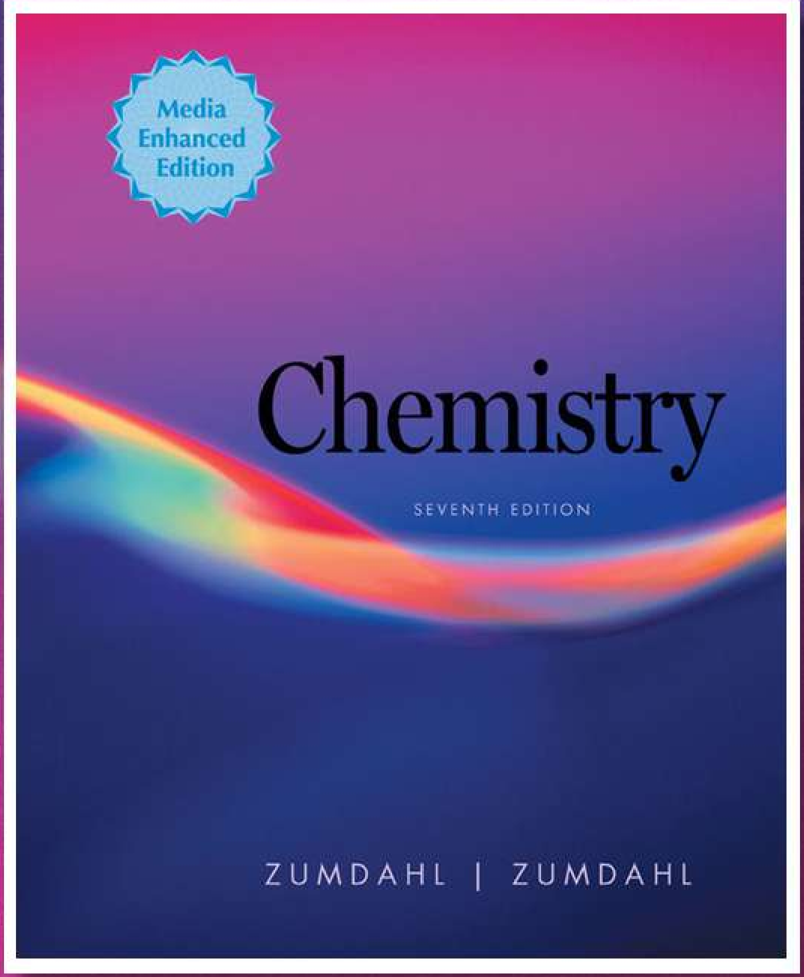


Chapter Eight

Bonding: General Concepts

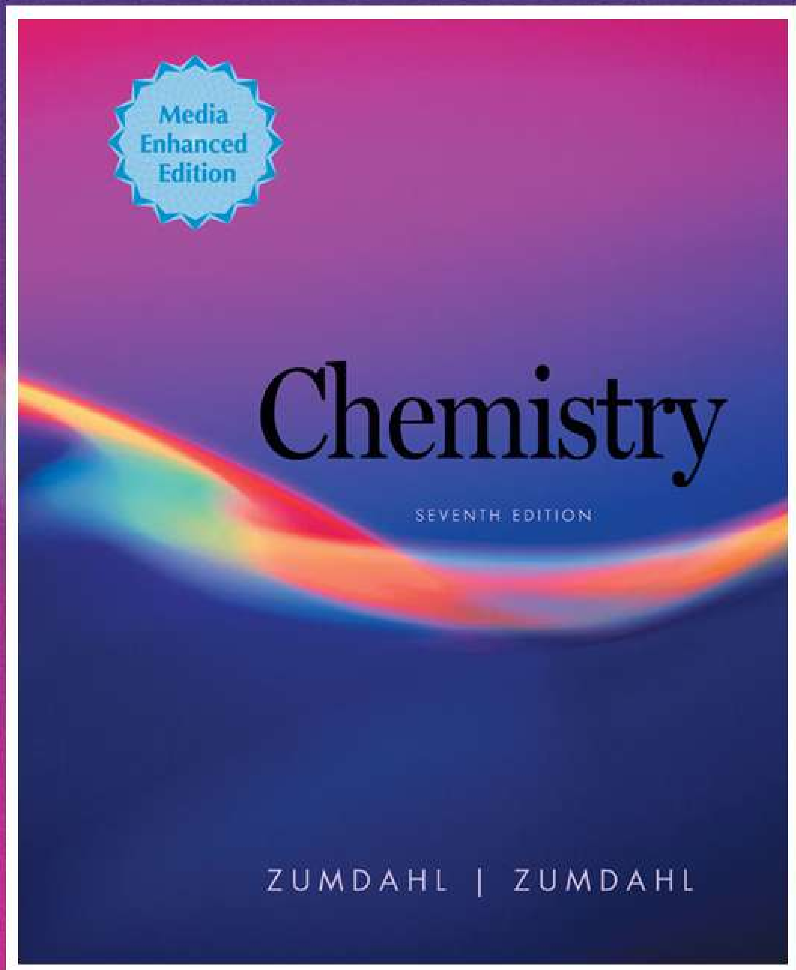
Quartz

Questions to Consider

What is meant by the term “chemical bond?”

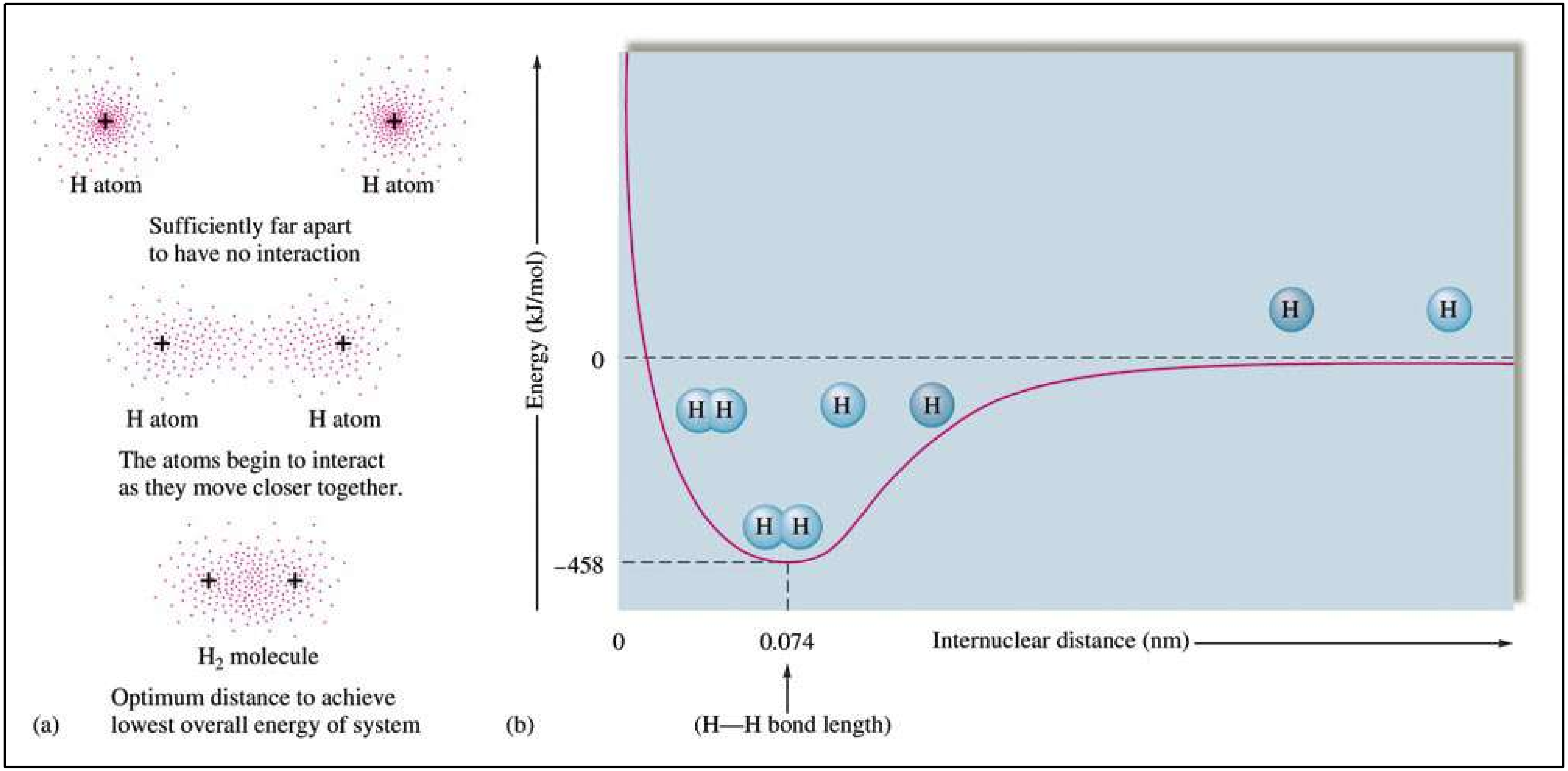
Why do atoms bond with each other to form molecules?

How do atoms bond with each other to form molecules?



Types of Chemical Bonds

Figure 8.1 a & b (a) The Interaction of Two Hydrogen Atoms (b) Energy Profile as a Function of the Distance Between the Nuclei of the Hydrogen Atoms



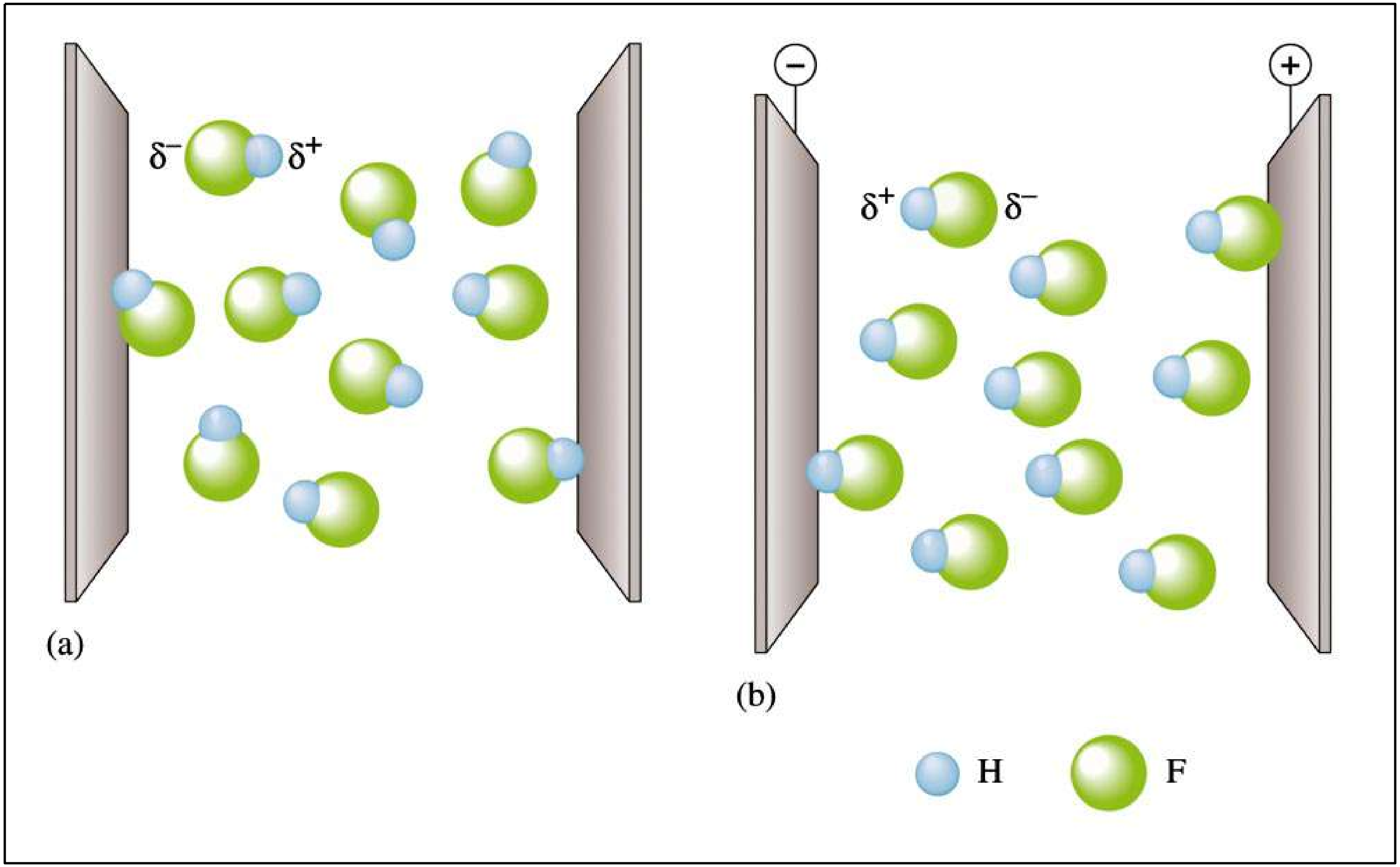
Key Ideas in Bonding

Ionic Bonding: Electrons are transferred

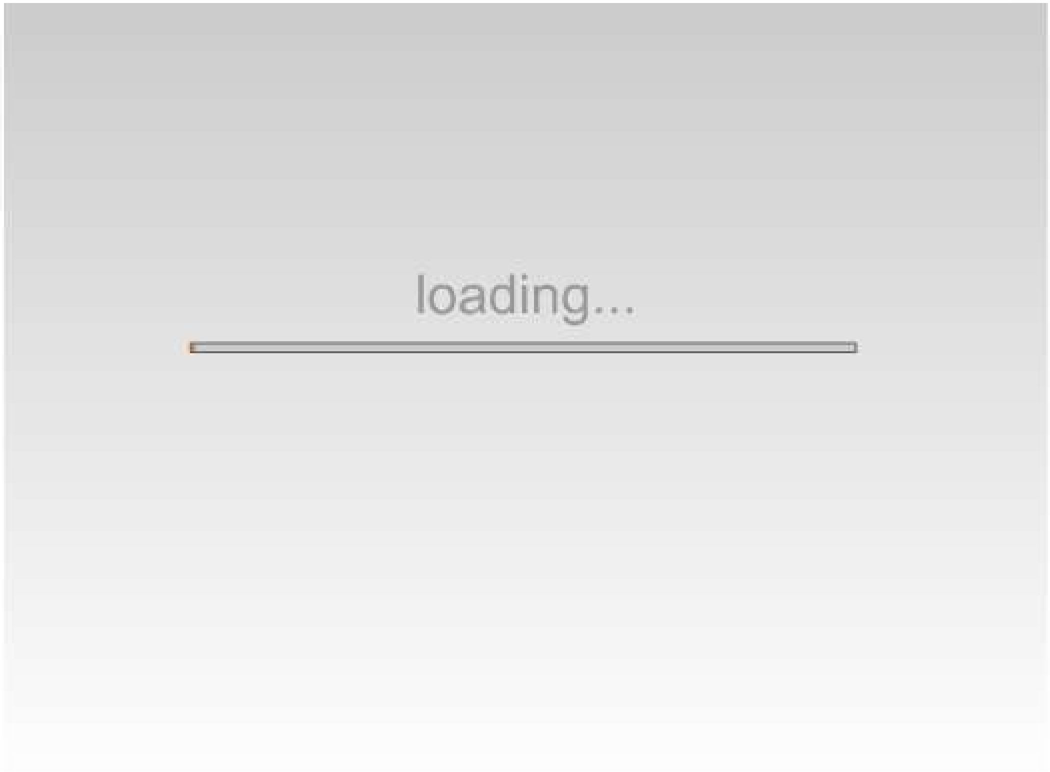
Covalent Bonding: Electrons are shared equally

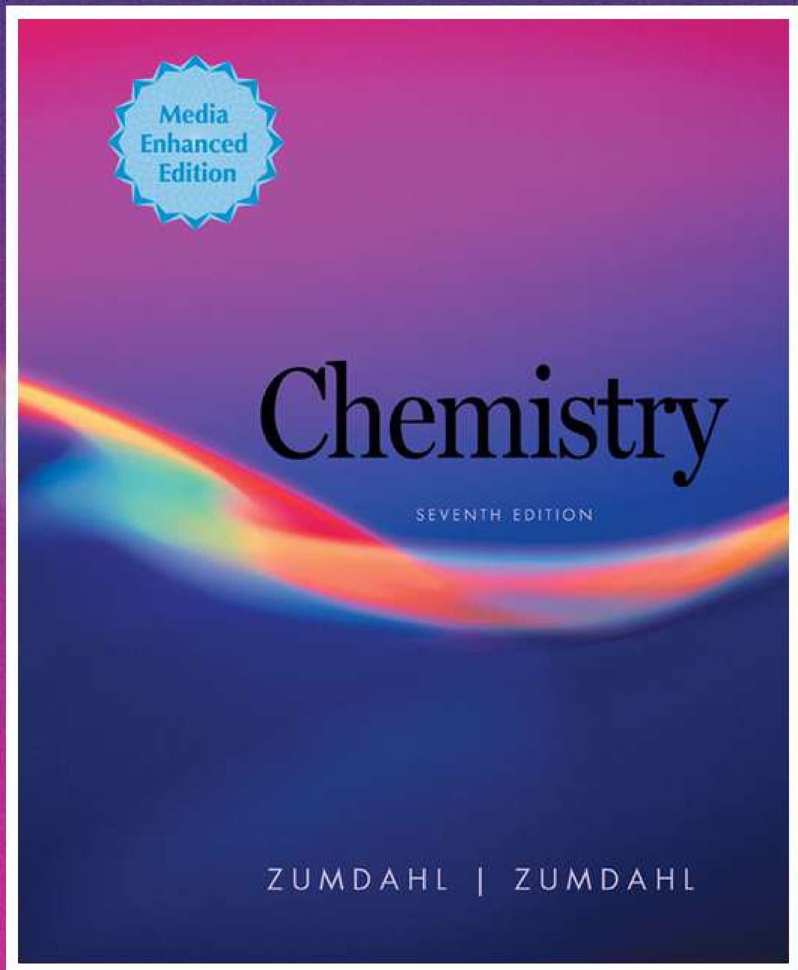
What about intermediate cases?

