Chemical Bonding I: Covalent Bonding

How are atoms held together in compounds?

Chemical Bonding

IONIC or COVALENT bonds or forces

Chemical Bonding

For most atoms, a filled outer shell contains 8 electrons ------ an octet

Atoms want to form octets when they combine to form compounds

Exceptions: hydrogen and helium have 2 electrons when filled
boron can have 6 electrons

Chemical Bonding

Ionic Compounds

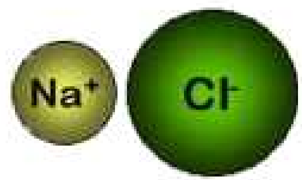
Bonds consist of attraction between a positive and negative ion

Bonds commonly form between metals and nonmetals

Chemical Bonding

Ionic Compounds

Sodium chloride NaCl

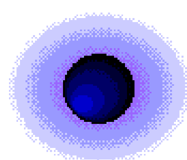
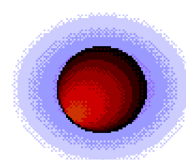


Chemical Bonding

Ionic Compounds

Sodium chloride NaCl

Cl^- Na^+

Chemical Bonding

Ionic Compounds

Ions are atoms that have gained or lost electrons to achieve an octet

metal Na þ $Na^+ + e^-$

nonmetal $Cl + e^-$ þ Cl^-

Chemical Bonding

Na: $1s^2 2s^2 2p^6 3s^1$

Cl: $1s^2 2s^2 2p^6 3s^2 3p^5$

Na gives 1 electron to Cl

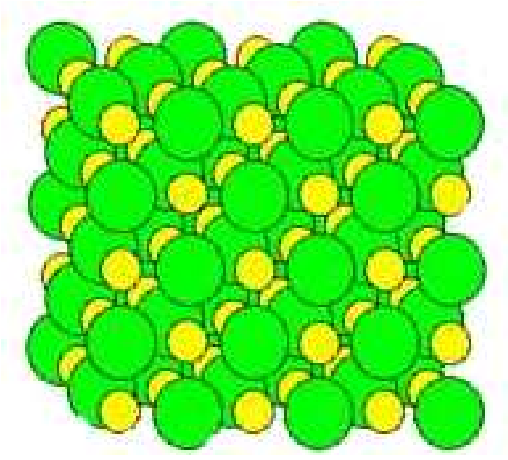
Chemical Bonding

Ionic Compounds

Don't exist as individual molecules

Tend to form crystals

Ions touch many others

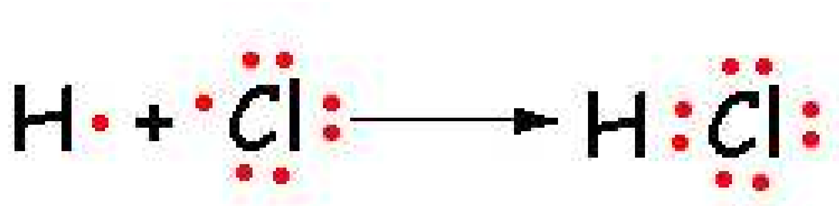


Chemical Bonding

Covalent Compounds

Two nonmetals share electrons & form compounds containing covalent bonds.

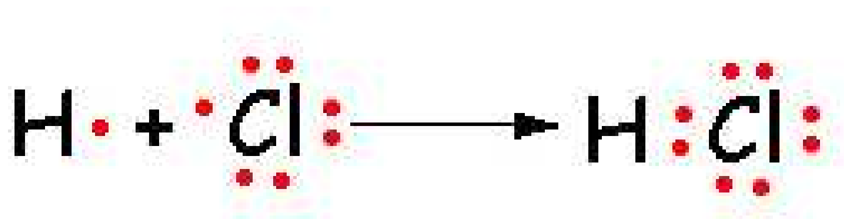
These are covalent or molecular compounds



Chemical Bonding

H_2 = H-H or H:H

Lewis structure: shows electrons



Chemical Bonding

Lewis Structures:
electron-dot structures

Atoms are stable if they have a filled or empty outer layer of electrons

Outer layer called valence shell

Chemical Bonding

Atoms will do one of two things to fill their valence shell:

1. **try to gain or lose electrons to achieve filled outer shell**
   when metals combine with nonmetals

