Typical Elements

Families

- **A group of elements that have similar properties**
- Trends in Different groups in the Periodic Table

Hydrogen

- **1 electron in energy level**
  - Hydrogen is usually considered as a family by itself
- **Can lose its electron and become H^+**
  - A bare proton
  - 1/ trillionth the size of an atom
  - Very unstable because of its size
- **It can share electrons**
  - Most nonmetals combine in this way with H
  - Examples HCl or H_2O
- **It can also gain an electron and be H^- a hydride ion**
  - Combines this way with metals that lose electrons easily.
  - Has a very weak hold on electron
  - Ionic hydrides are very reactive compounds.
- **The fourth type of bonding involves formation of bridges**
  - Bridges between two atoms by hydrogen as in the DNA Molecule A 4^{th} way is to form bridges, such as boron hydride, B_5H_9
- **A 5^{th} way is to add hydrogen to the double bonds of carbon in organic chemistry**

Alkali Metals Properties

- They are never found in elemental form in nature
- Very soft
- Stored under mineral oil in laboratory to keep from reacting
- Tarnish easily
- Have low melting points and low density
- Silver colored

Alkali Metals

- The alkali metal atoms increase in size with increasing atomic number: Li, Na, K, Rb, Cs, Fr
- Sodium compounds are used as catalysts and in the production of paper, glass, detergents, soaps, pigments, and petroleum products
- A catalyst is a substance that speeds up a reaction
- Lithium is used to make batteries.
- It forms the 1+ ion
- Alkali metals form binary compounds with most nonmetals
- Na and K are needed in the body for nerve impulse

Properties (continued)

- **When moving down the group the elements have**
  - decreasing electronegativity
  - decreasing melting and boiling point
  - increasing reactivity
  - Atoms become larger
  - The outer electron is farther from the nucleus
  - The lower level electrons shield the effect of larger nucleus (Shielding effect)

Alkali metals reaction with water

- vigorous reactions with water
- Reactions intensity increases as you move down the group
- Alkali metal + water → Alkali metal hydroxide + hydrogen gas
- Reactions can cause flames and sometimes explosions

Alkali metals reaction with ammonia

- dissolve in liquid ammonia to give blue solutions that are paramagnetic
- Saturated solutions are a deep purple color.

Alkaline earth metals

- beryllium (**Be**), magnesium (**Mg**), calcium (**Ca**), strontium **(Sr)**, barium (**Ba**) and radium (Ra)
- Well characterised homologous behaviour down the group
- Always combined with nonmetals in nature
- Some are very important nutrients
- silvery colored, soft, low-density metal
- two electrons in their outermost shell

Alkali Earth Metals

- Alkaline earth metals form the 2+ ion
- Most group 2 (IIA) compounds are soluble in water
- The metals (Ca, Sr, Ba, Ra) will displace hydrogen from water and other compounds
- Calcium oxide (lime) is used to make steel, cement, and heat-resistant bricks
- Calcium chloride is used in making paper and pulp
- Calcium is important in the structure of bones and teeth. Calcium ions are necessary for the contraction of muscles. Calcium ions also take part in the reaction that cause blood to clot

Alkaline earth metals (continued)

- the energetically preferred state of achieving a filled electron shell is to lose two electrons to form doubly charged positive ions
- react readily with halogens to form ionic
- with water, though not as rapidly as the alkali metals, to form strongly alkaline (basic) hydroxides
- Beryllium is an exception: It does not react with water or steam, and its halides are covalent

Lanthanide

- comprises the 15 elements with atomic numbers 57 through 71, from lanthanum to lutetium
- All lanthanides are f-block elements, corresponding to the filling of the 4f electron shell,
- fairly abundant in nature
- Cerium is the 26th most abundant element in the Earth's crust
- two of the lathanides have radioactive isotopes with long half-lives
- They obey the Oddo-Harkins rule, which states that odd-numbered elements are less abundant than their even-numbered neighbors.
- widely used in lasers

Lanthanide (Continued)

- deflect UV and Infrared electromagnetic radiation and are commonly used in the production of sunglass lenses
- Due to their specific electronic configurations, lanthanide atoms tend to lose three electrons
- All lanthanides closely resemble lanthanum
- shiny and silvery-white
- and tarnish easily when exposed to air
- are used to make steel
- react violently with most nonmetals
- are relatively soft but their hardness increases with their atomic number
- Lanthanides burn in air
- high melting and boiling points

Actinide

- encompasses the 15 chemical elements that lie between actinium and lawrencium on the periodic table, with atomic numbers 89 – 103
- display less similarity in their chemical properties than the lanthanide series
- radioactive
- Only thorium and uranium occur naturally in the earth's crust in anything more than trace quantities
- Neptunium and Plutonium have been known to show up naturally in trace amounts in uranium ores as a result of decay or bombardment
- The remaining actinides were discovered in nuclear fallout, or were synthesized in particle collide
- The latter half of the series possess exceedingly short half-lives.

