Section 6-2 Covalent Bonding

Molecule
A neutral group of atoms held together by covalent bonds. A single molecule is an individual unit that can exist on its own.

Molecular Compound
A chemical compound whose simplest units are molecules

Chemical Formula
Indicates relative numbers of atoms of each kind in a chemical compound by using atomic symbols and numerical subscripts

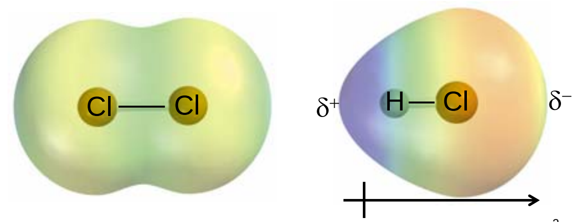
Molecular Formula
Shows the types and numbers of atoms combined in a single molecule of a molecular compound

Diatomic Molecule
A molecule containing only two atoms

Covalent Bond Types

Nonpolar Covalent | Polar Covalent

:C̤̈l:C̤̈l: | H :C̤̈l:

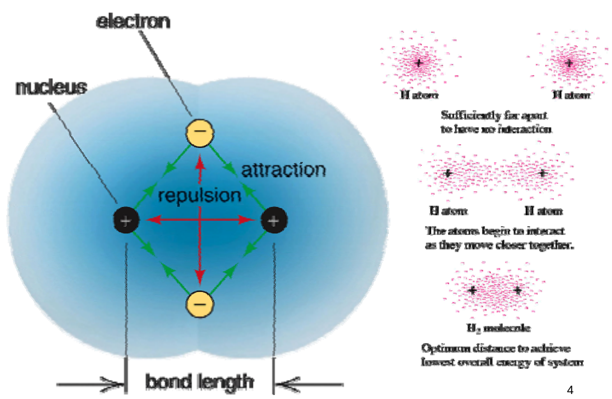


Covalent Bond Formation

- Atoms are at a lower potential energy when bonded to other atoms
- Approaching nuclei and electrons are attracted to each other
  → Decrease in potential energy
- Nuclei repel each other
  → Increase in potential energy
- Electrons repel each other
  → Increase in potential energy

The potential energy is at a minimum when the distance at which the repulsion of like charges equals the attraction of opposite charges.

Attractive and Repulsive Forces



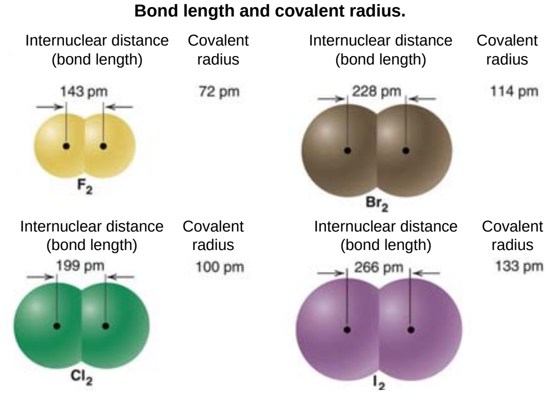
Bond Energy

Bond Length
The distance between two bonded atoms at their minimum potential energy. This is reported as average because the atoms will slightly vibrate.

Bond Energy
The energy required to break one mole of chemical bonds and form neutral isolated atoms. (kJ/mol)

- Bond Energy and Bond Length will vary depending on the specific elements that have combined.
- It can vary from molecule to molecule so table values are reported as averages.

Bond length and covalent radius.



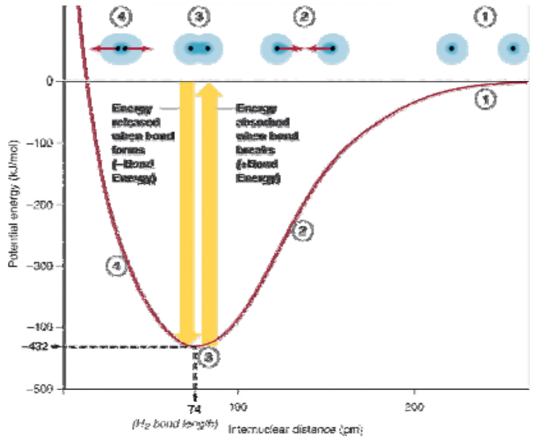


Table 9.3 Average Bond Lengths (pm)