2. **try to share electrons**
   when nonmetals combine with nonmetals

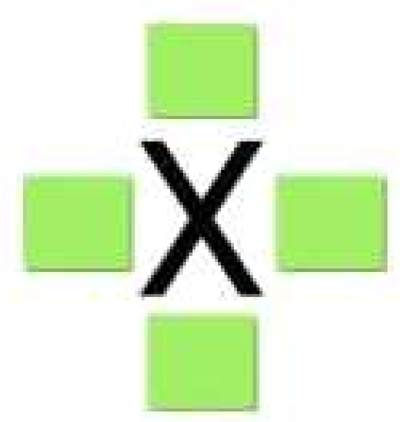
Chemical Bonding

We use Lewis Structures to help keep track of electrons around atoms, ions and molecules.

G.N.Lewis

If the number of electrons in the valence shell of an atom is known, writing Lewis symbols is easy

Chemical Bonding



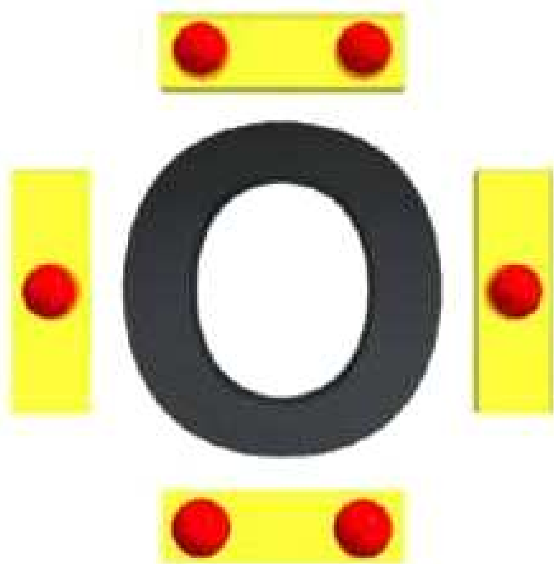
Draw the atomic symbol

Count the electrons in the valence shell

Treat each side as a box that can hold up to 2 electrons

Start filling box - don’t make pairs unless you have to