Figure 8.2 The Effect of an Electric Field on Hydrogen Fluoride Molecules



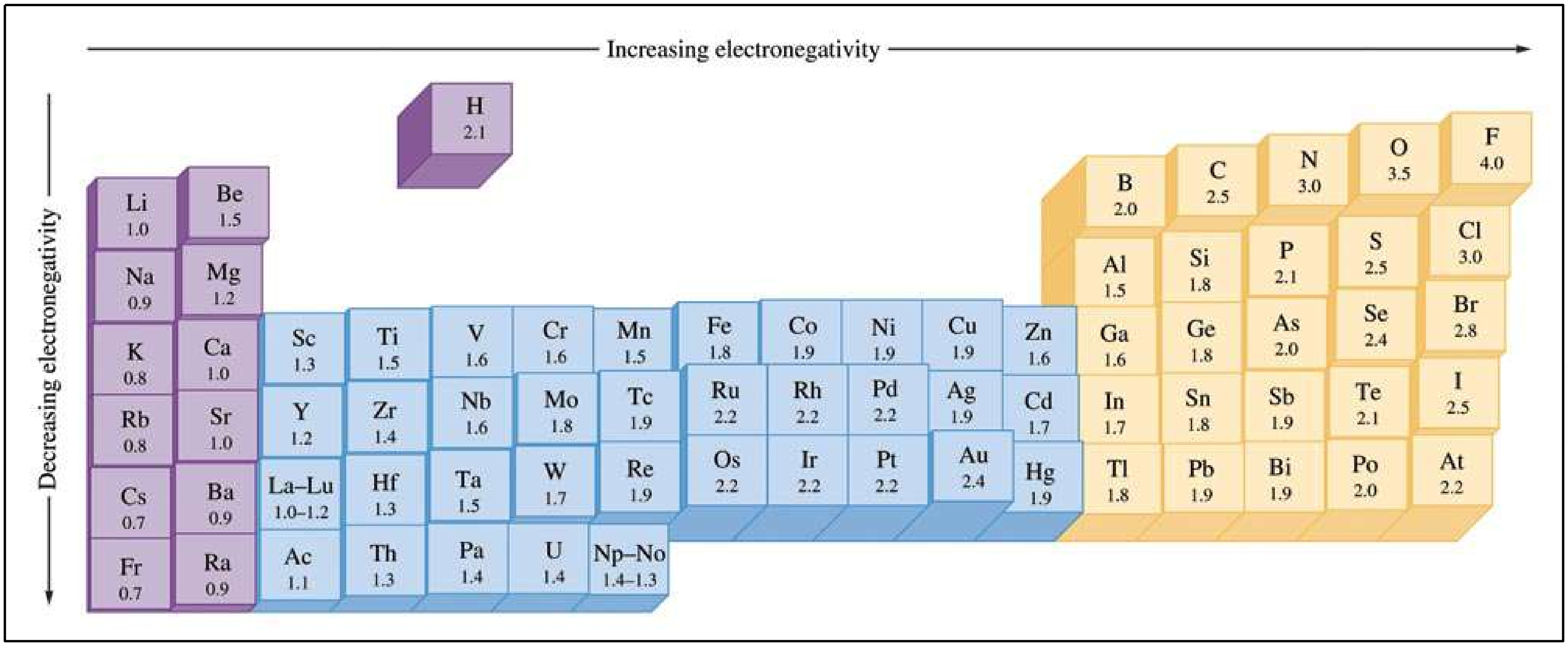
Polar Molecules





Electronegativity

Figure 8.3 The Pauling Electronegativity Vaules



React 2

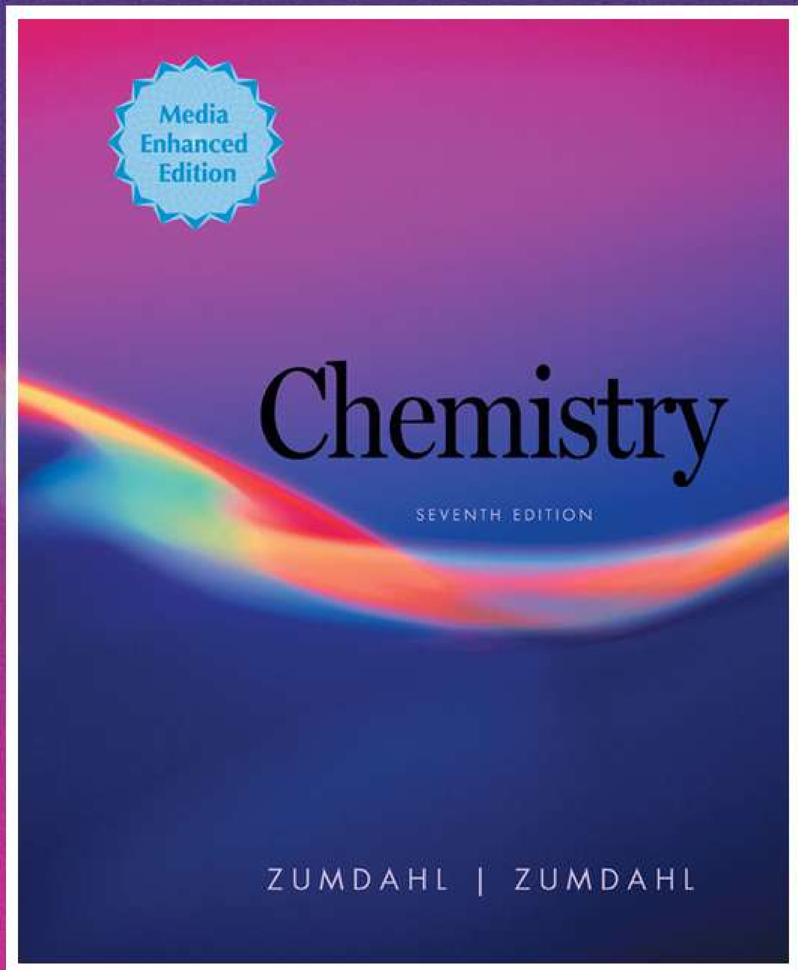
If lithium and fluorine react, which has more attraction for an electron? Why?

In a bond between fluorine and iodine, which has more attraction for an electron? Why?

React 3

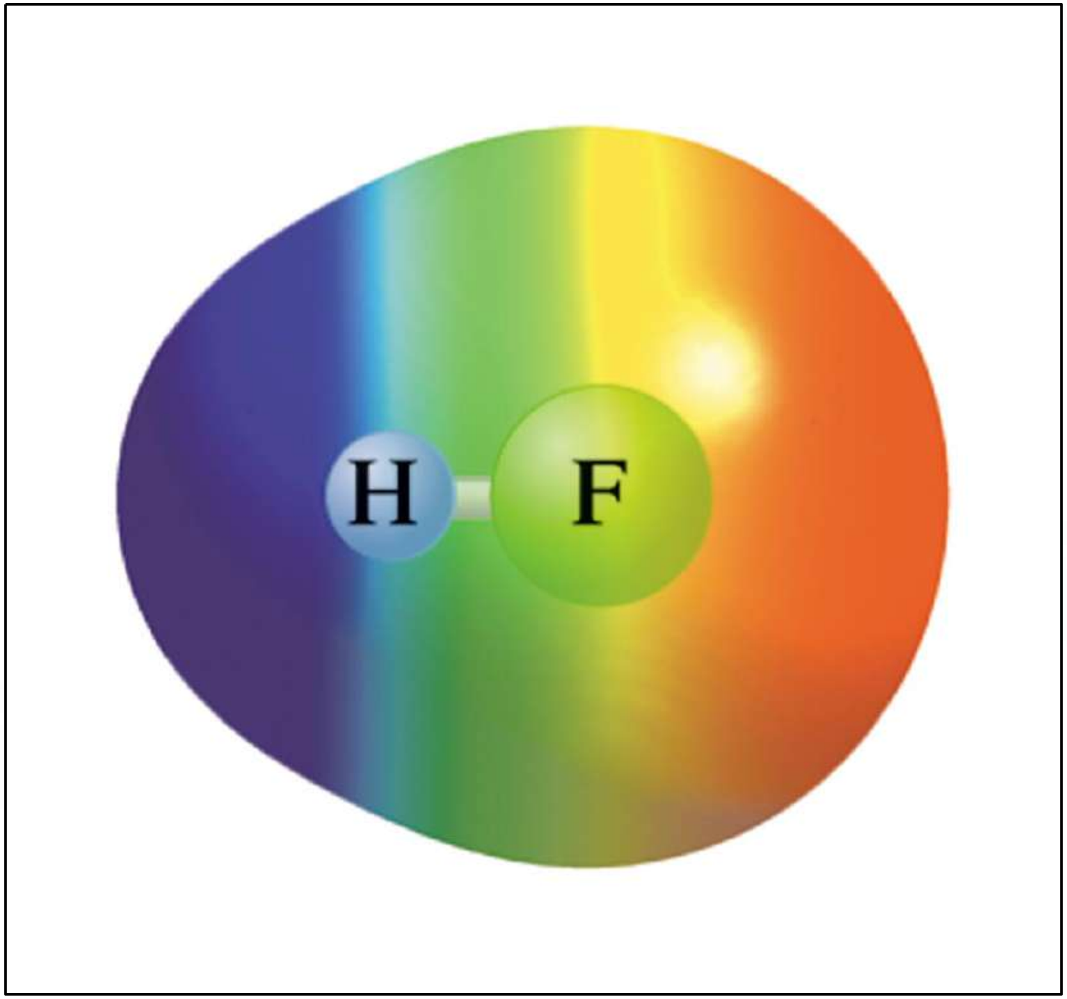
What is the general trend for electronegativity across rows and down columns on the periodic table?

Explain the trend.

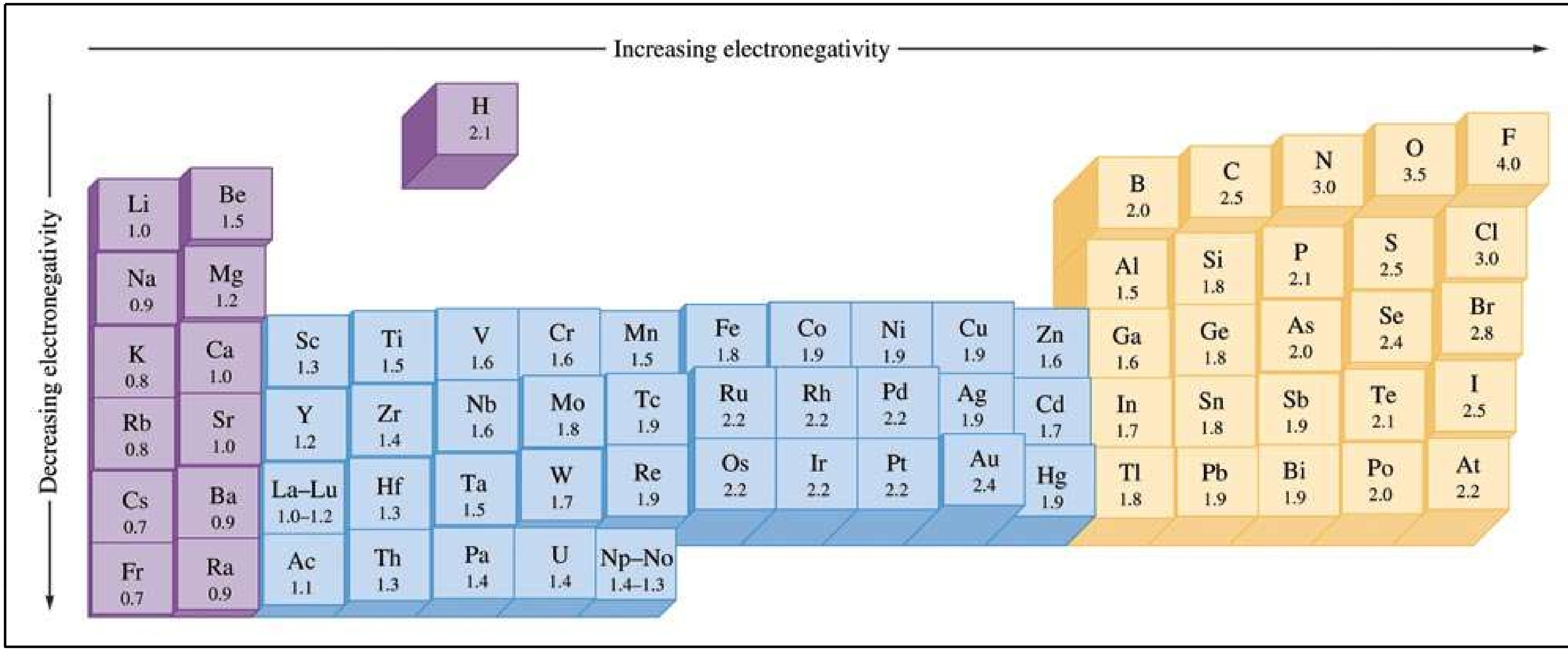


Bond Polarity and Dipole Moments

Figure 8.4 An Electrostatic Potential Map of HF



The Pauling Electronegativity Values



React 4

Arrange the following bonds from most to least polar:

(a.) N-FO-FC-F

(b.)C-FN-OSi-F

(c.)H-ClB-ClS-Cl

React 5

Which of the following bonds would be the least polar yet still be considered polar covalent?

Mg-O   C-O   O-O   Si-O   N-O

React 6

Which of the following bonds would be the most polar without being considered ionic?

Mg-O   C-O   O-O   Si-O   N-O

Figure 8.5 a-c The Charge Distribution in the Water Molecule

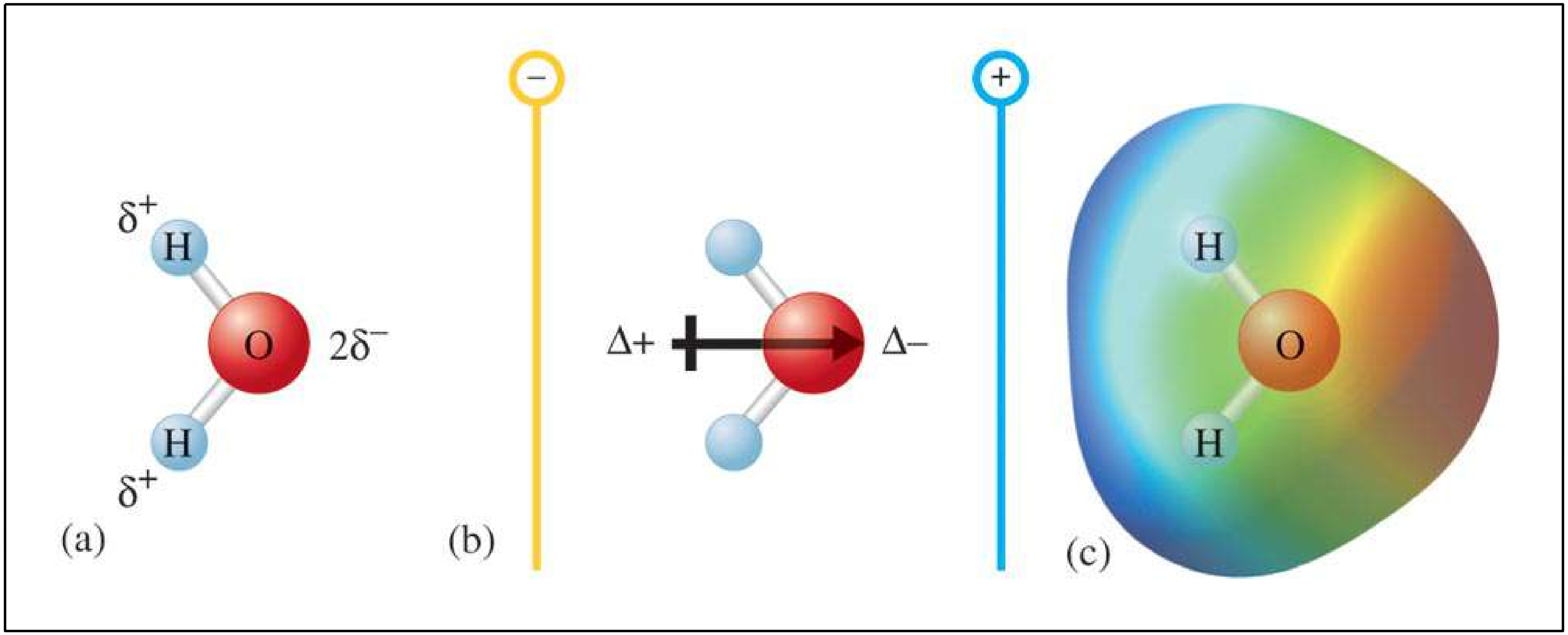


Figure 8.6 a-c The Structure and Charge Distribution of the Ammonia Molecule

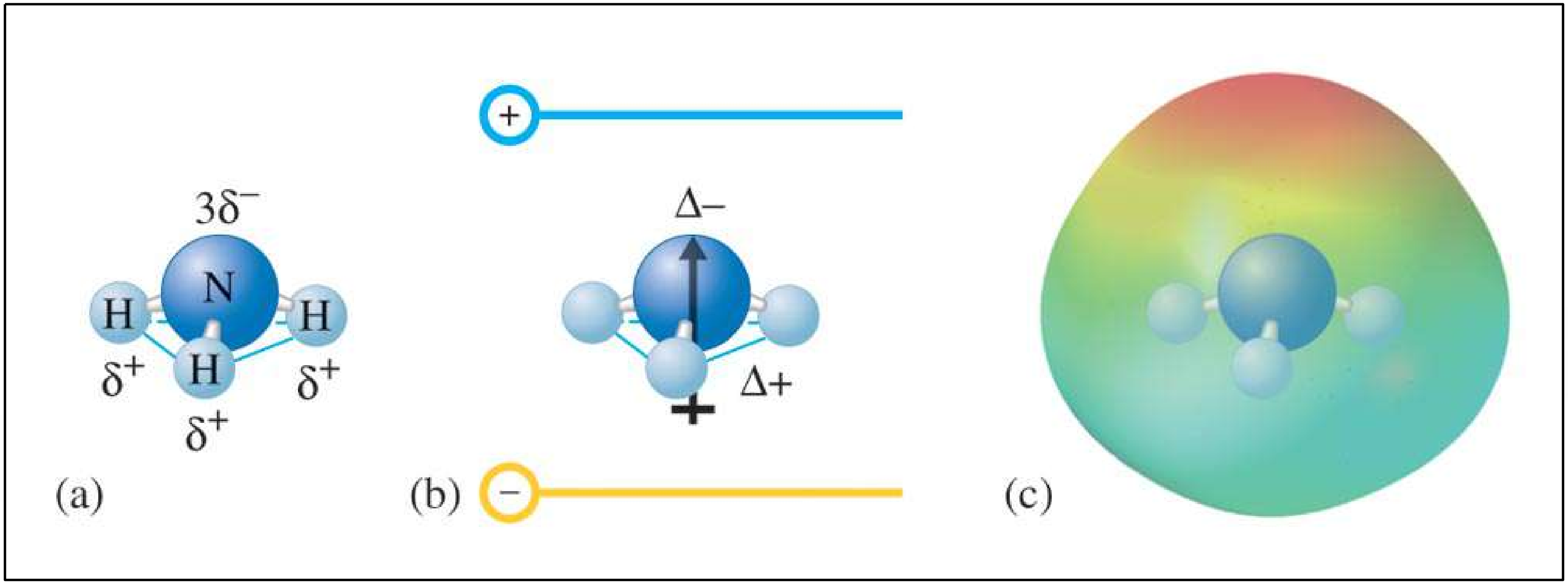
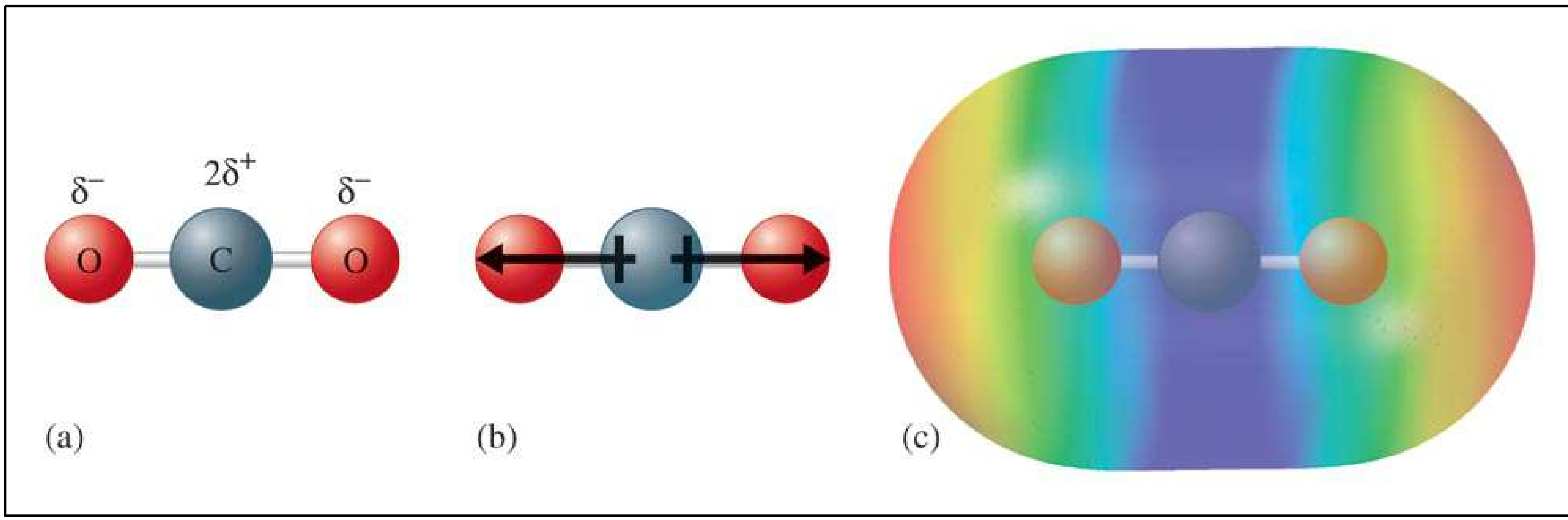
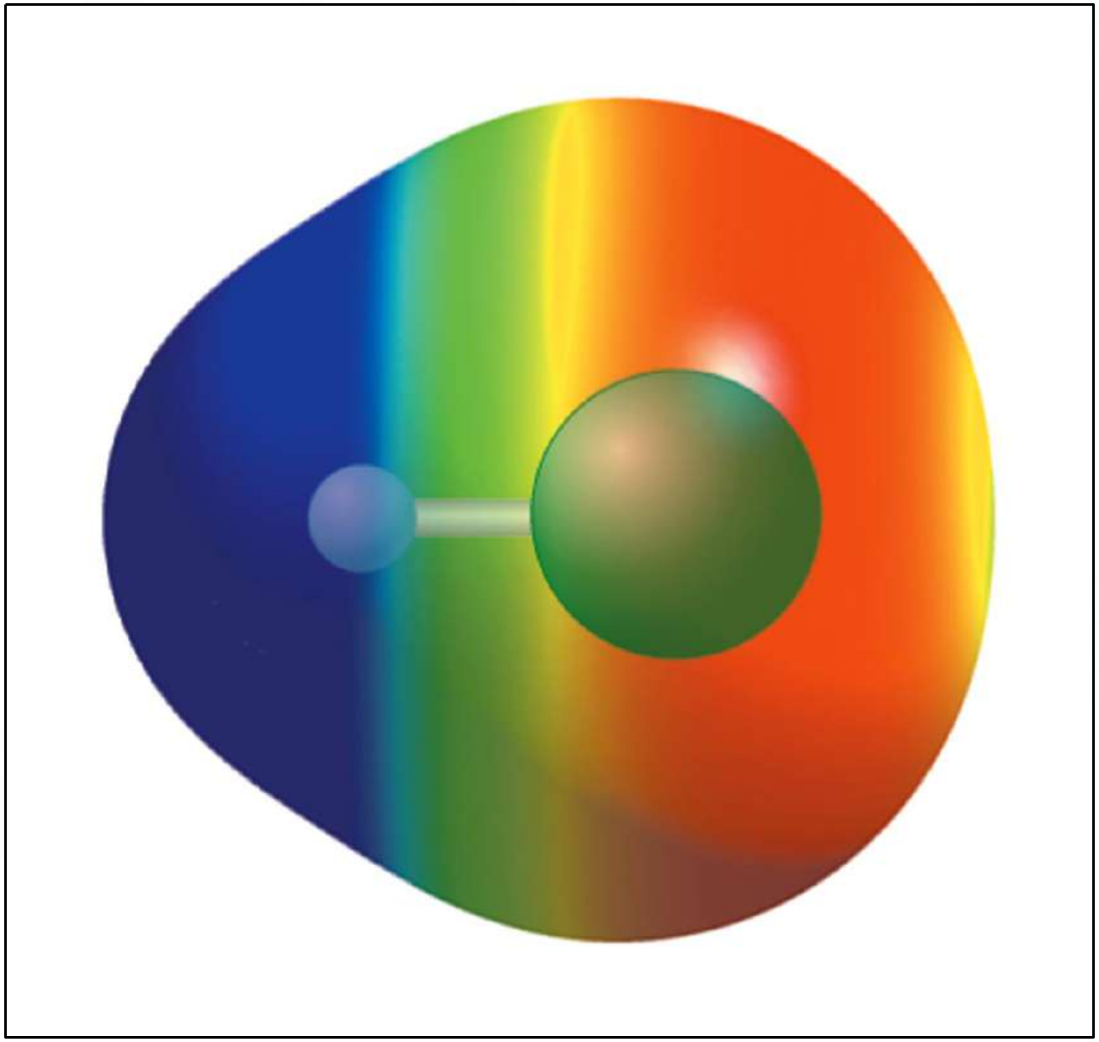