Bond	Length	Bond	Length	Bond	Length	Bond	Length
Single Bonds							
H—H	74	N—H	101	Si—H	148	S—H	134
H—F	92	N—N	146	Si—Si	234	S—P	210
H—Cl	127	N—P	177	Si—O	161	S—S	204
H—Br	141	N—O	144	Si—S	210	S—F	158
H—I	161	N—S	168	Si—N	172	S—Cl	201
		N—F	139	Si—F	156	S—Br	225
		N—Cl	191	Si—Cl	204	S—I	234
C—H	109	N—Br	214	Si—Br	216		
C—C	154	N—I	222	Si—I	240	F—F	143
C—Si	186					F—Cl	166
C—N	147	O—H	96	P—H	142	F—Br	178
C—O	143	O—P	160	P—Si	227	F—I	187
C—P	187	O—O	148	P—P	221	Cl—Cl	199
C—S	181	O—S	151	P—F	156	Cl—Br	214
C—F	133	O—F	142	P—Cl	204	Cl—I	243
C—Cl	177	O—Cl	164	P—Br	222	Br—Br	228
C—Br	194	O—Br	172	P—I	243	Br—I	248
C—I	213	O—I	194			I—I	266
Multiple Bonds							
C=C	134	N=N	122	C≡C	121	N≡N	110
C=N	127	N=O	120	C≡N	115	N≡O	106
C=O	123	O_2	121	C≡O	113		

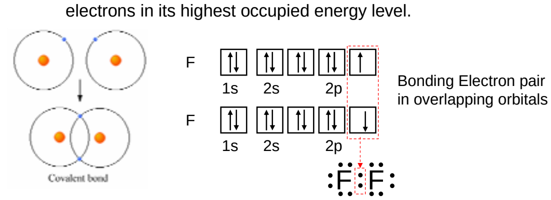
Table 9.2 Average Bond Energies (kJ/mol)

Bond	Energy	Bond	Energy	Bond	Energy	Bond	Energy
Single Bonds							
H—H	432	N—H	391	Si—H	323	S—H	347
H—F	565	N—N	160	Si—Si	226	S—S	266
H—Cl	427	N—P	209	Si—O	368	S—F	327
H—Br	363	N—O	201	Si—S	226	S—Cl	271
H—I	295	N—F	272	Si—F	565	S—Br	218
		N—Cl	200	Si—Cl	381	S—I	~170
C—H	413	N—Br	243	Si—Br	310		
C—C	347	N—I	159	Si—I	234	F—F	159
C—Si	301					F—Cl	193
C—N	305	O—H	467	P—H	320	F—Br	212
C—O	358	O—P	351	P—Si	213	F—I	263
C—P	264	O—O	204	P—P	200	Cl—Cl	243
C—S	259	O—S	265	P—F	490	Cl—Br	215
C—F	453	O—F	190	P—Cl	331	Cl—I	208
C—Cl	339	O—Cl	203	P—Br	272	Br—Br	193
C—Br	276	O—Br	234	P—I	184	Br—I	175
C—I	216	O—I	234			I—I	151
Multiple Bonds							
C=C	614	N=N	418	C≡C	839	N≡N	945
C=N	615	N=O	607	C≡N	891		
C=O	745 (799 in CO_2)	O_2	498	C≡O	1070		

Octet Rule

Octet Rule

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



Exceptions to the Octet Rule

– Hydrogen forms bonds where it is surrounded by 2 electrons
– Boron can form bonds where it is surrounded by 6 electrons
– Some elements can have more than 8 electrons when combined with highly electronegative elements.

Electron-Dot Notation

Electron-Dot Notation

An electron configuration notation in which only the valence electrons of an atom of a particular element are shown, indicated by dots placed around the elements symbol.

Group	1A(1)	2A(2)	3A(13)	4A(14)	5A(15)	6A(16)	7A(17)	8A(18)
Config.	ns^1	ns^2	ns^2np^1	ns^2np^2	ns^2np^3	ns^2np^4	ns^2np^5	ns^2np^6
Period 2	•Li	•Be•	•B•	•C•	•N•	:O•	:F:	:Ne:
Period 3	•Na	•Mg•	•Al•	•Si•	•P•	:S•	:Cl:	:Ar:

Nonmetals - The number of unpaired dots indicates the number of electrons it gains, or the number of covalent bonds it usually forms.

Metals – The total number of dots is the maximum number of electrons it may lose when forming a cation.