Chemical Bonding



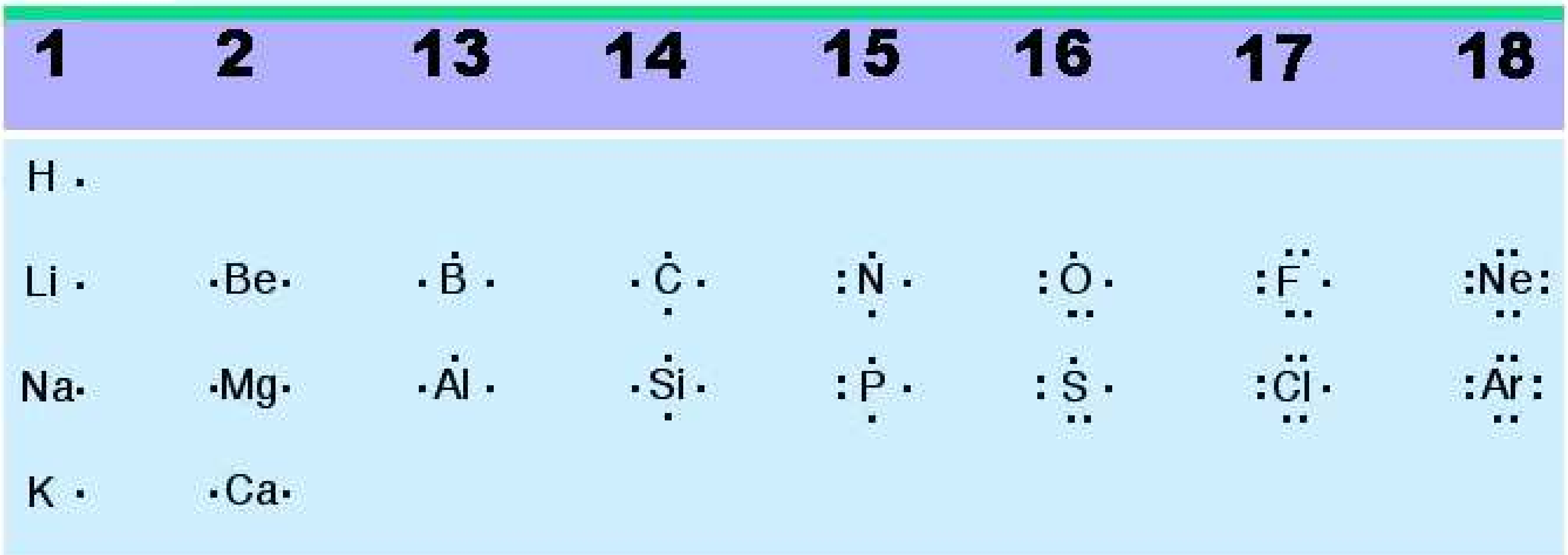
6 valence electrons

O: $1s^2 2s^2 2p^4$

¶ **This is the Lewis symbol for oxygen**

Chemical Bonding

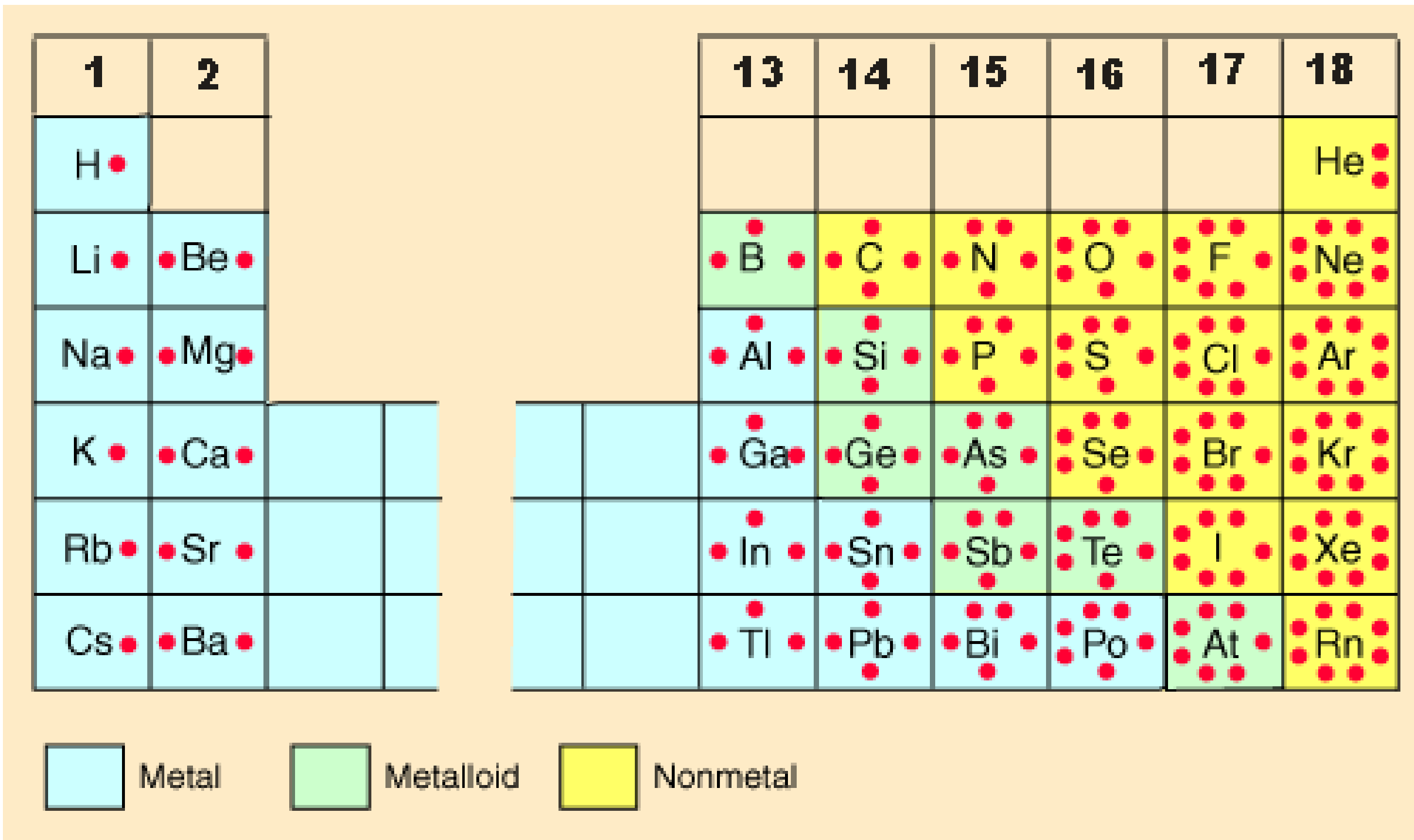
Lewis symbols for common elements



No. dots = No. valence electrons

Chemical Bonding

Lewis symbols for group elements

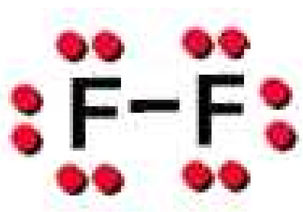


Chemical Bonding

When nonmetals join they share electrons

Chemical Bonding

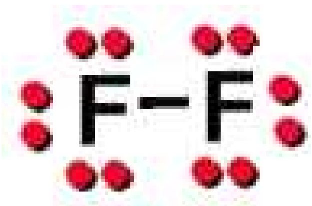
Two atoms of fluorine combine to give one molecule = F_2