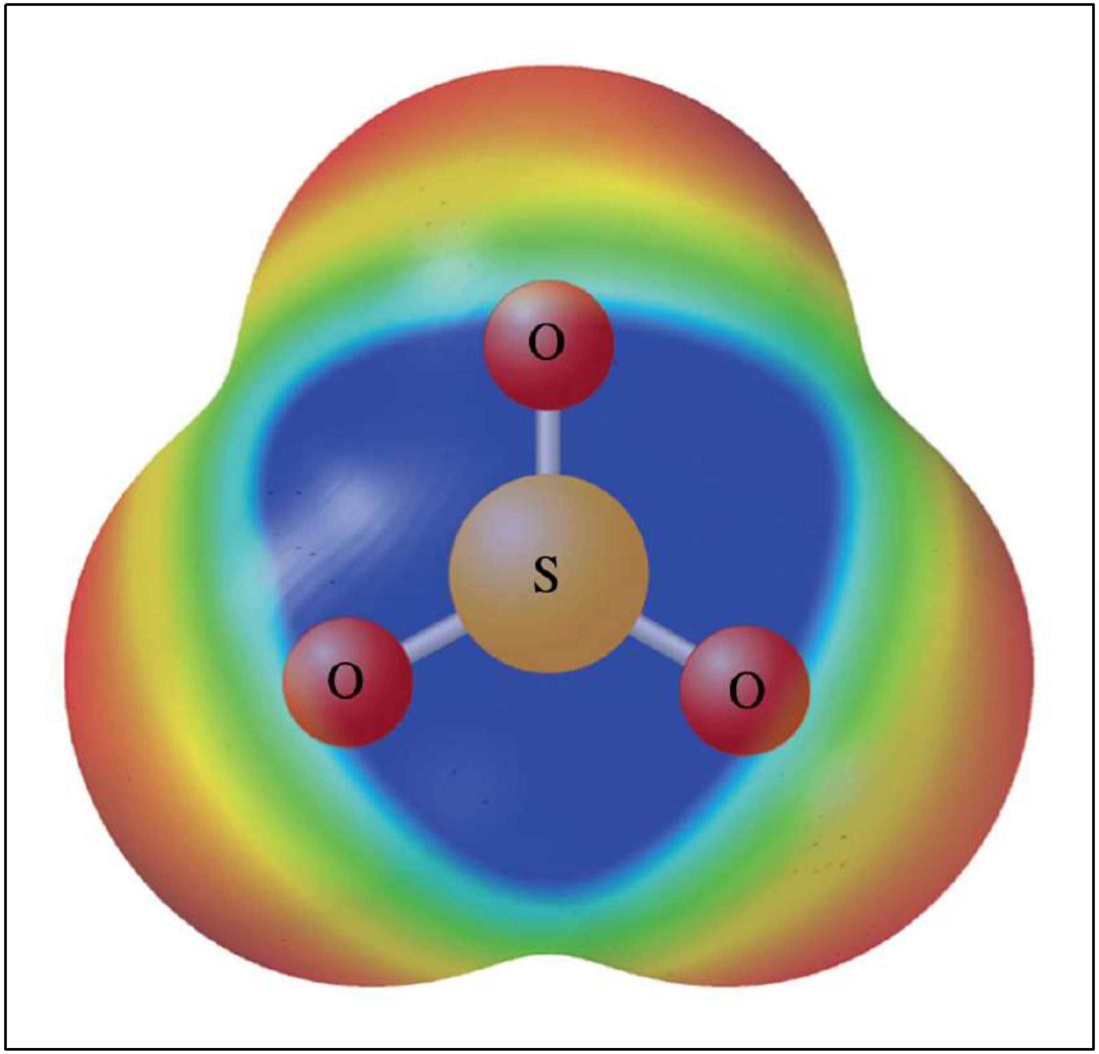
Figure 8.7 a-c The Carbon Dioxide Molecule



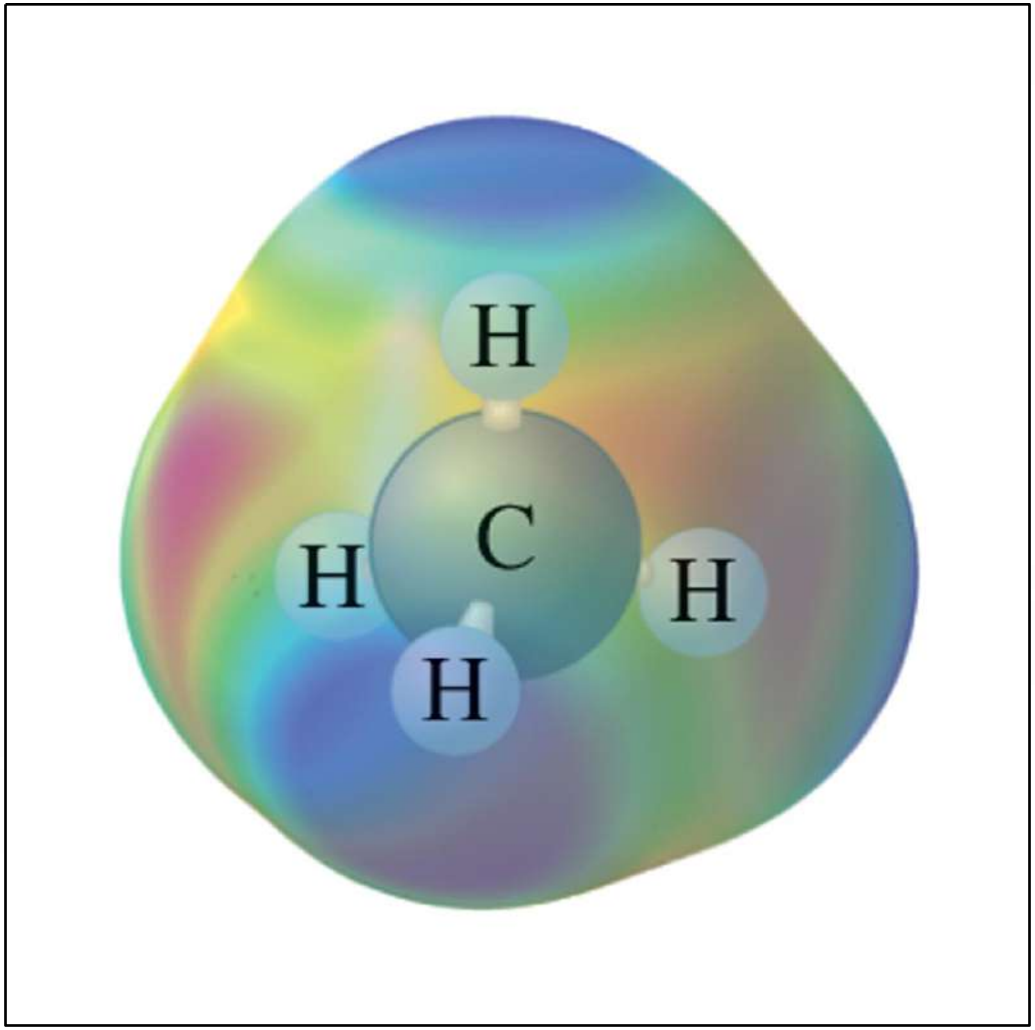
e.p. Diagram HCL



e.p.Diagram SO_3



e.p. Diagram CH_4



e.p. Diagram H2s

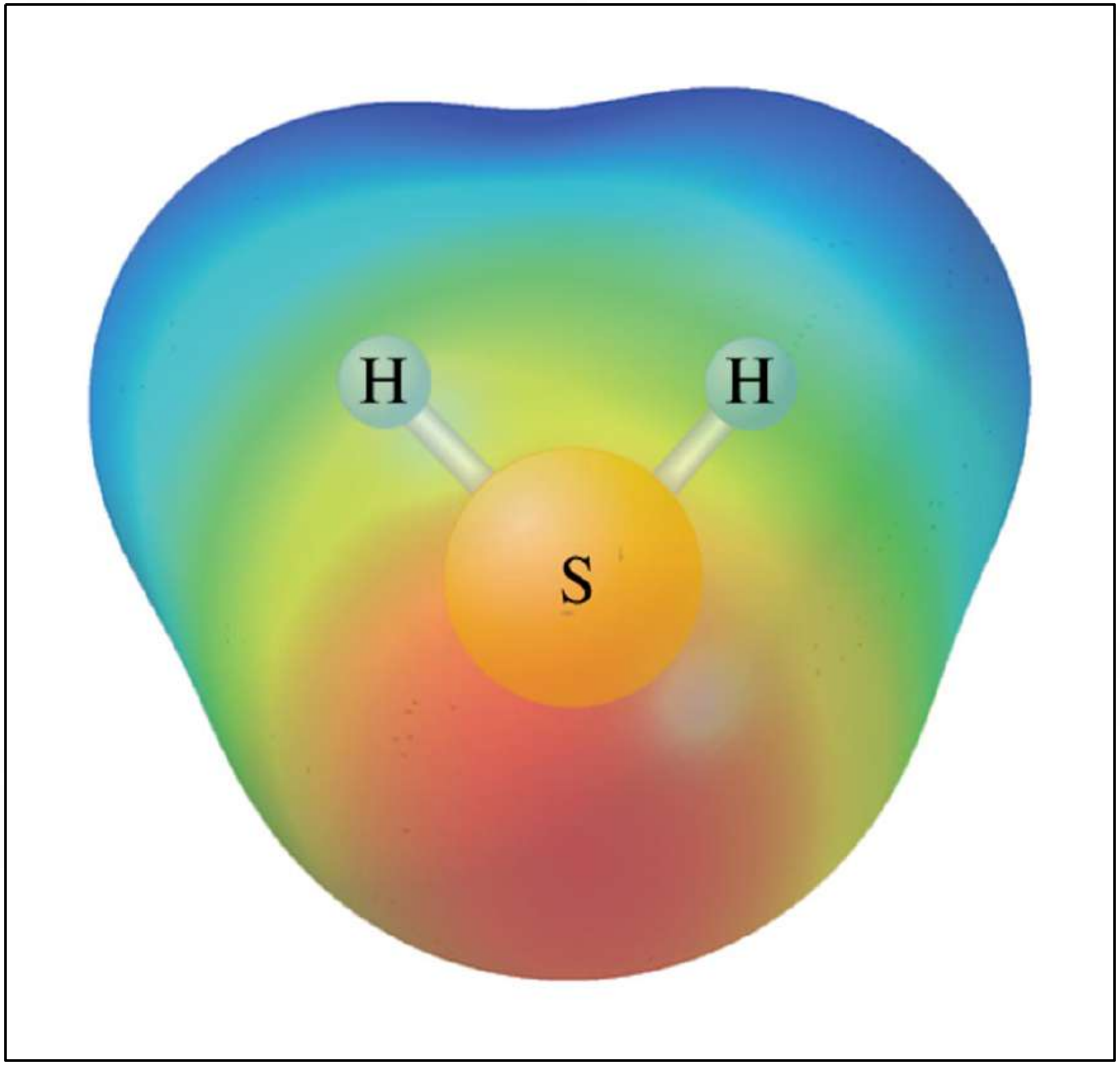
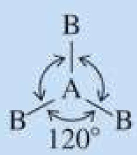
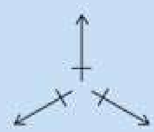
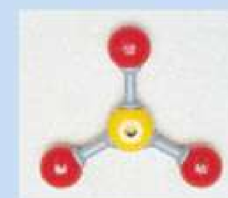
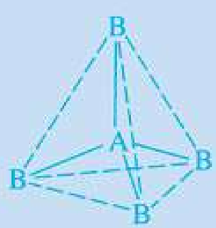
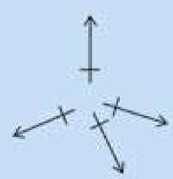
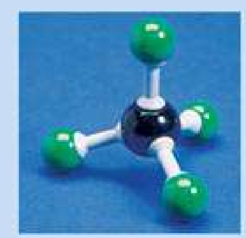
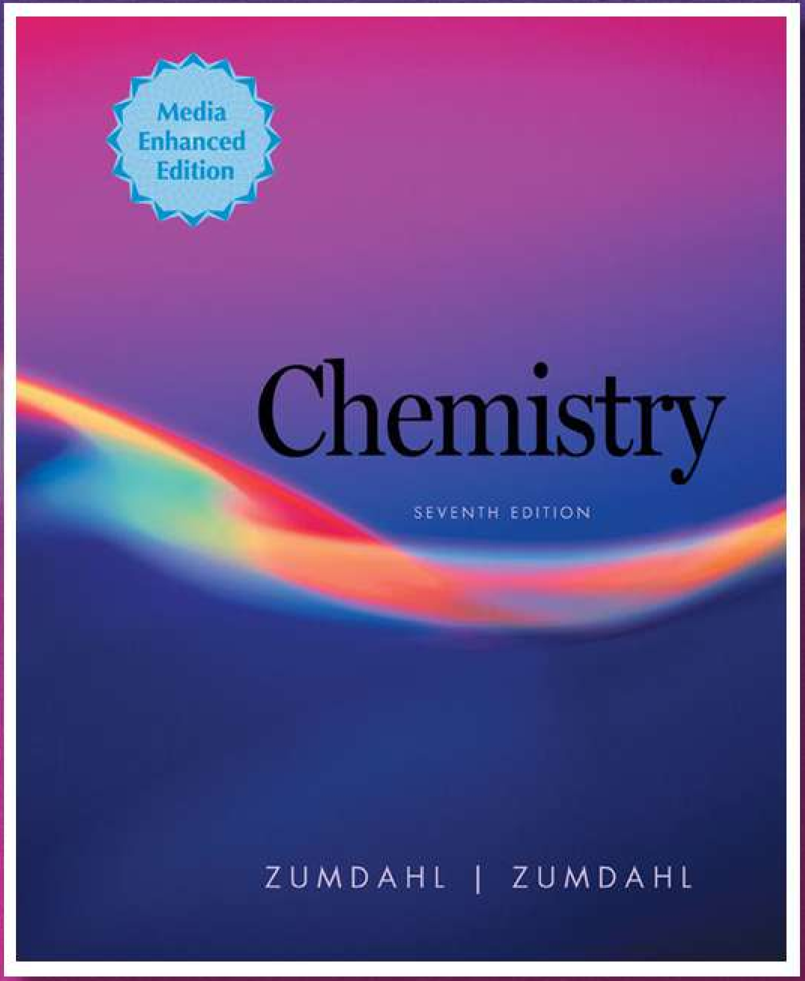


Table 8.2 Types of Molecules with Polar Bonds but No Resulting Dipole Moment

TABLE 8.2 Types of Molecules with Polar Bonds but No Resulting Dipole Moment

Type			Cancellation of Polar Bonds	Example	Ball-and-Stick Model
Linear molecules with two identical bonds	B—A—B	CO_2			
Planar molecules with three identical bonds 120 degrees apart				SO_3	
Tetrahedral molecules with four identical bonds 109.5 degrees apart				CCl_4	



Ions: Electron Configurations and Sizes

Ionic Radii

loading...

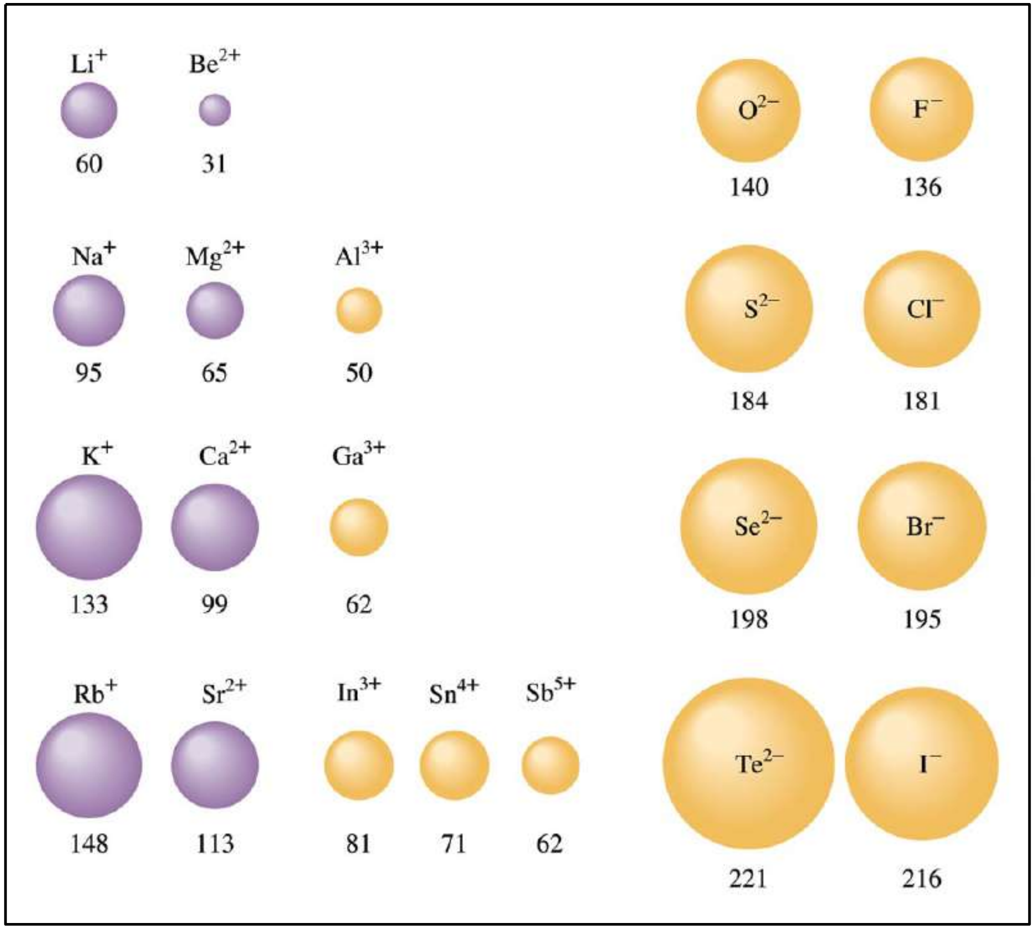
A Bauxite Mine

Table 8.3 Common Ions with Noble Gas Configurations in Ionic Compounds

TABLE 8.3 Common Ions with Noble Gas Configurations in Ionic Compounds

Group 1A	Group 2A	Group 3A	Group 6A	Group 7A	Electron Configuration
H^-, Li^+	Be^{2+}				[He]
Na^+	Mg^{2+}	Al^{3+}	O^{2-}	F^-	[Ne]
K^+	Ca^{2+}		S^{2-}	Cl^-	[Ar]
Rb^+	Sr^{2+}		Se^{2-}	Br^-	[Kr]
Cs^+	Ba^{2+}		Te^{2-}	I^-	[Xe]

Figure 8.8 Sizes of Ions Related to Positions of the Elements on the Periodic Table



React 7

Choose an alkali metal, an alkaline metal, a noble gas, and a halogen so that they constitute an isoelectronic series when the metals and halogen are written as their most stable ions.

What is the electron configuration for each species?

Determine the number of electrons for each species.

Determine the number of protons for each species.

Rank the species according to increasing radius.

Rank the species according to increasing ionization energy.

