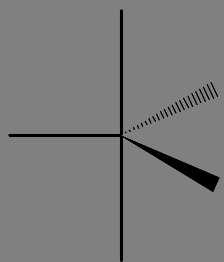


AX_2E_2

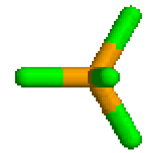
Cl_2O

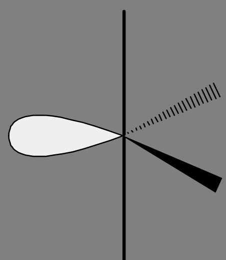


VSEPR: Trigonal Bi-pyramidal

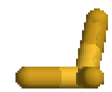


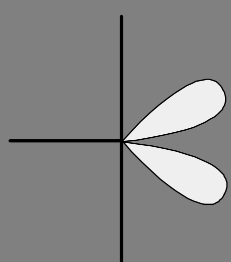
AX_5 PCl_5



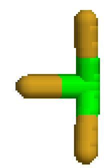


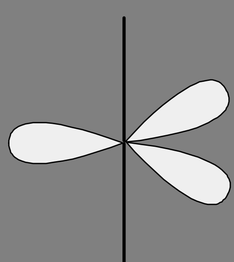
AX_4E SF_4





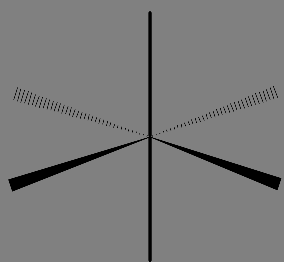
AX_3E_2 ClF_3





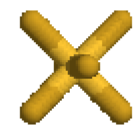
AX_2E_3 I_3^-

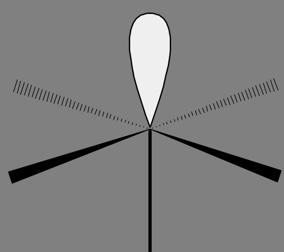
VSEPR: Octahedral



AX_6

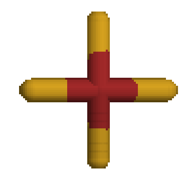
SF_6

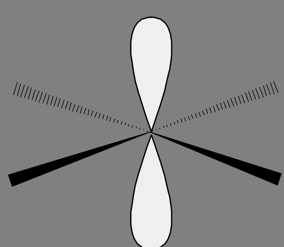




AX_5E

BrF_5





AX_4E_2

ICl_4^-