Sometimes use a dash to represent shared electrons

Chemical Bonding

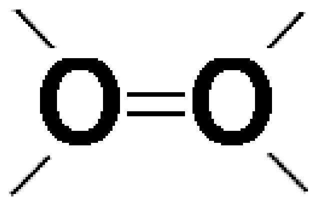
Electrons can be shared or unshared

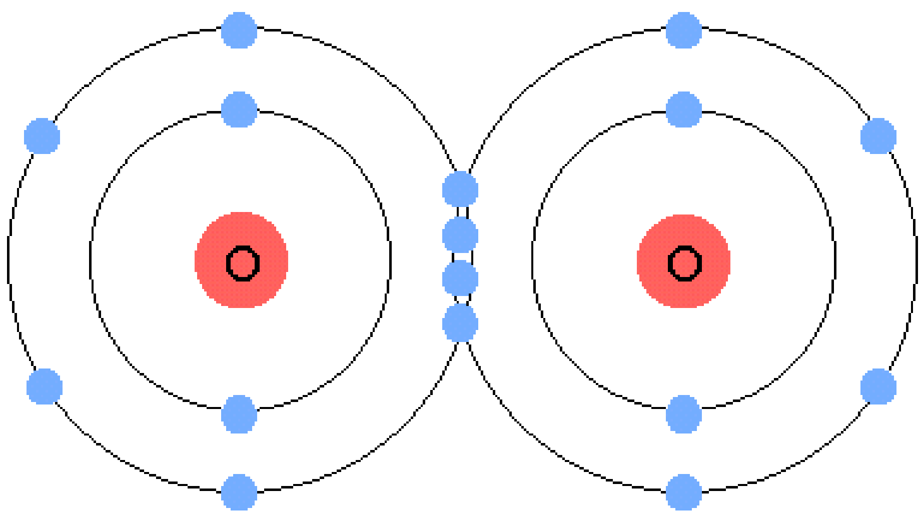


One pair of shared electrons equals a single covalent bond

Chemical Bonding

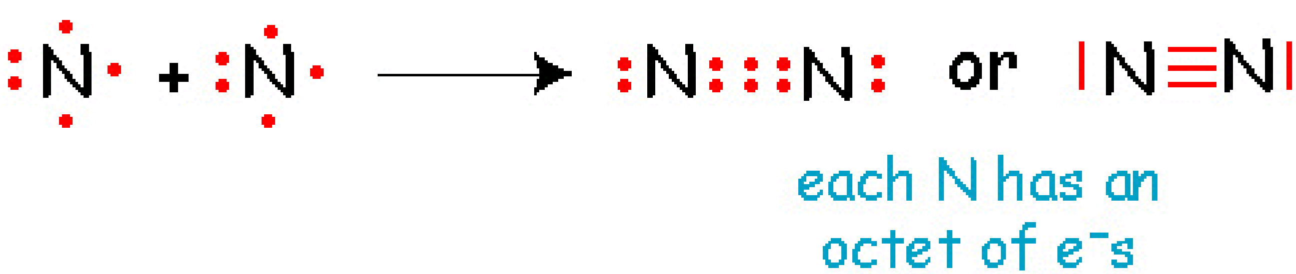
Bonds can be double (2 dashes) bonds





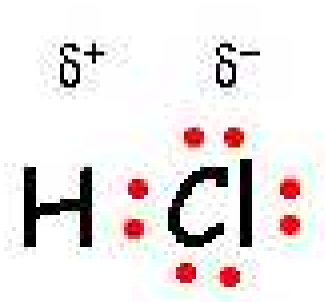
Chemical Bonding

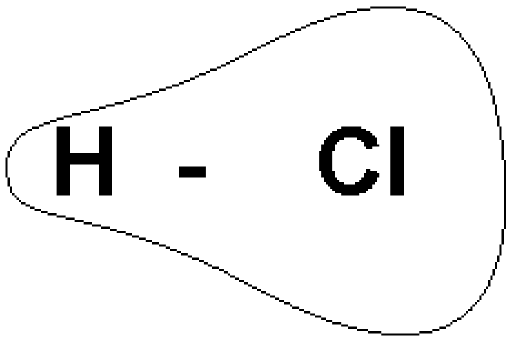
Bonds can be triple (3 dashes) bonds



Chemical Bonding

Atom's electronegativity determines which element shares the electrons the most. Produces a polar covalent bond





Chemical Bonding

Electronegativity

Measurement of element's ability to attract electrons

range 0.5 - 4.0

Metals: low
Nonmetals: high

Chemical Bonding

Electronegativity values

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

Chemical Bonding

Electronegativity

H_2 H:H e^- equally shared
nonpolar bond

H:Cl   Cl pulls e^- more
polar bond

$^{*+}$H:Cl^{*-} dipole or polarized

dipole moments

Chemical Bonding

Electronegativity differences between bonded atoms determines bond type

) EN	Type of bond
< 0.5	nonpolar covalent
0.5 - 1.9	polar covalent
> 1.9	ionic

Chemical Bonding

Bond	) EN	Type of bond
C-H	2.5-2.1	nonpolar covalent
H-F	4.0-2.1	polar covalent
Na-Cl	3.0-0.9	ionic

Writing Lewis Structures

Arrangement of atoms and e^-

Shows bonding (shared) and nonbonding (unshared) e^-

Use for covalent molecules and ions

H_2O H-O-H H:O:H

terminal

central

Writing Lewis Structures

General rules:

Usually only single bonds to
H Cl F Br I when terminal

1 or 2 bonds to O 3 bonds to N

Most 2nd period nonmetals obey octet rule

Other period nonmetals obey octet rule, but can have >8 e^- when central

Writing Lewis Structures

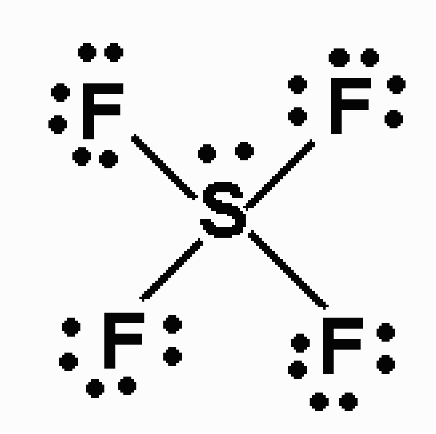
General rules:

Will examine simple compounds general formula: AX_n

A is central atom X is terminal

n is 1-6

SF_4



Writing Lewis Structures

Step 1

show arrangement of atoms

least electronegative usually central

frequently first atom in formula: ClF_3

$$\begin{array}{ccc} & F & \\ F & Cl & F \end{array}$$

Writing Lewis Structures

Step 2

calculate total No. of valence e^-

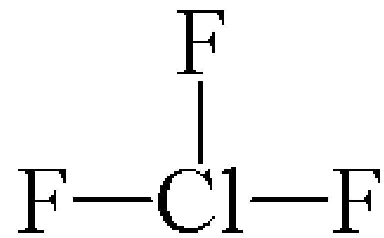
= sum of group numbers ± e^- if ion

= 4 × 7 = 28 for ClF_3

will be either bonding or nonbonding electrons

Writing Lewis Structures

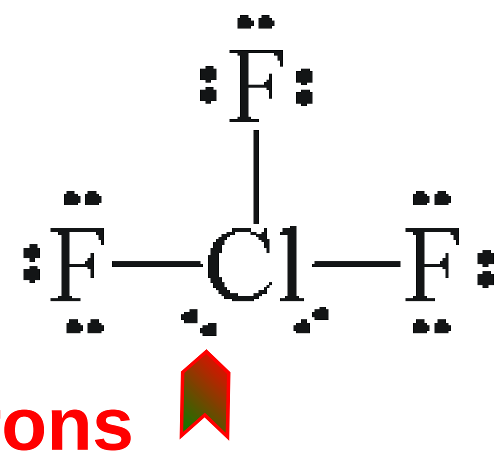
Step 3



count 2 e$^-$ for each bond in step 1

6 bonding electrons
22 (28-6) nonbonding electrons

distribute e$^-$ obeying octet rule



2 nonbonding electrons

Writing Lewis Structures

If too many e^- needed on an atom: octet rule not obeyed Add nonbonding e^- to any 3rd period element