What we can “read” from the periodic table:

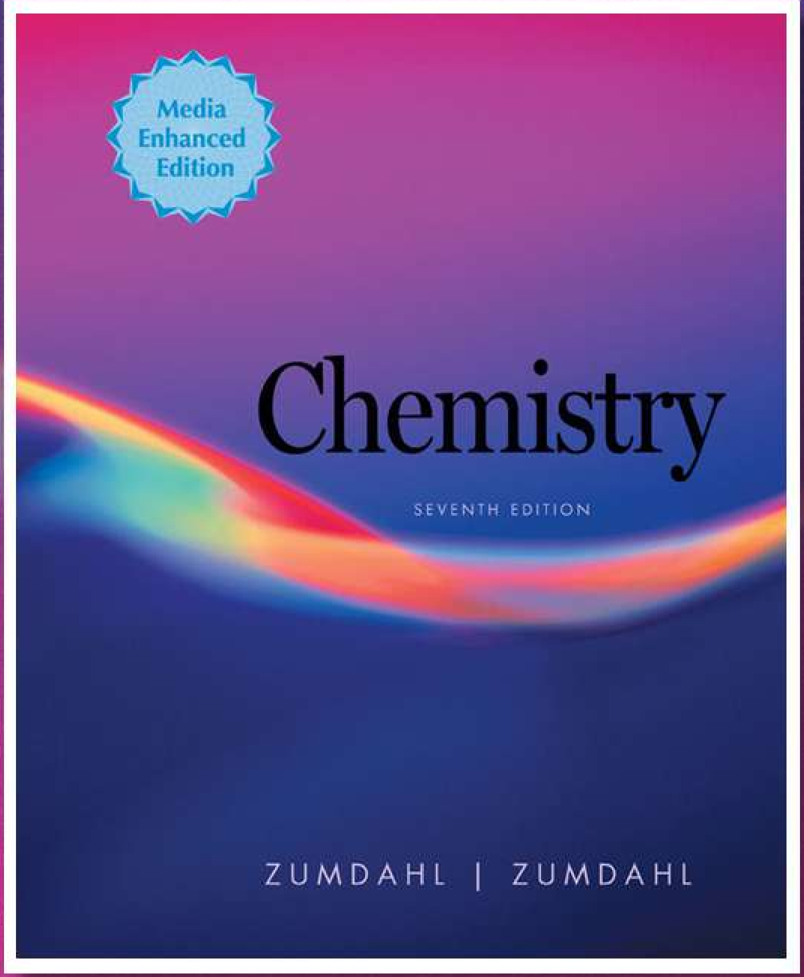
Trends for

- Atomic size
- Ion radius
- Ionization energy
- Electronegativity

Electron configurations

Predicting formulas for ionic compounds

Ranking polarity of covalent bonds



Energy Effects in Binary Ionic Compounds

Formation of an Ionic Solid

1. Sublimation of the solid metal
   - M(*s*) $\rightarrow$ M(*g*) [endothermic]
2. Ionization of the metal atoms
   - M(*g*) $\rightarrow$ $M^+(g) + e^-$ [endothermic]
3. Dissociation of the nonmetal
   - $\frac{1}{2}X_2(g) \rightarrow X(g)$ [endothermic]

Formation of an Ionic Solid (continued)

4. Formation of X^- ions in the gas phase:
   - $X(g) + e^- \rightarrow X^-(g)$ [exothermic]
5. Formation of the solid MX
   - $M^+(g) + X^-(g) \rightarrow MX(s)$

   [quite exothermic]

Lithium Fluoride

Figure 8.9 The Energy Changes Involved in the Formation of Lithium Fluoride from Its Elements

$F_2 \rightarrow 2F$

154

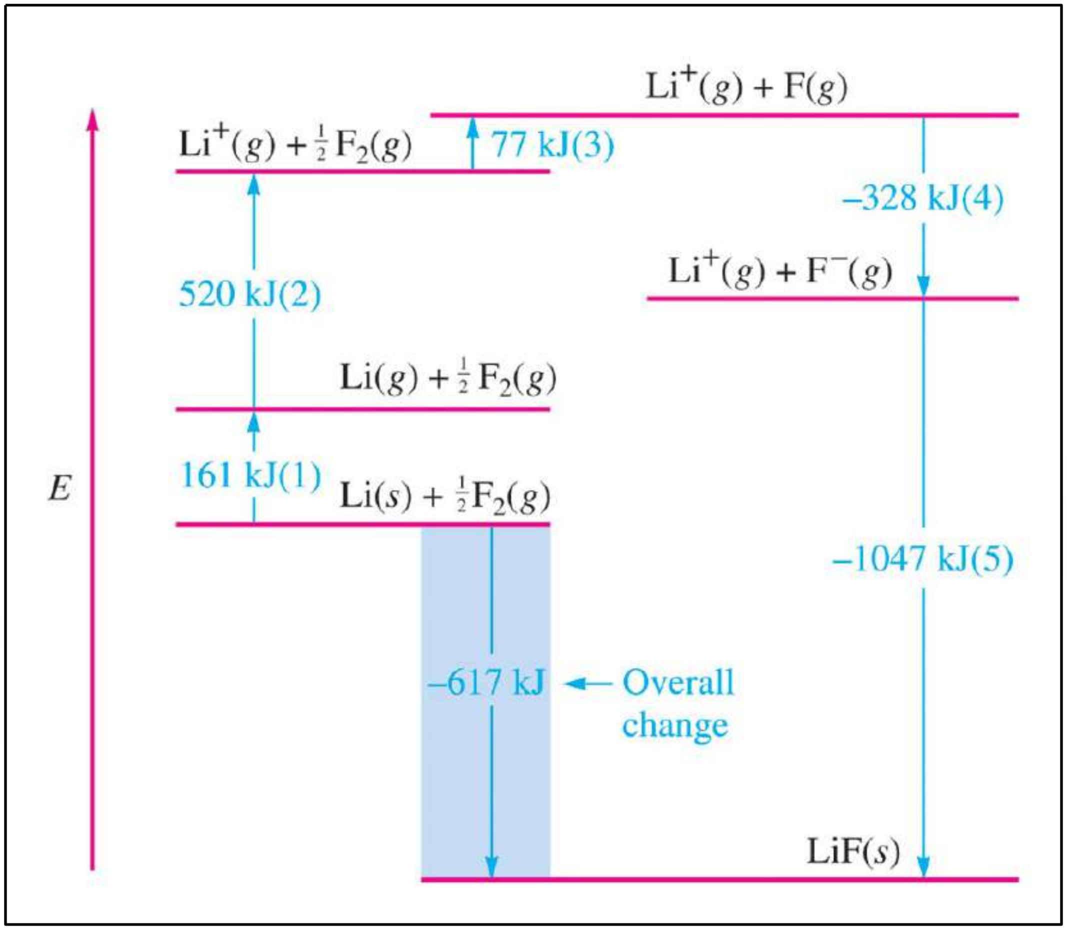


Figure 8.10 a & b The Structure of Lithium Fluoride

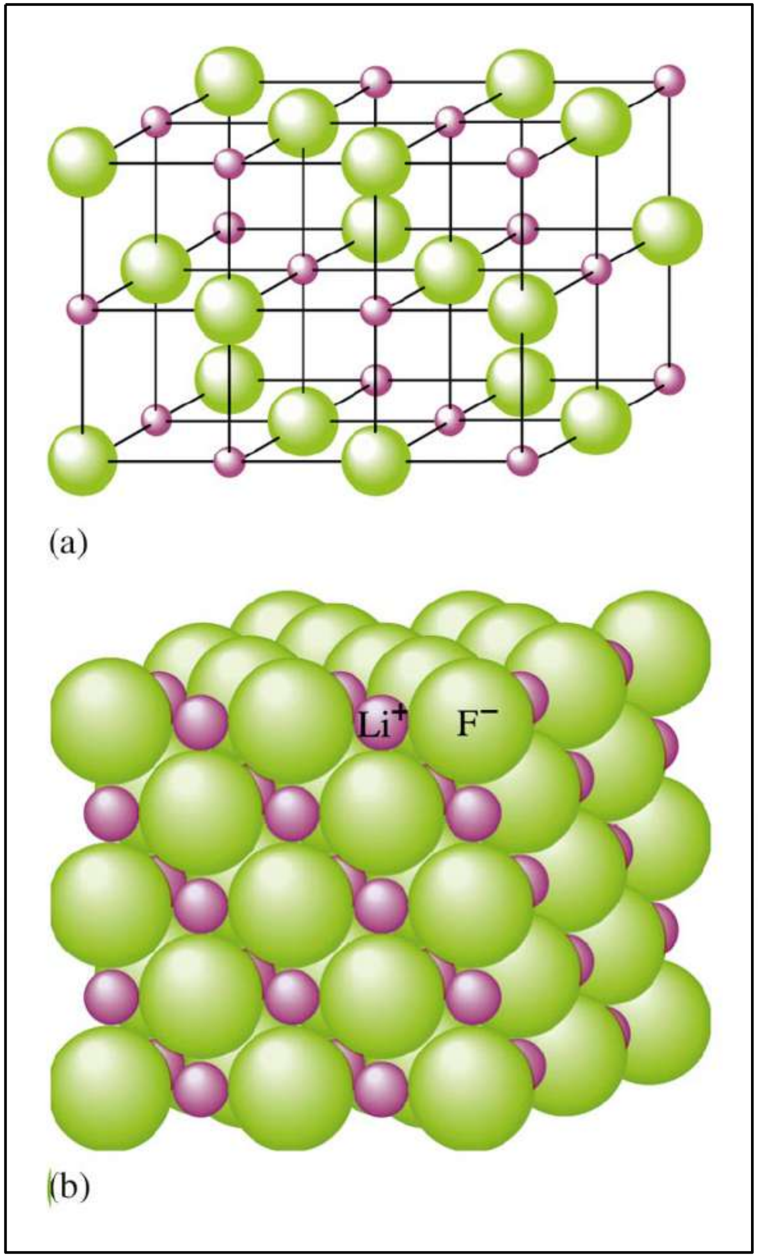
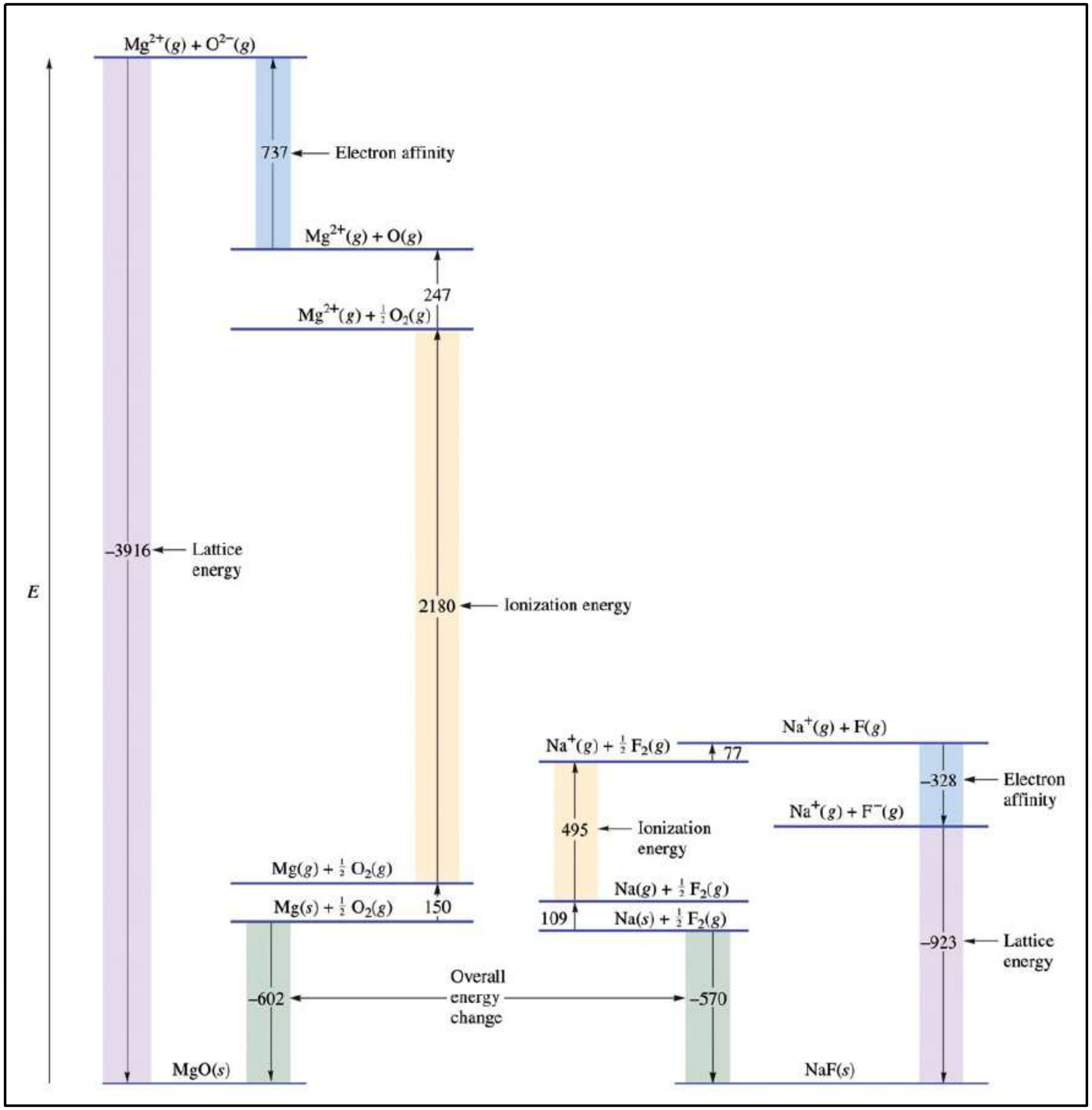
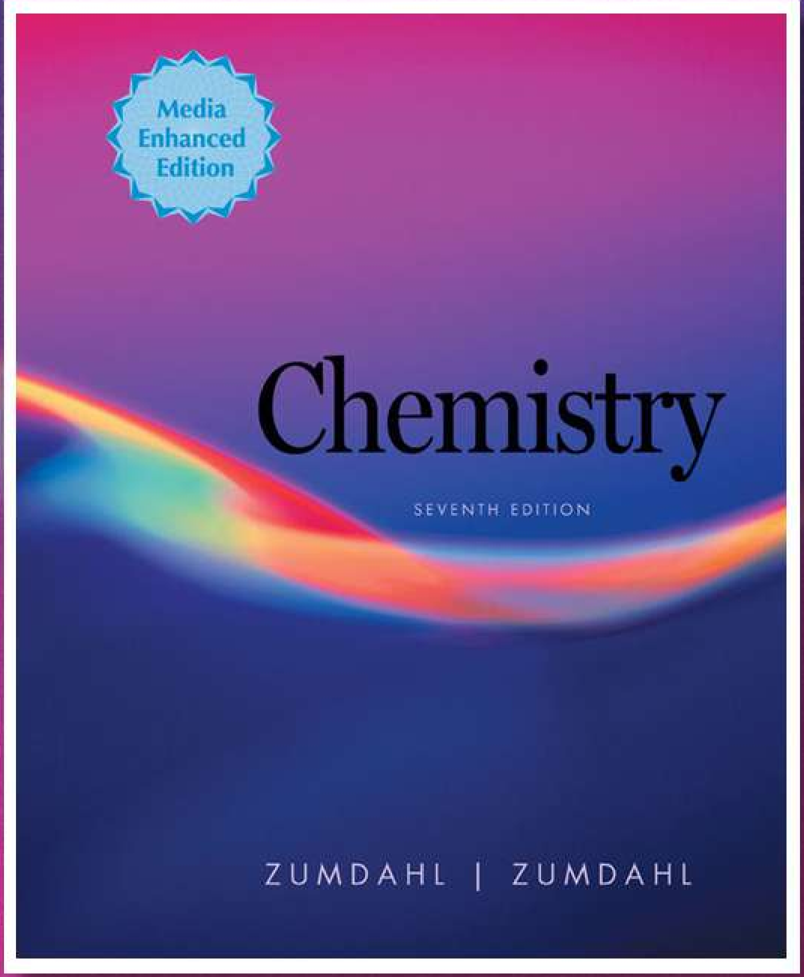


Figure 8.11 Comparison of the Energy Changes Involved in the Formation of Solid Sodium Fluoride and Solid Magnesium Oxide



Molten, NaCl Conducts an Electric Current, Indicating the Presence of Mobile Na^+ and Cl^- Ions



Partial Ionic Character of Covalent Bonds

Figure 8.12 a-c The Three Possible Types of Bonds

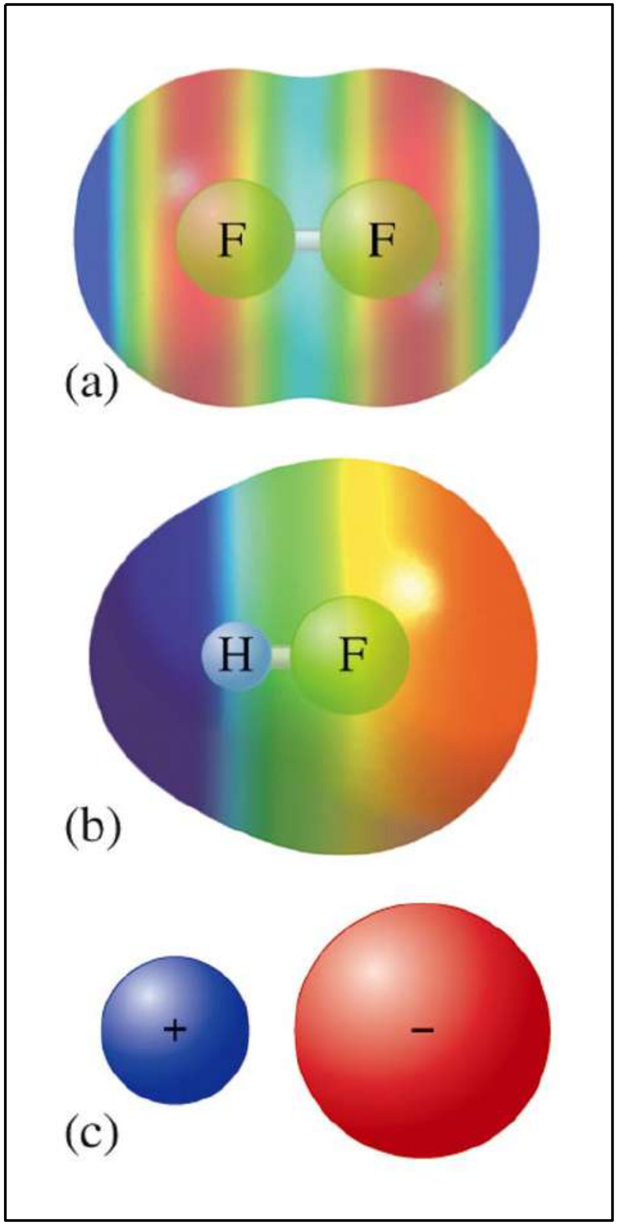


Figure 8.13 The Relationship Between the Ionic Character of a Covalent Bond and the Electronegativity Difference of the Bounded Atoms