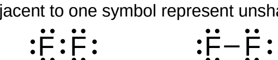
Lewis Structures

Unshared Pair or Lone Pair

A pair of unshared electrons that is not involved in bonding and that belongs exclusively to one atom

Lewis Structures

– atomic symbols represent nuclei and inner-shell electrons
– dot-pairs or dashes between atomic symbols represent electron pairs in covalent bonds
– Dots adjacent to one symbol represent unshared electrons



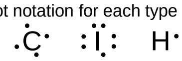
Structural Formula

Indicates the kind, number, arrangement, and bonds but not unshared electron pairs

F– F

Draw a Lewis Structure for CH_3I

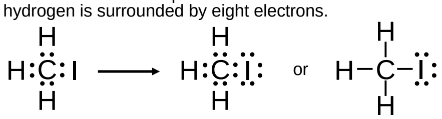
- Write the electron-dot notation for each type of atom



- Determine the number of valence electrons to be shared

I have…	I need…	
C 1 x 4e = 4e	C 1 x 8e = 8e	22e Needed
I 1 x 7e = 7e	I 1 x 8e = 8e	- 14e Present
H 3 x 1e = 3e	H 3 x 2e = 6e	8e Shared
14e	22e	

- Form a skeleton structure for the molecule. If carbon is present, it is the central atom. Otherwise, the least electronegative atom is central (hydrogen is never central). Connect the atoms by electron pair bonds. Add unshared pairs of electrons so each nonmetal other than hydrogen is surrounded by eight electrons.



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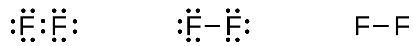
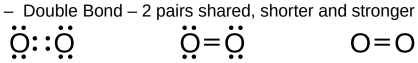
Bond Order (Single or Multiple Bonds)

- Every pair of electrons shared between atoms is a bond
  - Single Bond – 1 pair shared

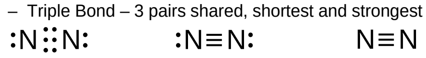


Multiple Bonds

- Double Bond – 2 pairs shared, shorter and stronger bond



- Triple Bond – 3 pairs shared, shortest and strongest bond



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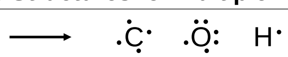
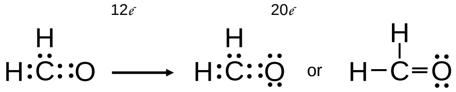
Lewis Structures for Multiple Bonds

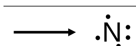
CH_2O



I have…	I need…	
C 1 x 4e = 4e	C 1 x 8e = 8e	20e Needed
O 1 x 6e = 6e	O 1 x 8e = 8e	- 12e Present
H 2 x 1e = 2e	H 2 x 2e = 4e	8e Shared
12e	20e	



N_2



I have…	I need…
N 2 x 5e = 10e	N 2 x 8e = 16e

16e Needed
- 10e Present
6e Shared

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Table 9.4 The Relation of Bond Order, Bond Length, and Bond Energy

Bond	Bond Order	Average Bond Length (pm)	Average Bond Energy (kJ/mol)
C—O	1	143	358
C=O	2	123	745
C≡O	3	113	1070
C—C	1	154	347
C=C	2	134	614
C≡C	3	121	839
N—N	1	146	160
N=N	2	122	418
N≡N	3	110	945

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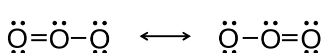
Resonance Structures

Resonance

Refers to bonding in molecules or ions that cannot be correctly represented by a single Lewis Structure



- Both forms of the molecule are constantly alternating or resonating
- Both bonds are identical in energy and shared electrons
- The bond order is an average of resonating bonds

$$\frac{\text{3 Shared Electron Pairs}}{\text{2 Bonds}} = \text{1.5 Bond}$$

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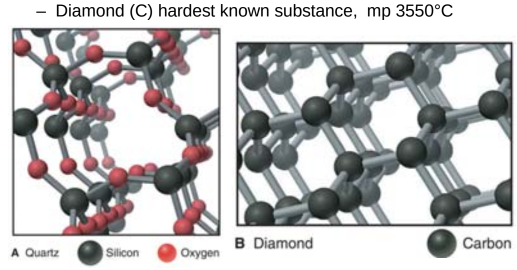
Covalent bonds of network covalent solids.

- The physical properties of network covalent solids, are related to the strength of their covalent bonds.
  - In these substances there are no individual molecules, the covalent bonding extends in 3-D throughout the substance.
  - Ex Quartz (SiO_2) very hard, mp 1550°C
  - Diamond (C) hardest known substance, mp 3550°C



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