If too few e^- to go around: need double/triple bond

Formal Charges

Charge given to atoms:
keeps track of valence e^-

Calculate for each atom

Formal charge =

No. valence e^- - No. shared e^- - No. unshared e^-

Formal Charges

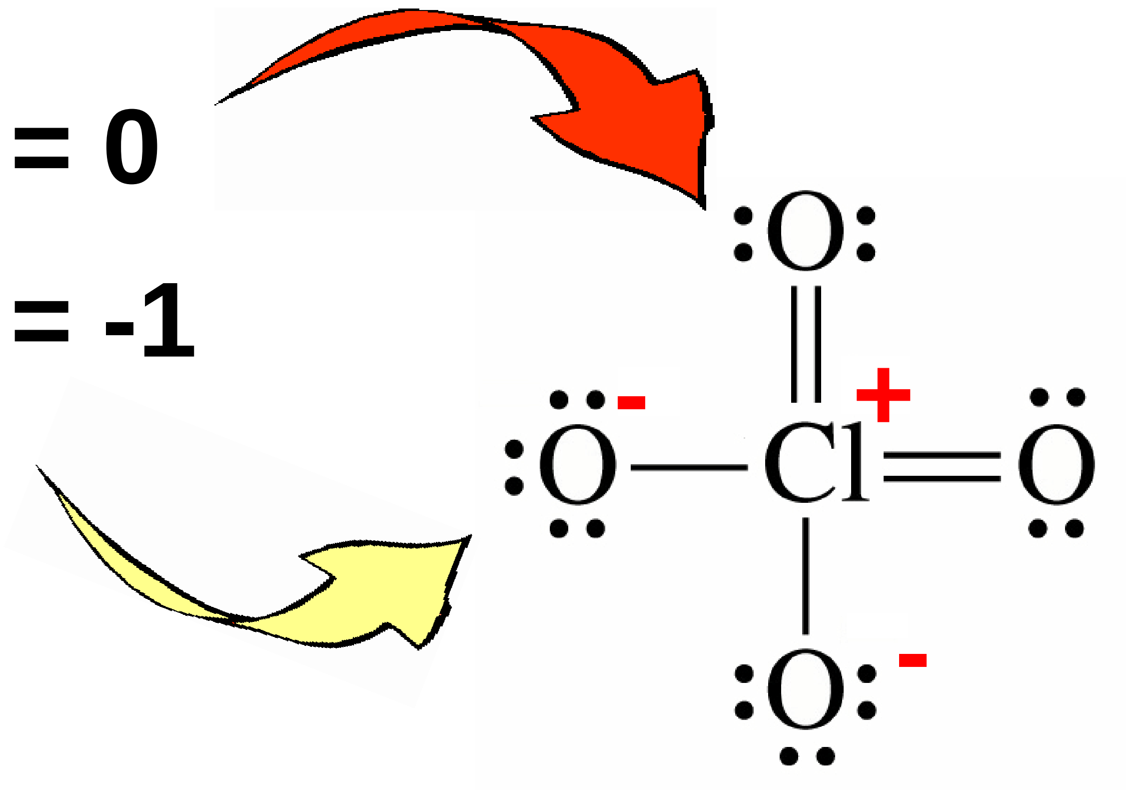
For ClO_4^-

No. valence e^- - No. shared e^- - No. unshared e^-

Cl = 7 - 6 - 0 = +1

O = 6 - 2 - 4 = 0

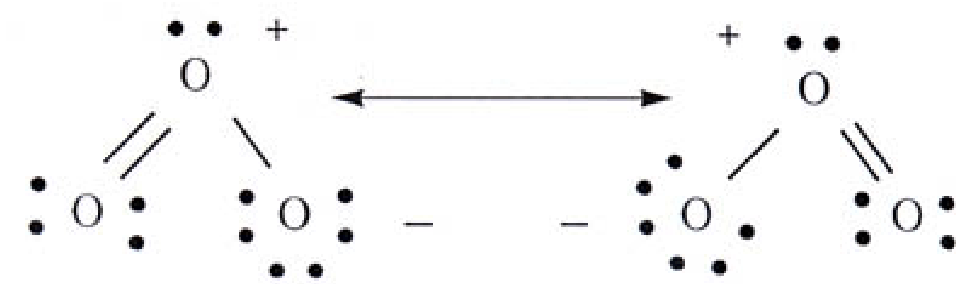
O = 6 - 1 - 6 = -1



Resonance

>2 Lewis structures representing a real molecule

O_3 two resonance forms