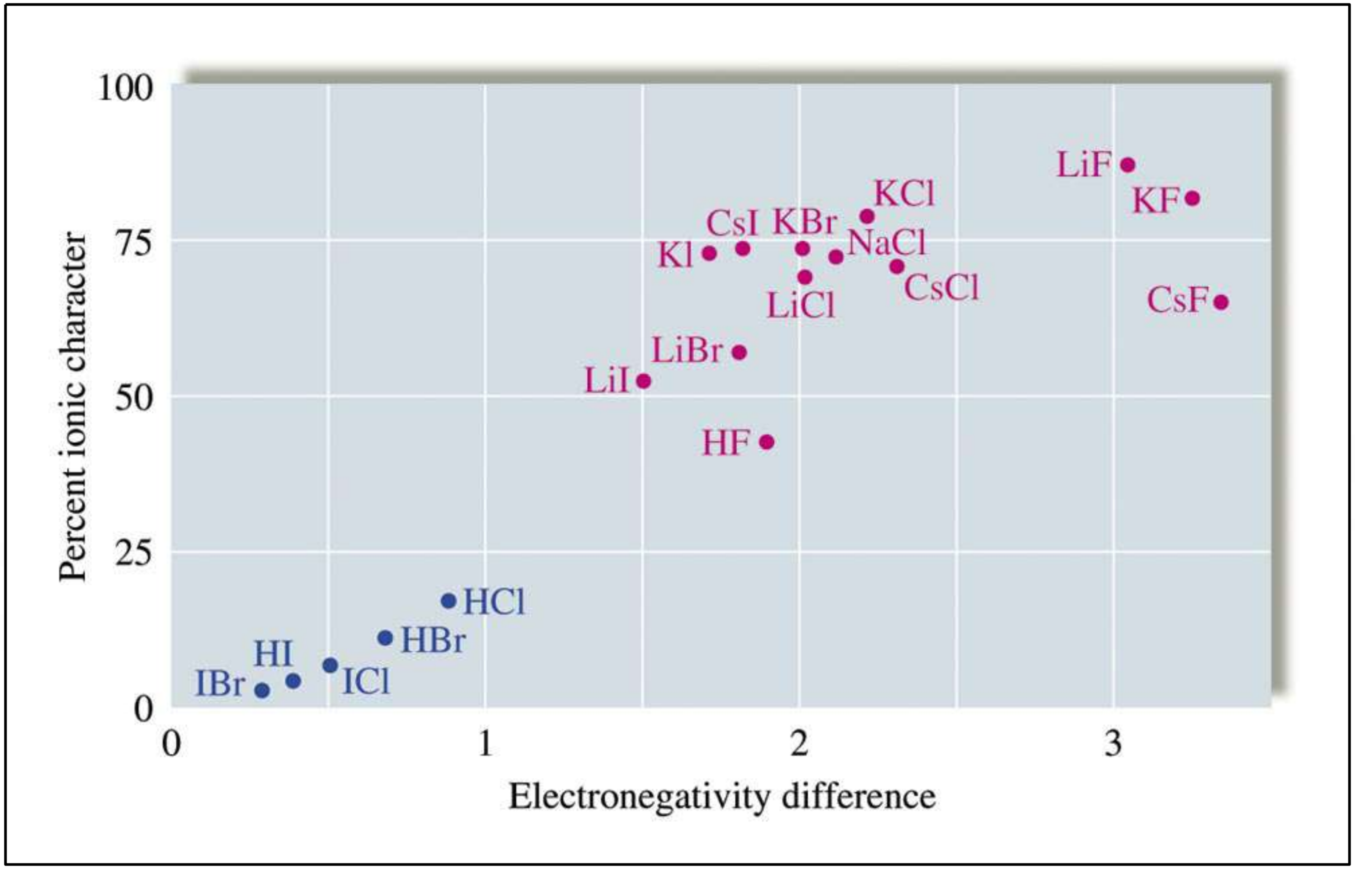


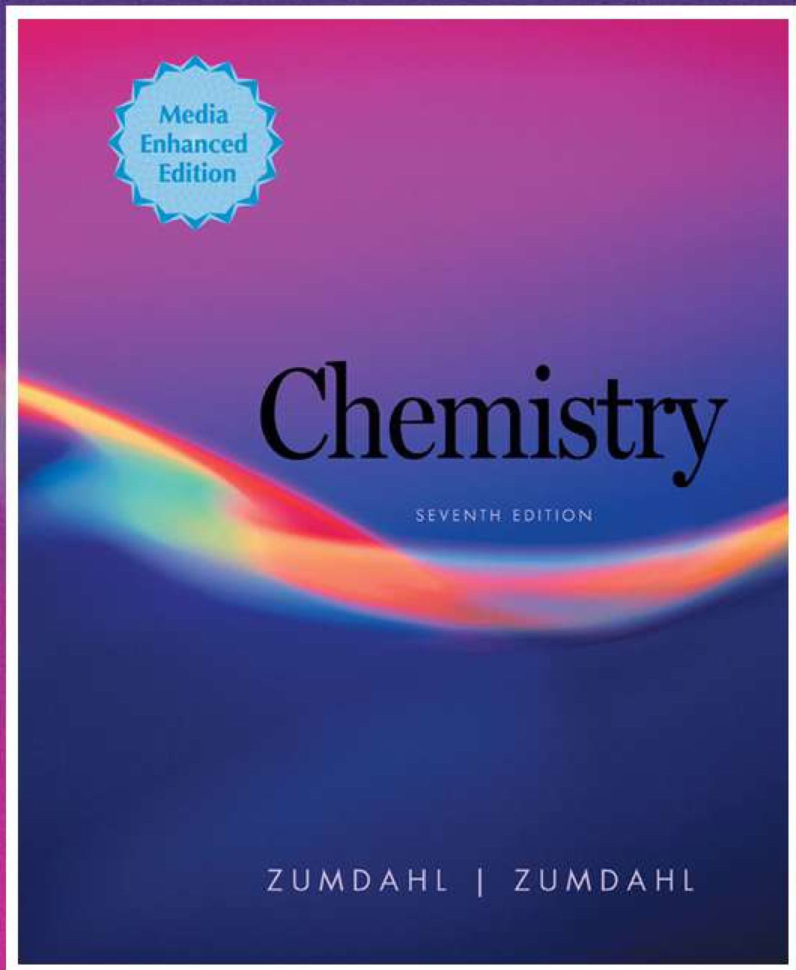
Table 8.1 The Relationship Between Electronegativity and Bond Type

TABLE 8.1 The Relationship Between Electronegativity and Bond Type

Electronegativity Difference in the Bonding Atoms	Bond Type
Zero	Covalent
↓	↓
Intermediate	Polar covalent
↓	↓
Large	Ionic

Covalent character ↑

Ionic character ↓



The Covalent Chemical Bond: A Model

Models

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

Fundamental Properties of Models

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

Table 8.4 Average Bond Energies (kj/mol)

TABLE 8.4 Average Bond Energies (kJ/mol)

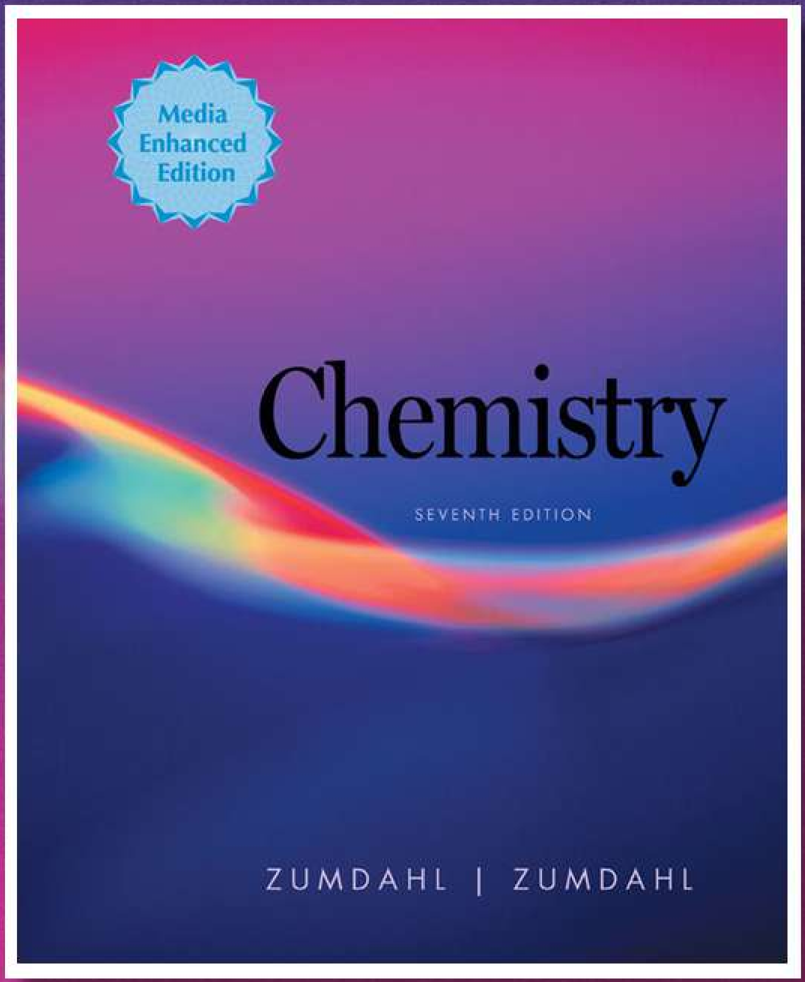
Single Bonds						Multiple Bonds	
H—H	432	N—H	391	I—I	149	C=C	614
H—F	565	N—N	160	I—Cl	208	C≡C	839
H—Cl	427	N—F	272	I—Br	175	O=O	495
H—Br	363	N—Cl	200			C=O*	745
H—I	295	N—Br	243	S—H	347	C≡O	1072
		N—O	201	S—F	327	N=O	607
C—H	413	O—H	467	S—Cl	253	N=N	418
C—C	347	O—O	146	S—Br	218	N≡N	941
C—N	305	O—F	190	S—S	266	C≡N	891
C—O	358	O—Cl	203			C=N	615
C—F	485	O—I	234	Si—Si	340		
C—Cl	339			Si—H	393		
C—Br	276	F—F	154	Si—C	360		
C—I	240	F—Cl	253	Si—O	452		
C—S	259	F—Br	237				
		Cl—Cl	239				
		Cl—Br	218				
		Br—Br	193				

*C=O(CO_2) = 799

Table 8.5 Bond Lengths for Selected Bonds

TABLE 8.5 Bond Lengths for Selected Bonds

Bond	Bond Type	Bond Length (pm)	Bond Energy (kJ/mol)
C—C	Single	154	347
C=C	Double	134	614
C≡C	Triple	120	839
C—O	Single	143	358
C=O	Double	123	745
C—N	Single	143	305
C=N	Double	138	615
C≡N	Triple	116	891



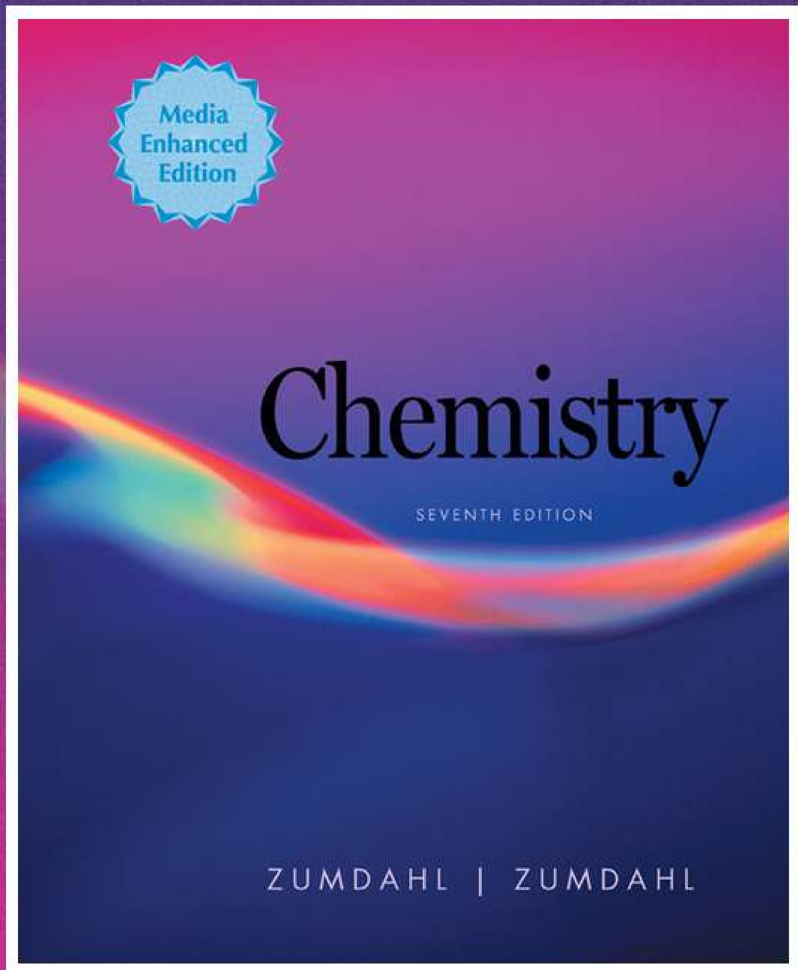
The Localized Electron Bonding Model

Localized Electron Model

A molecule is composed of atoms that are bound together by sharing pairs of electrons using the atomic orbitals of the bound atoms.

Localized Electron Model

1. Description of valence electron arrangement (Lewis structure).
2. Prediction of geometry (VSEPR model).
3. Description of atomic orbital types used to share electrons or hold long pairs.



Lewis Structures

Lewis Structure

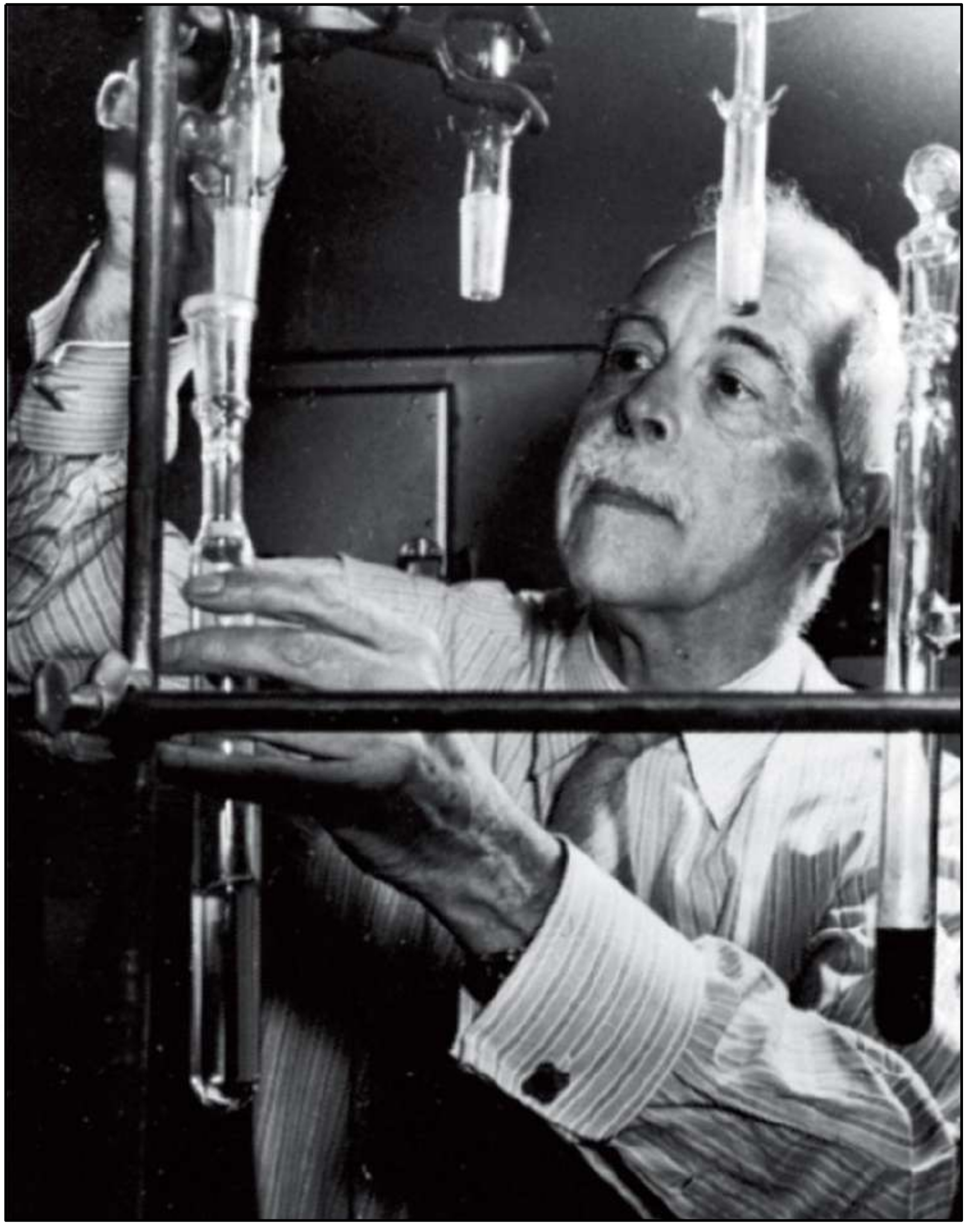
Shows how valence electrons are arranged among atoms in a molecule.

Reflects central idea that stability of a compound relates to noble gas electron configuration.

Lewis Structures

1. Sum the valence electrons.
2. Place bonding electrons between pairs of atoms.
3. Atoms usually have noble gas configurations.

Figure 8.14
G.N. Lewis



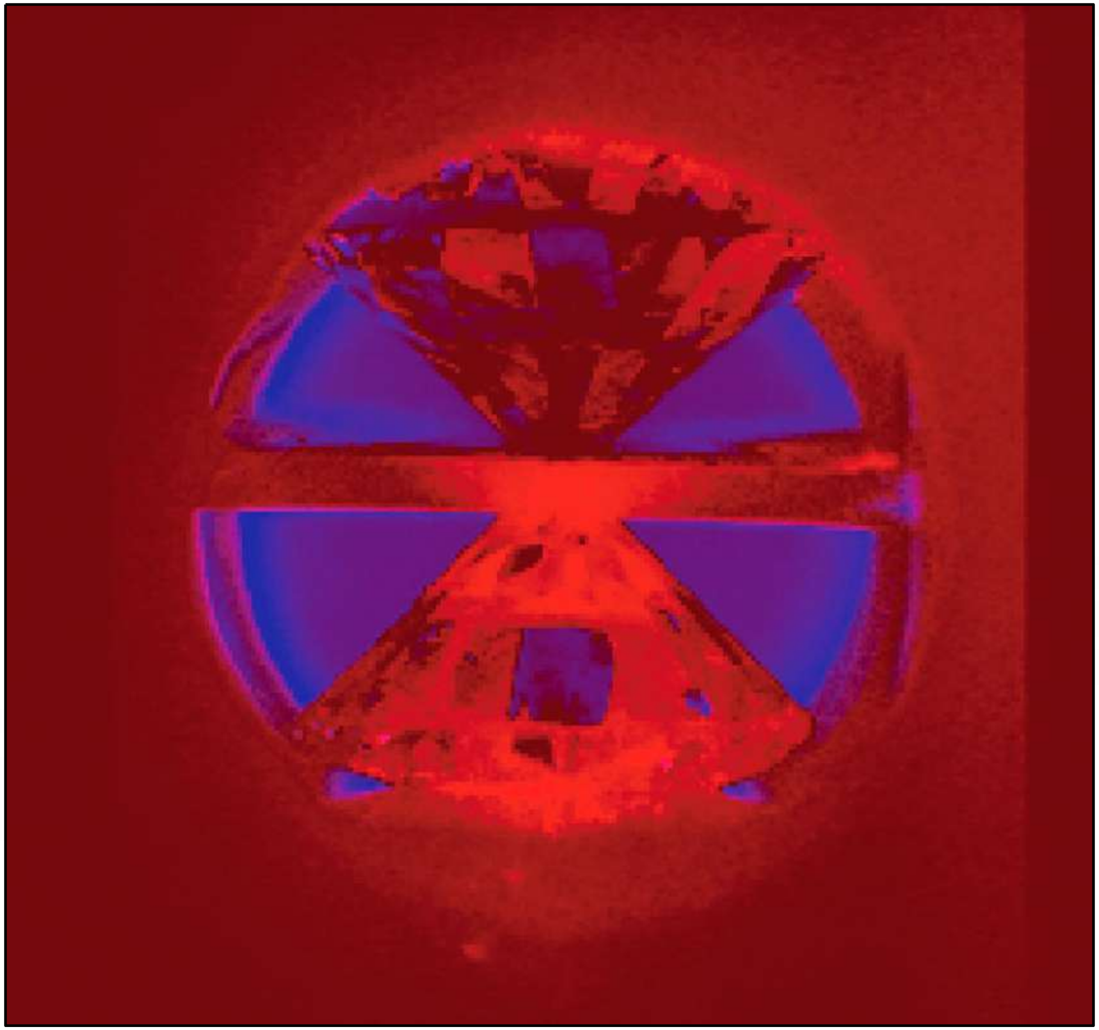
React 8

Draw a Lewis structure for each of the following molecules:

BrINClHOF

- H_2
- N_2
- O_2
- F_2

A Diamond Anvil Cell Used to Study Materials at Very High Pressures



React 9

Draw a Lewis structure for each of the following molecules:

HF

H_2O

NH_3

CH_4

CCl_4

CO

CO_2

H_2O_2

C_2H_6

CH_3OH

CN^-

NH_4^+

React 10

Draw a Lewis structure for each of the following molecules:

CO

CO_2

CH_3OH

BF_3

C_2H_6O

PCl_5

NO_3^-

SF_6

BeH_2

BrF_7

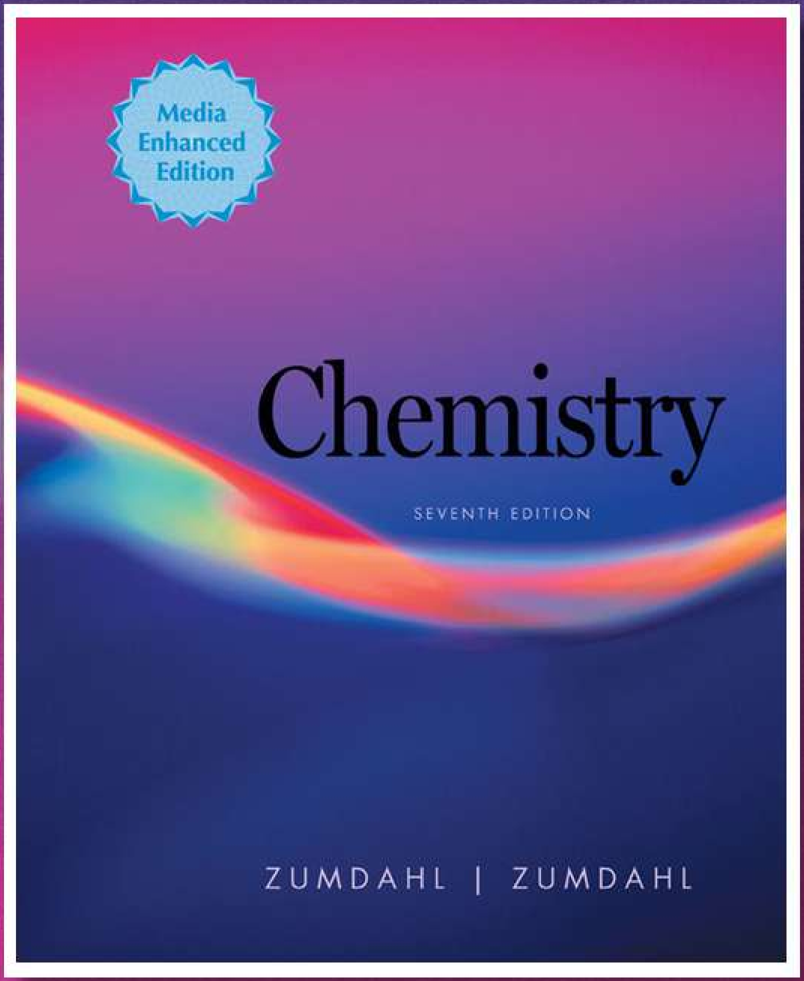
I_3^-

NO

NO_2

NO_3^-

XeO_3



Molecular Structure: The VSEPR Model

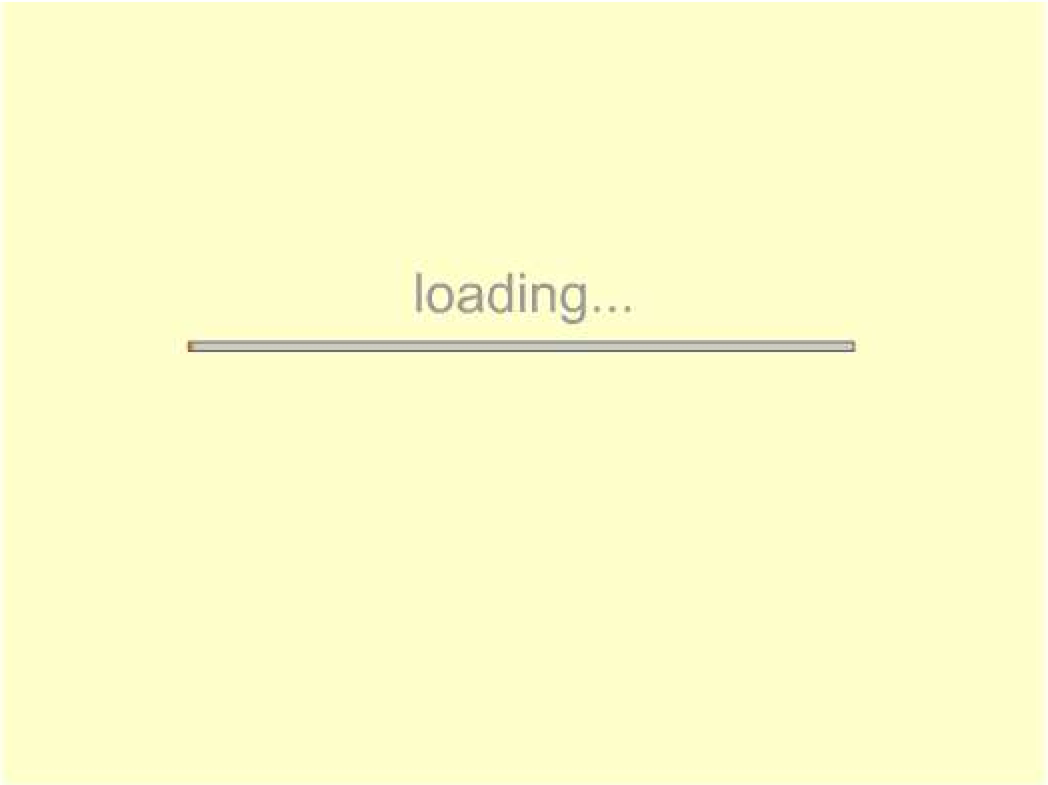
VSEPR Model

The structure around a given atom is determined principally by minimizing electron pair repulsions.

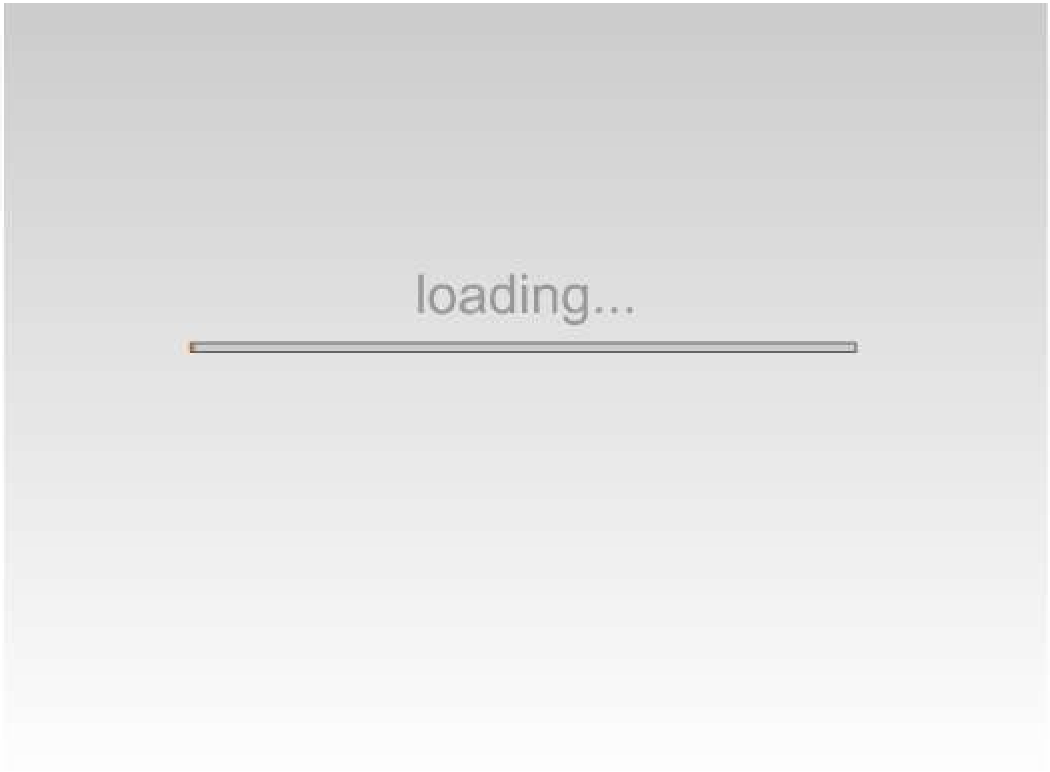
Predicting a VSEPR Structure

1. Draw Lewis structure.
2. Put pairs as far apart as possible.
3. Determine positions of atoms from the way electron pairs are shared.
4. Determine the name of molecular structure from positions of the atoms.

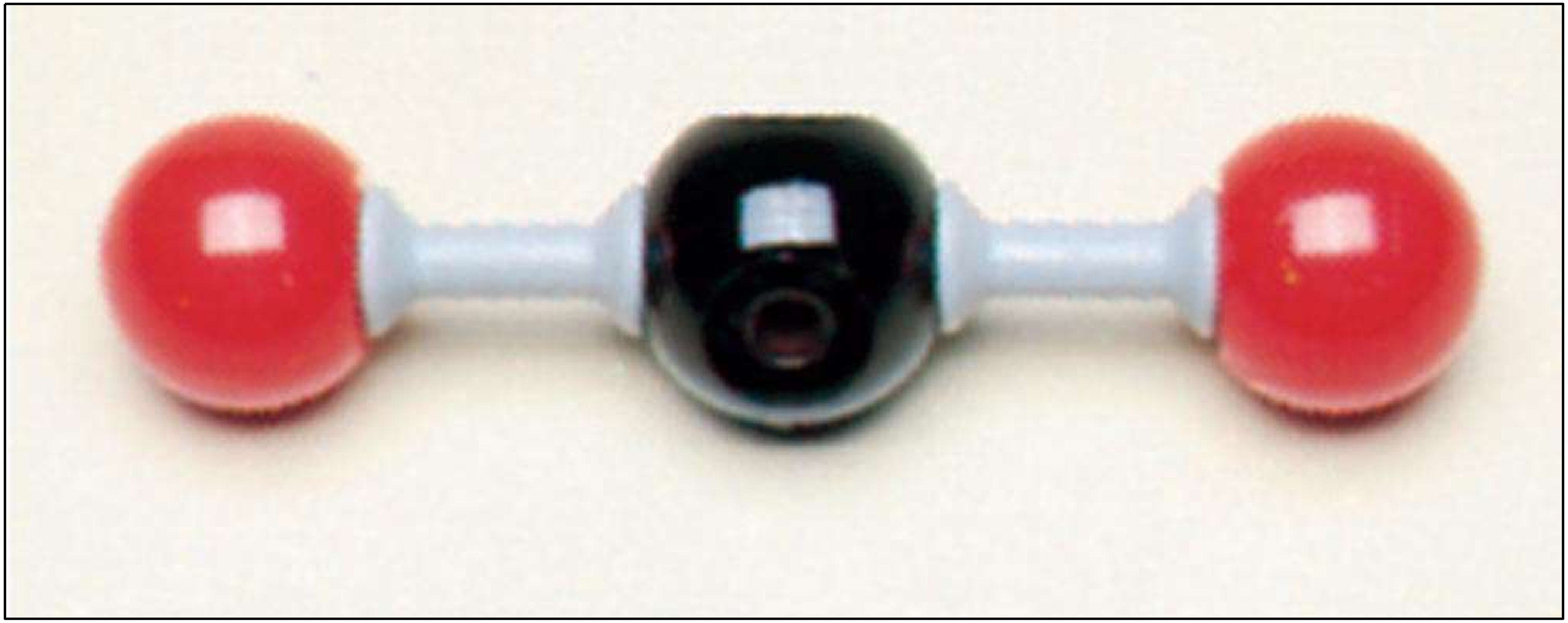
VSEPR



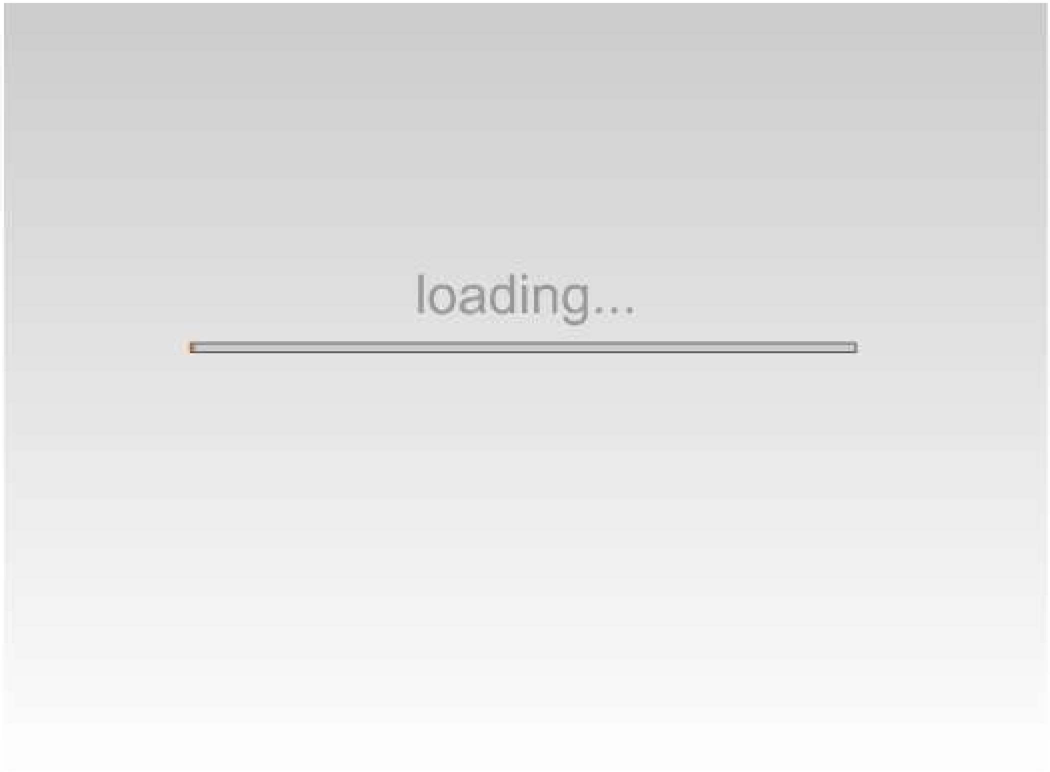
VSEPR: Two Electron Pairs



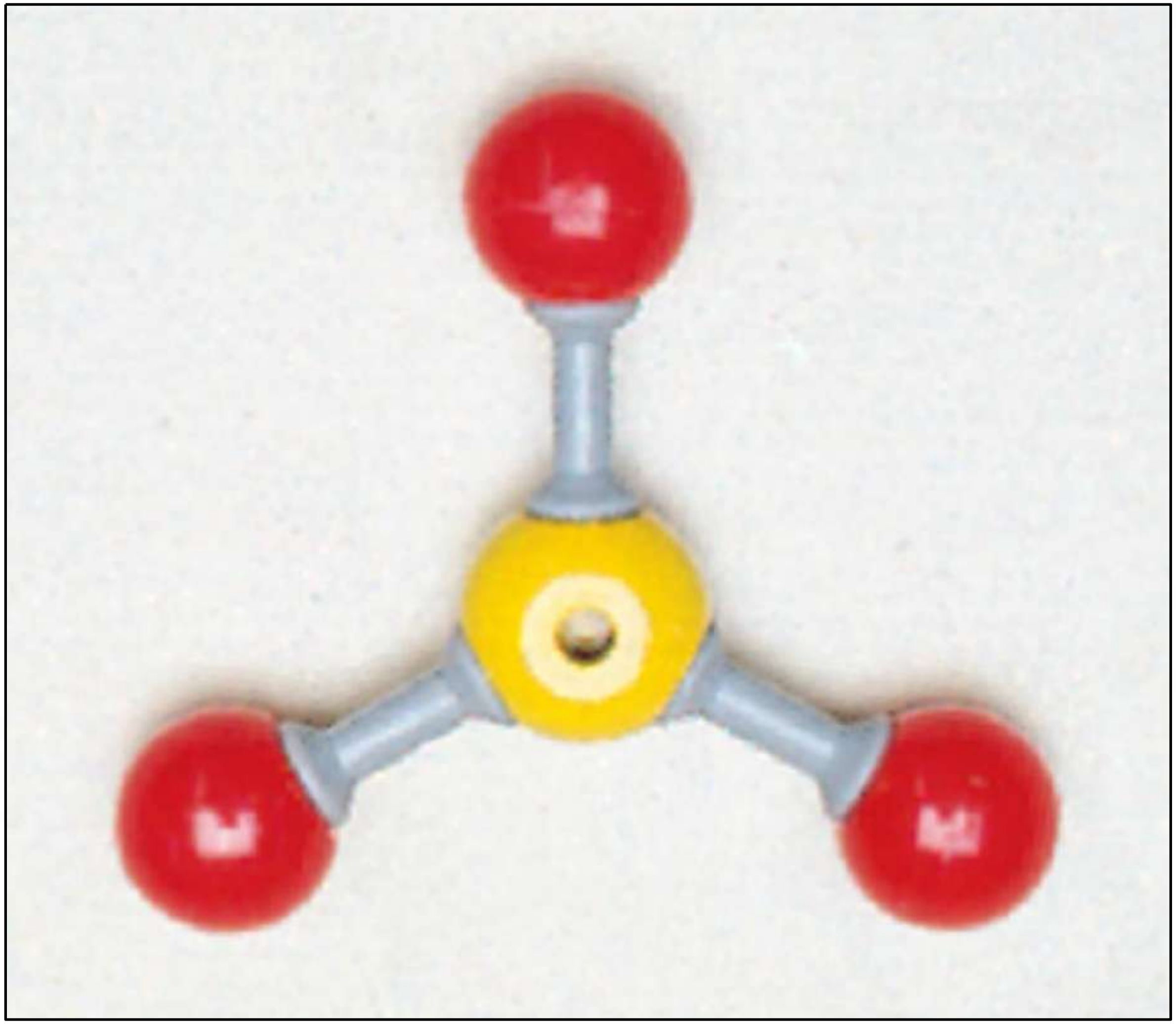
Linear Molecules with Two Identical Bonds



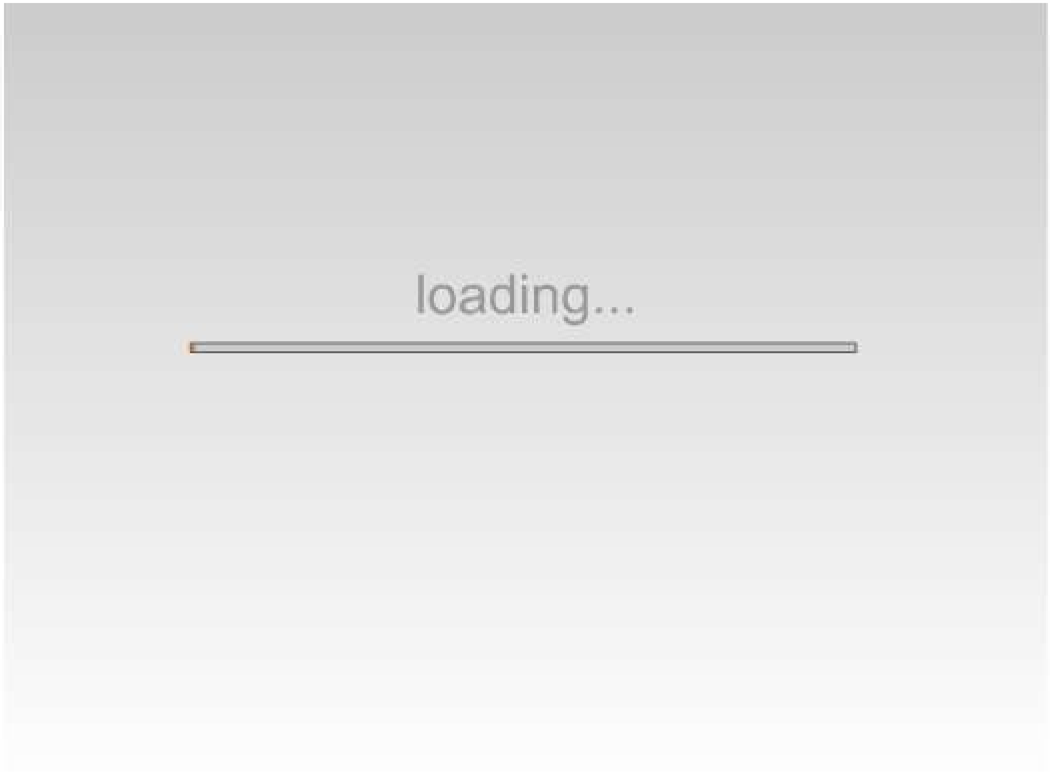
VSEPR: Three Electron Pairs



Planar Molecules with Three Identical Bonds 120 Degrees Apart



VSEPR: Four Electron Pairs



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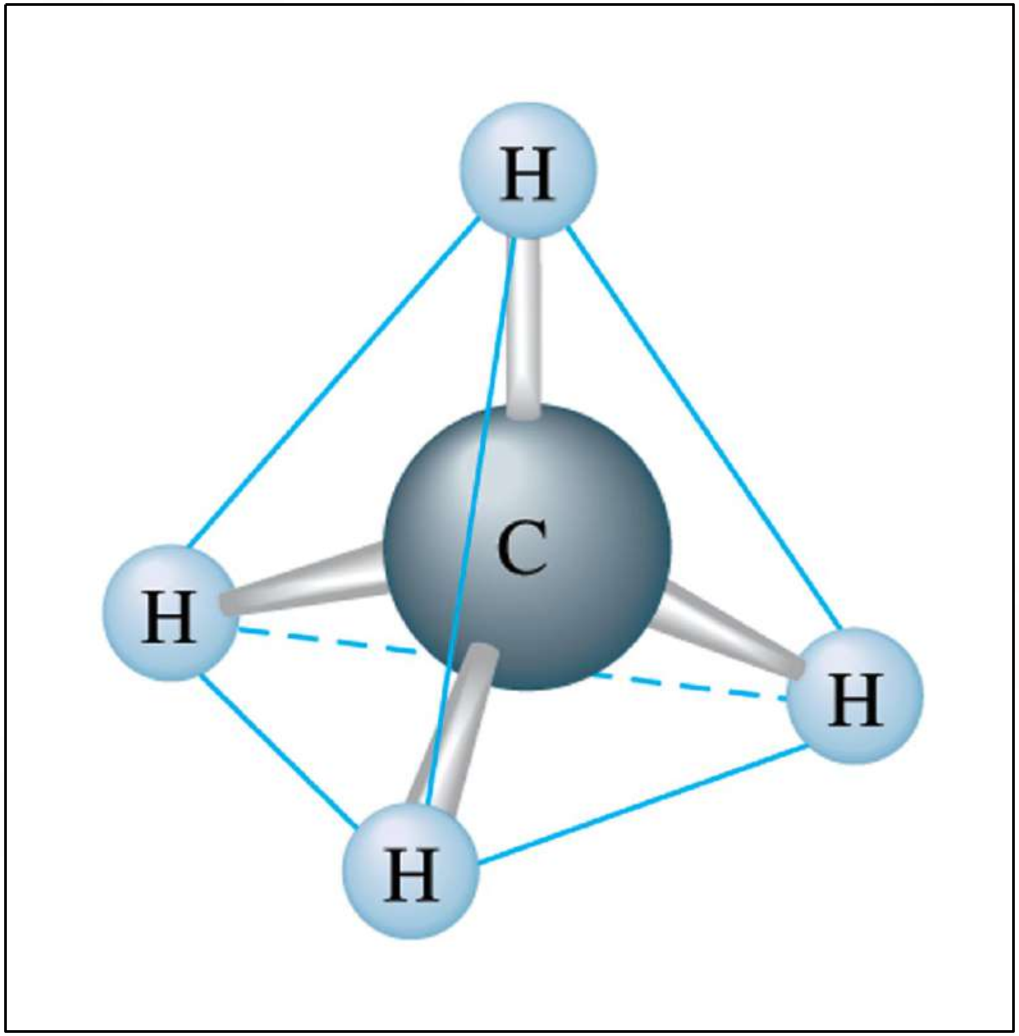
Balloons Tied Together Naturally Form Tetrahedral Shape