Covalent bond strengths

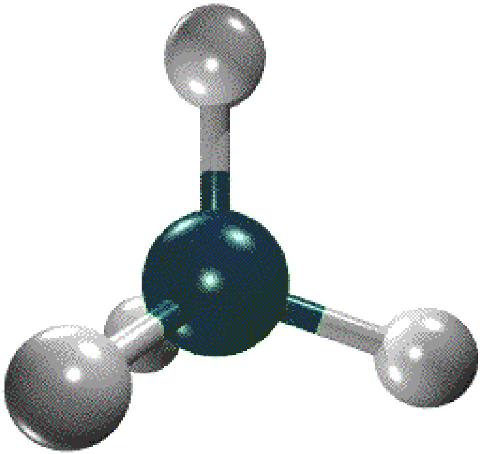
H_2 ¸ 2 H)H = + 436 kJ/mol

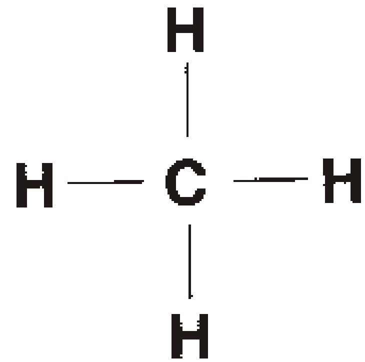
)H = bond dissociation energy
related to bond strength

Values in Table 9.2 For C-H : 414 kJ

Triple bonds strongest:
C!C > C' C > C/C

Covalent bond strengths





Methane

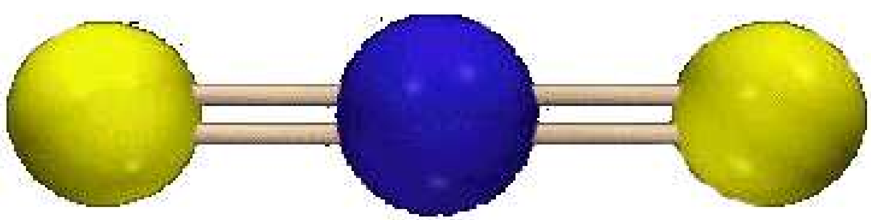
CH_4 ± C + 4 H

)H = 4 × 414 = 1656 kJ

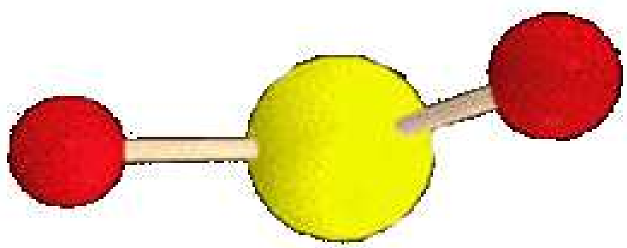
Chemical Bonding

Molecules are not flat

Have 3D structure and shape



Linear shape for CO_2



Bent shape for H_2O