Tetrahedral Molecules with Four Identical Bonds 109.5 Degrees Apart

Figure 8.15 The Molecular Structure of Methane



NH3

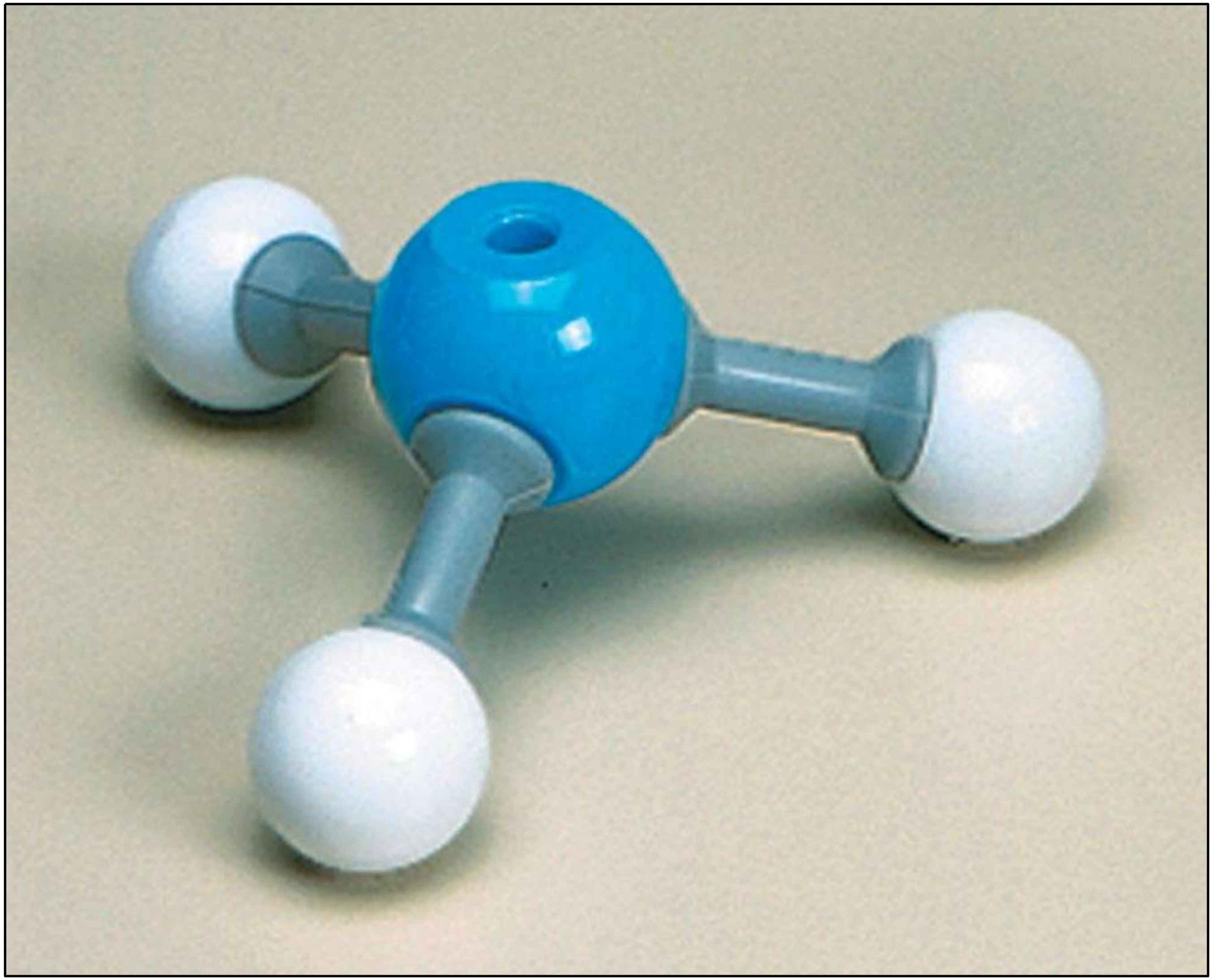


Figure 8.16 a-c The Molecular Structure of Ammonia is a Trigonal Pyramid

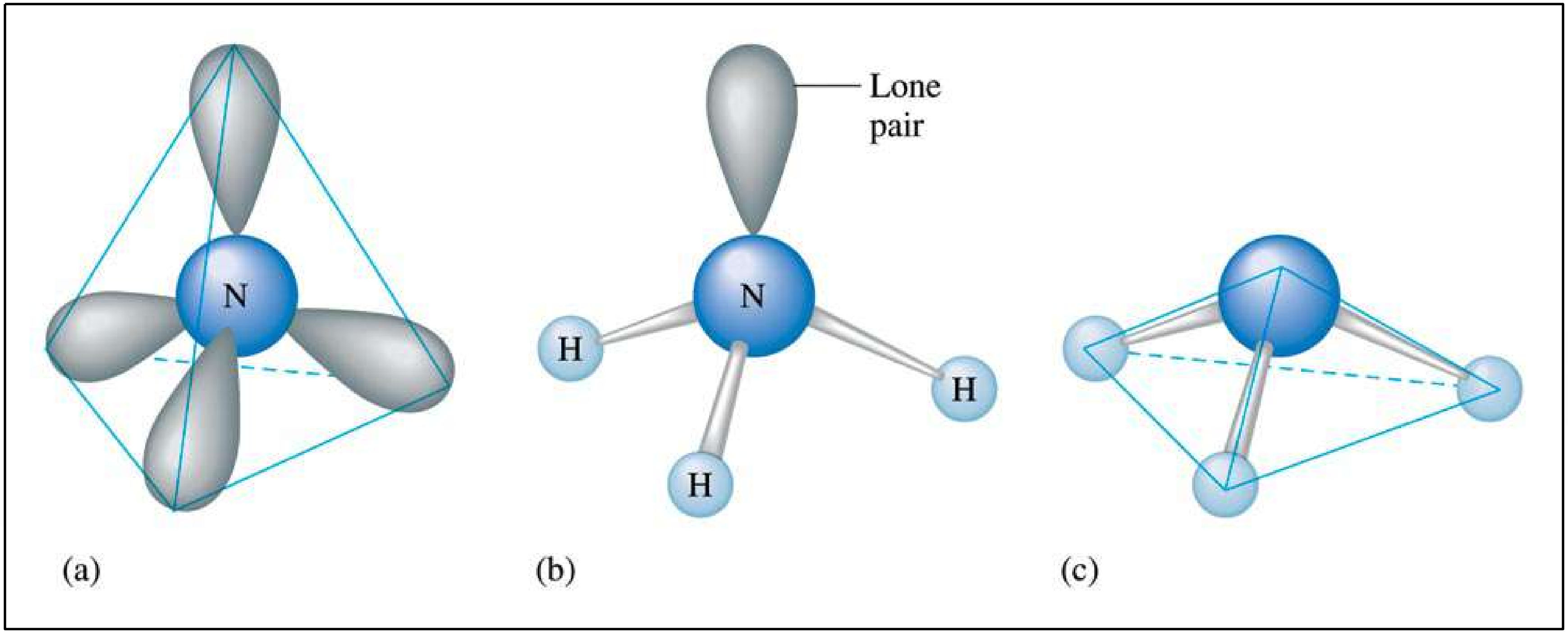


Figure 8.17 a-c The Tetrahedral Arrangement of Oxygen In a Water Molecule

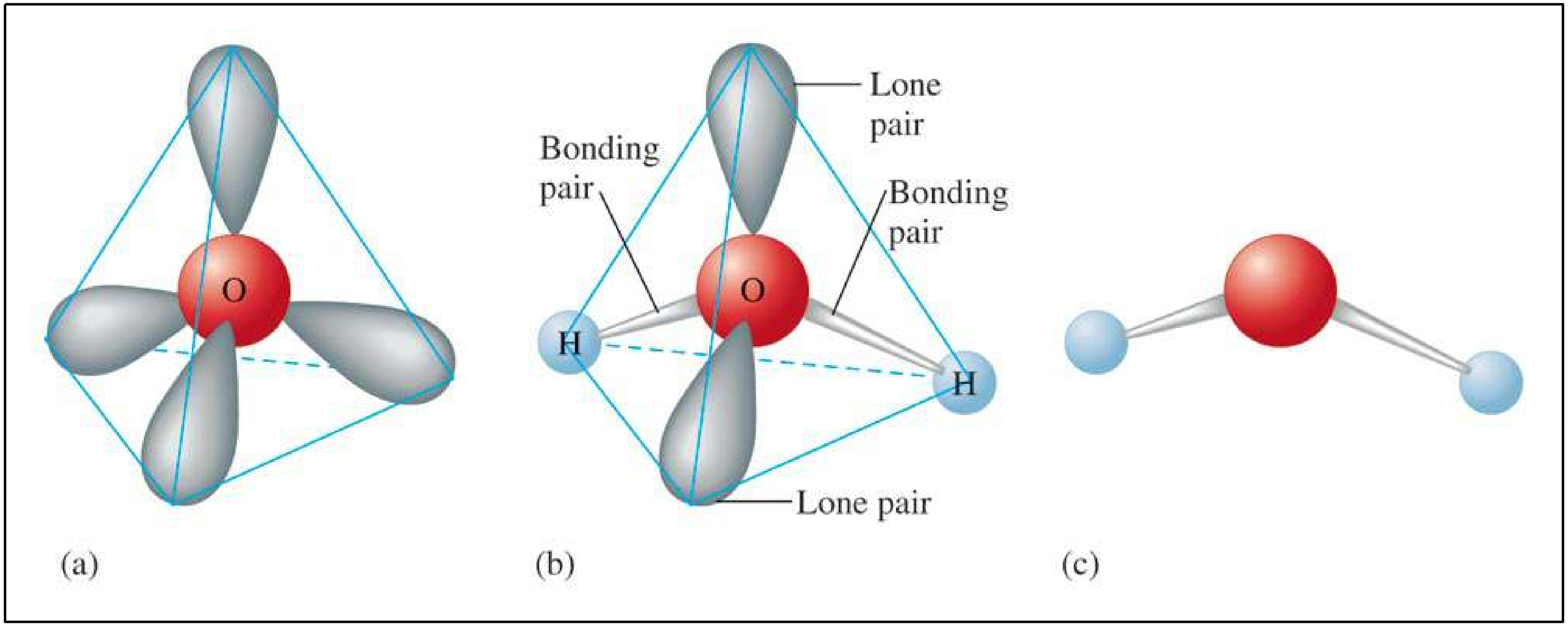


Figure 8.19 a & b In a Bonding Pair of Electrons the Electrons are Shared by Two Nuclei (b) In a Lone Pair, Both Electrons Must Be Close to a Single Nucleus

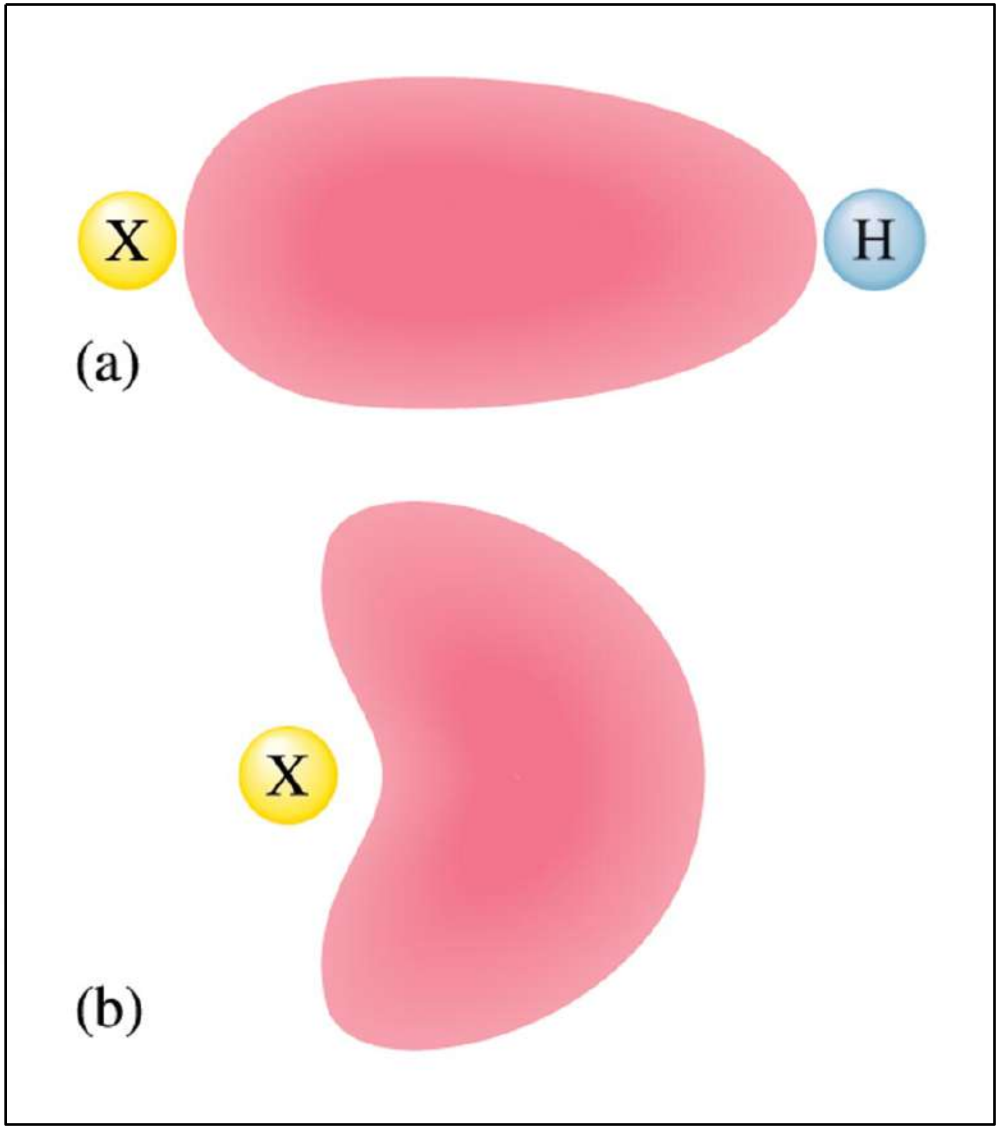


Figure 8.18 The Bond Angles In the $CH4$, NH_3, and H_20 Molecules

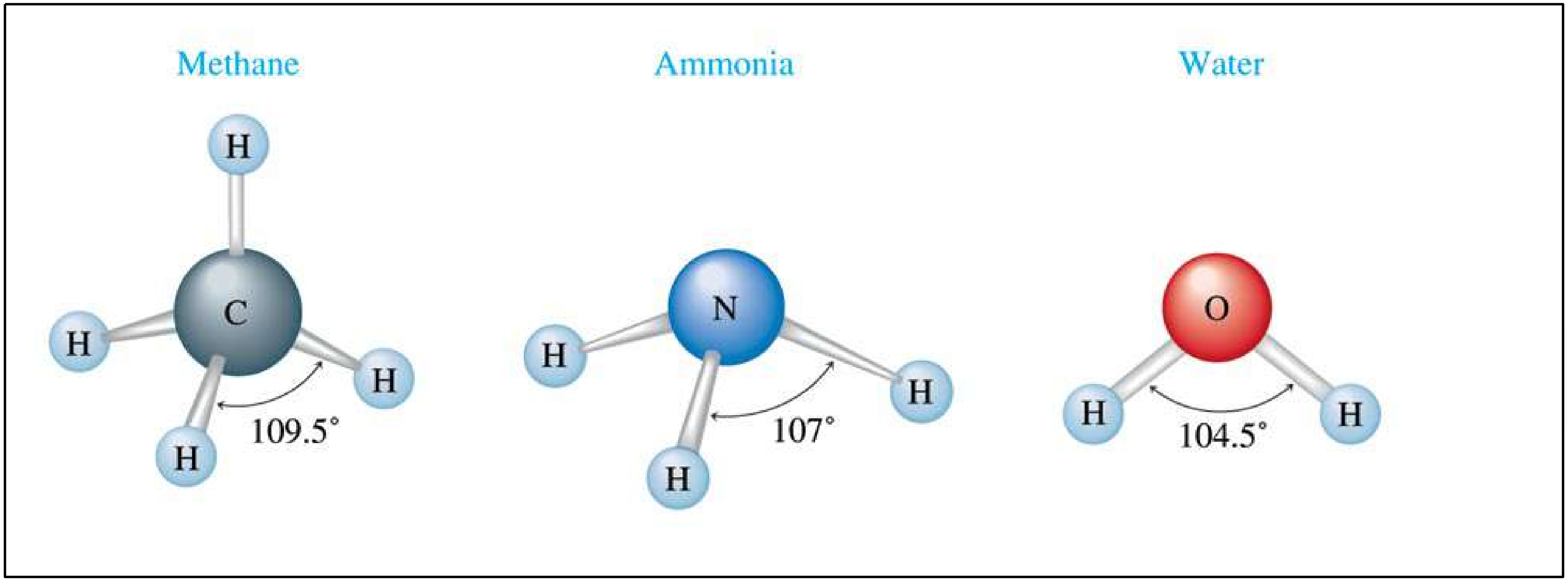


Table 8.6 Arrangements of Electron Pairs Around an Atom Yielding Minimum Repulsion

TABLE 8.6 Arrangements of Electron Pairs Around an Atom Yielding Minimum Repulsion

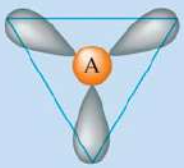
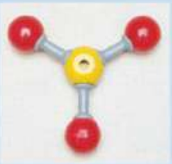
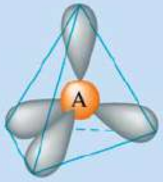
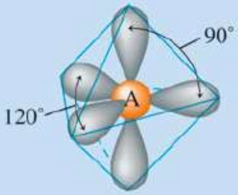
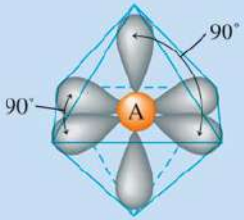
Number of Electron Pairs	Arrangement of Electron Pairs		Example
2	Linear		
3	Trigonal planar		
4	Tetrahedral		
5	Trigonal bipyramidal		
6	Octahedral		

Table 8.7 Structures of Molecules that Have Four Electron Pairs Around the Central Atom

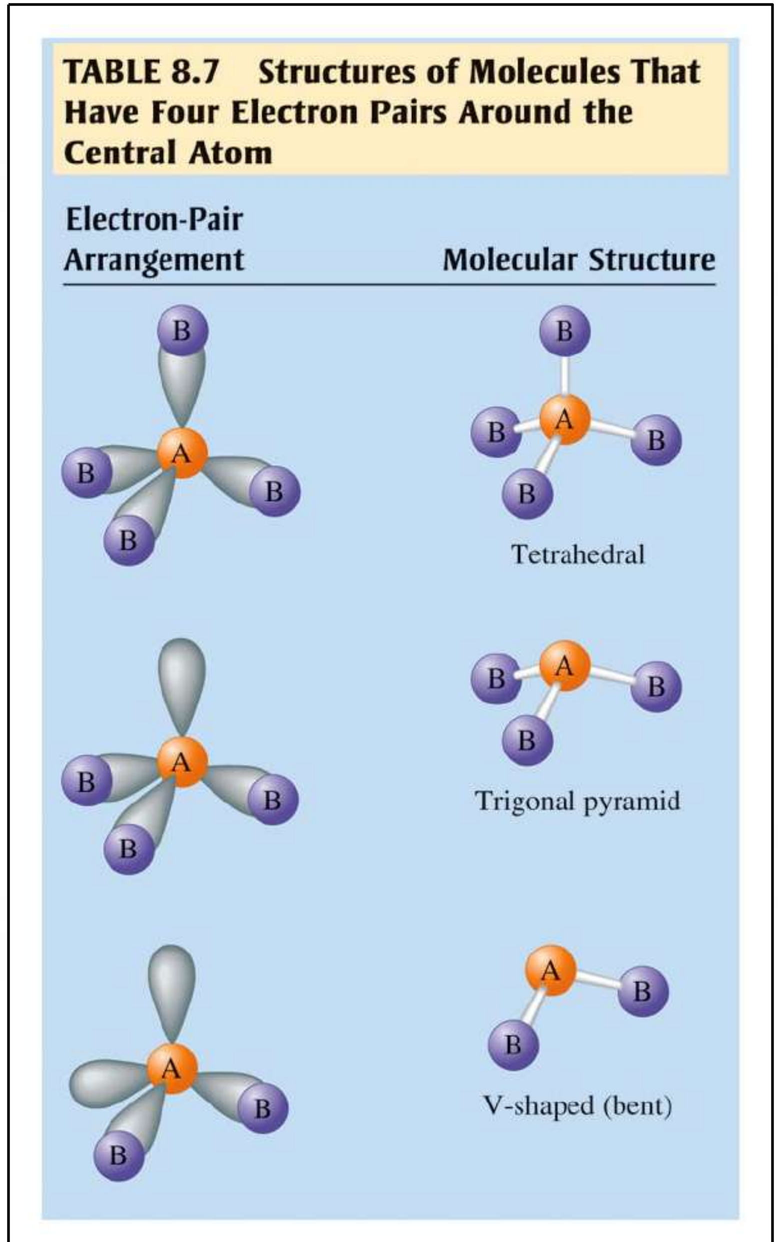


Table 8.8 Structures of Molecules with Five Electron Pairs Around the Central Atom

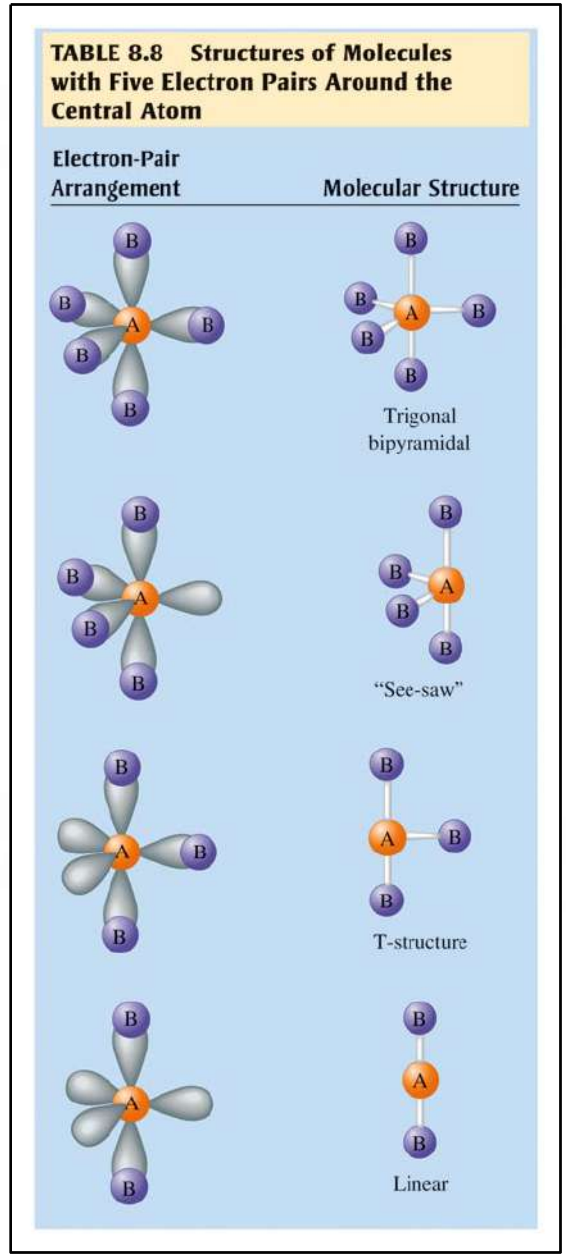


Figure 9.22a The Structure of the PCl5 Molecule

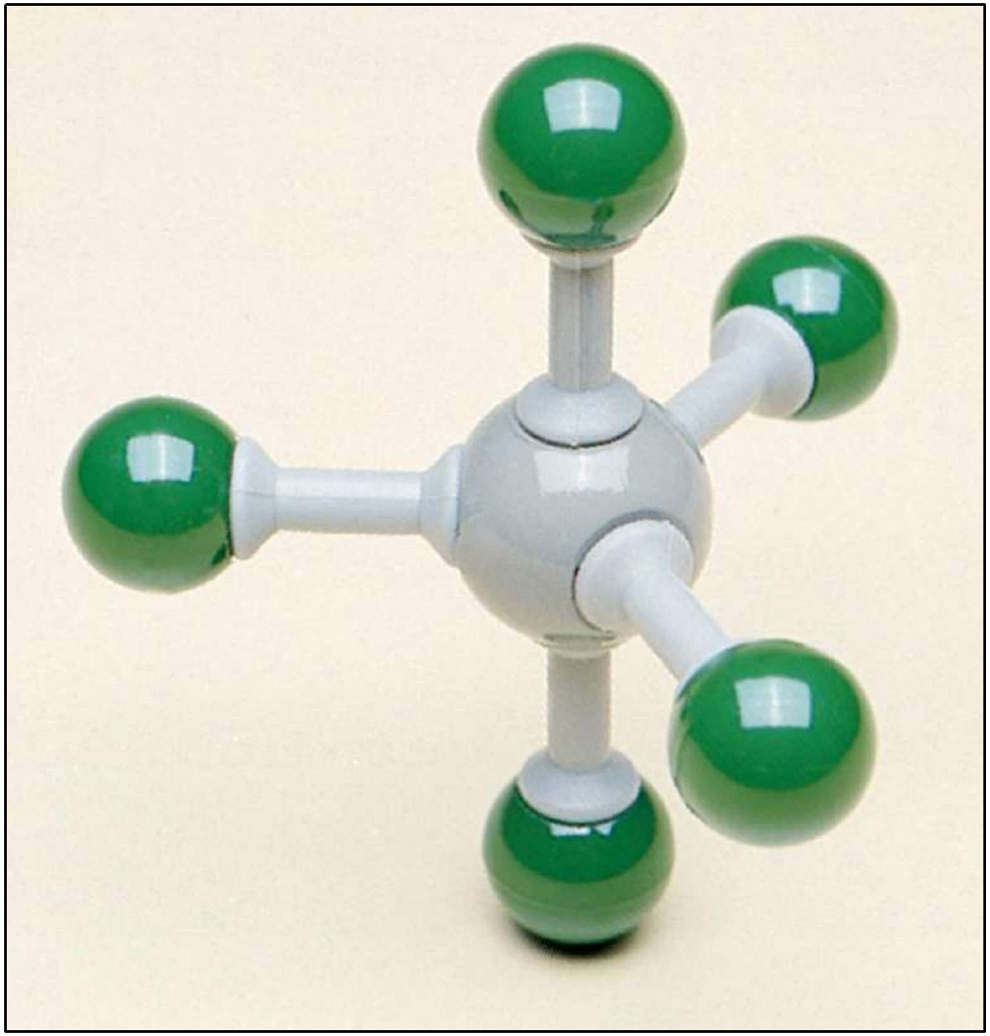
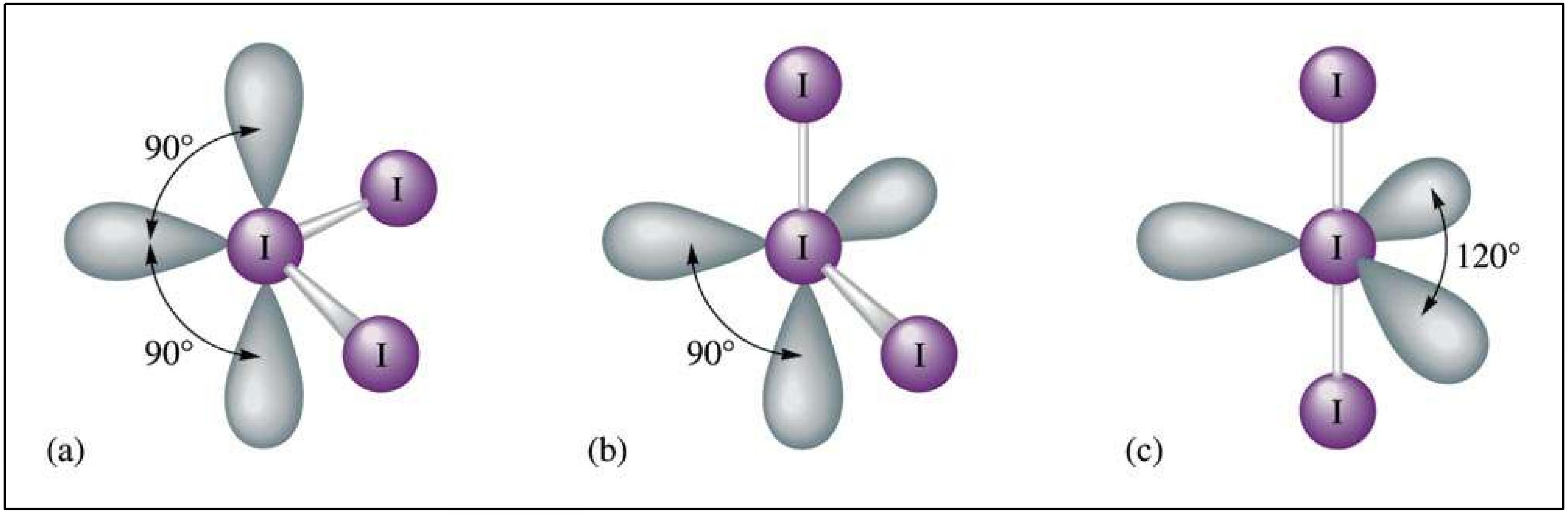


Figure 8.21 a-c Three Possible Arrangements of the Electron Pairs in the I_3^- Ion



VSEPR: Iodine Pentafluoride

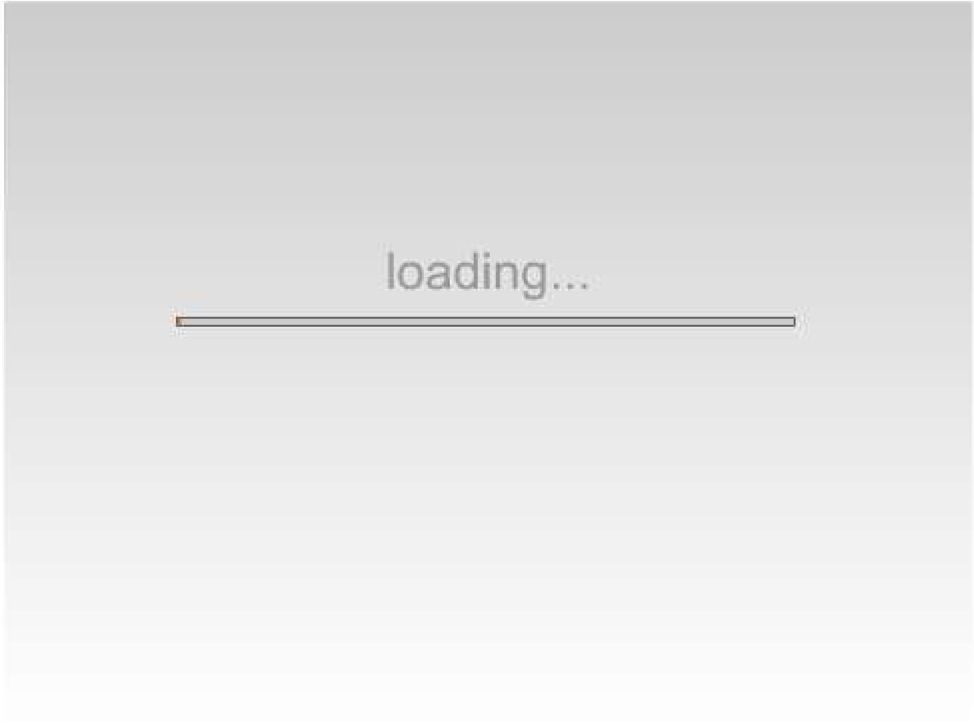


Figure 8.20 a & b Possible Electron Pair Arrangements for XeF4

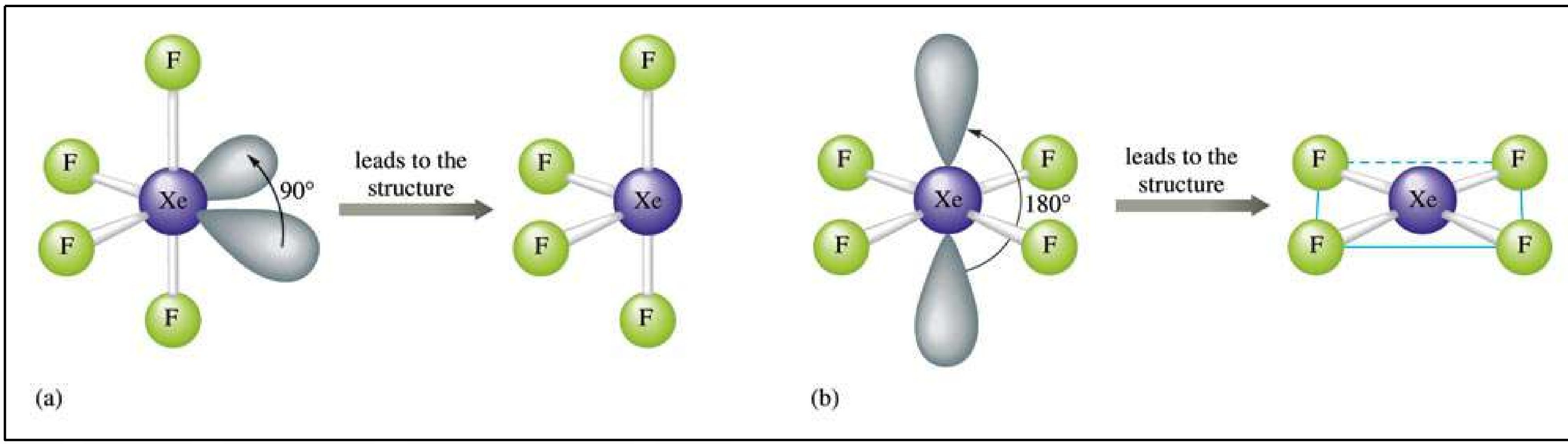
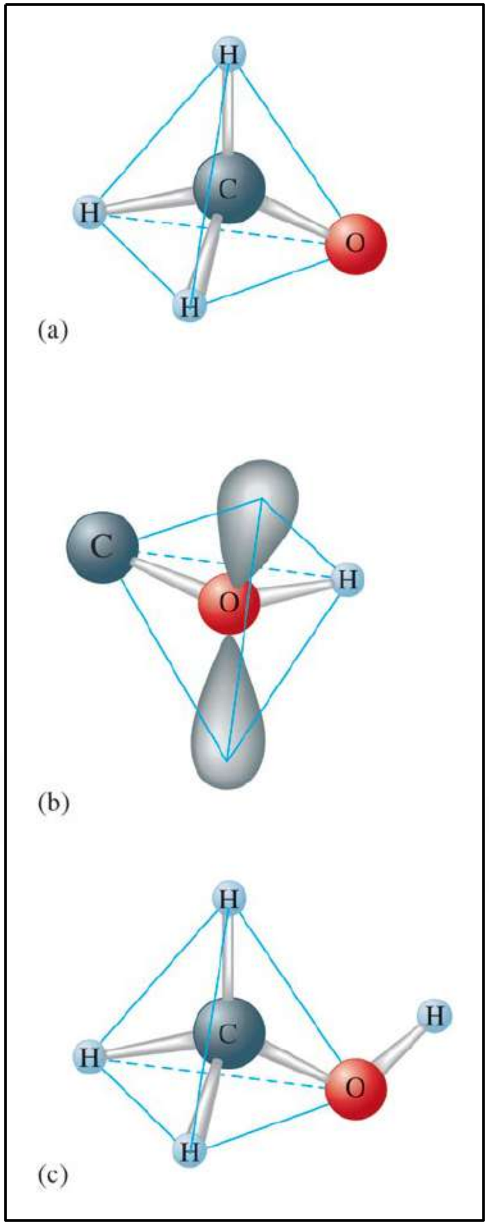
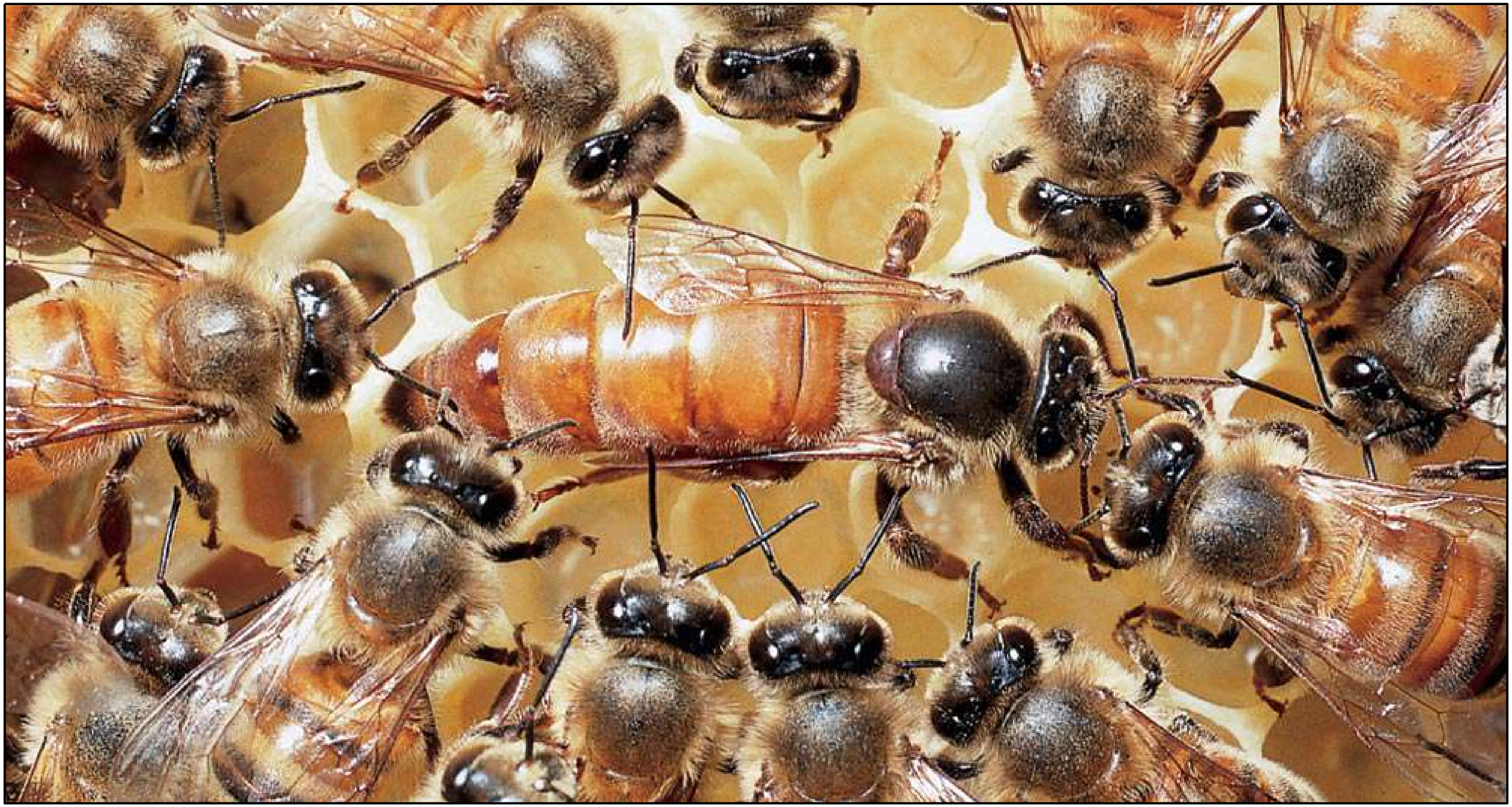


Figure 8.22 a-c The Molecular Structure of Methanol



Queen Bee



React 11

Determine the shape for each of the following molecules, and include bond angles:

HCN

PH_3

SF_4

O_3

KrF_4

React 12

To determine the shape of a molecule, what is always the first step?

How do we treat multiple bonds in VSEPR theory?

If more than one atom can exceed the octet rule, where do the extra electrons go?

React 13

True or false:

A molecule that has polar bonds will always be polar.

-If true, explain why.

-If false, provide a counter-example.

React 14

True or false:

Lone pairs make a molecule polar.

-If true, explain why.

-If false, provide a counter-example.