Transition Metals

- 40 chemical elements 21 to 30, 39 to 48, 71 to 80, and 103 to 112
- Less reactive
- Hard metals
- Used in jewelry and constructions

Transition Metals (Continued)

- They often form colored compounds
- They can have a variety of different oxidation states
- They are often good catalysts
- They are silvery-blue at room temperature (except copper and gold).
- They are solids at room temperature (except mercury).
- They form complex ions

Transition Metals (Continued)

- high tensile strength, density and melting and boiling points
- multiple stable oxidation states
- The number of oxidation states of each ion increases up to Mn, after which they decrease.
- When the elements are in lower oxidation states, they can be found as simple ions.

Transition Metals

- Transition metals have many uses. Au, Ag, Cu, Ni, and Pt are coinage metals. Catalytic converters contain Pt, Pa, and Rh. Os is used to harden pen points. Co-60 is used to treat cancer. Mo is used in spark plugs
- Transition elements, used alone or as alloys, are our principal structural metals: Ti through Zn. TiO_2 is used in paints. MnO_2 is used in batteries. Fe and Cr oxides are used in audiotapes and videotapes

Transition Metals

- Cr is important because it resists corrosion. It is used in stainless steel and chromeplate regular steel
- Cr reacts by losing 3 electrons to form the Cr^{3+} ion
- Cr also forms the 6+ states in CrO_4^{2-} , and $Cr_2O_7^{2-}$Many Cr compounds are colored. Small amount of Cr are found in crystals of rubies and emeralds
- Zn behaves different because of its full d sublevel. It has one oxidation state, 2+
- Metallic Zn is corrosion resistant. It is used to coat Fe. This process is called galvanizing
- Zn is essential to proper body function

Earth metals

- boron (**B**), aluminum (**Al**), gallium (**Ga**), indium (**In**), thallium (**Tl**), and ununtrium (**Uut**) (unconfirmed).
- Poor metals
- Boron is a metalloid
- The rest are poor metals
- 3 valence electrons
- Aluminum is the most plentiful metal in Earth’s crust
- Aluminum (Gp 13, IIIA) tends to share its 3 outer electrons in forming compounds
- Aluminum sulfate is used in water purification, paper manufacture, and fabric dyeing

Carbon Family

- carbon (**C**), silicon (**Si**), germanium (**Ge**), tin (**Sn**), lead (**Pb**), and ununquadium (**Uuq**).
- Each of the elements in this group has 4 electrons in its outer energy level
- Elements important to life and computers
- Important semiconductors
- Carbon is the basis of life
- All look really different
- The tendency to lose electrons increases as the size of the atom increases
- Carbon alone forms negative ions
- Tin and lead both are metals while ununquadium is a synthetic short-lived radioactive metal
- Can form up to 4 bonds
- React in similar ways

Carbon

- Carbon reacts by sharing 4 electrons
- Diamond and graphite are 2 allotropes of carbon
- Carbon dioxide is used in refrigeration, beverages, and in making other chemicals
- Small crystals of dry ice are used in cloud-seeding
- Silicon is the 2^{nd} most plentiful element in Earth's crust
- Silicon bonds by sharing electrons
- Tin: 4+ is more stable than 2+; and lead: 2+ is more stable than 4+.
-

Carbon Family

- The carbon atom is what life's molecule is centered around
  - Carbon has two main allotropes
    - Allotrope – is an element that can be in two different forms such as carbon in the form of a diamond and graphite
- Silicates (compounds of silicone) are extremely important in the computer industry

Pnictogen or Nitrogen Family

- phosphorus (**P**), arsenic (**As**), antimony (**Sb**), bismuth (**Bi**) and ununpentium (**Uup**) (unconfirmed)
- Nitrogen makes up ¾ atmosphere
- Important in living things
- 5 electrons in their outermost shell

Nitrogen and Phosphorus

- N_2 and P_4 are found in Gp 15 (VA)
- N_2 occurs in oxidation states from 3- through 5+
- P_4 occurs only in 3-, 0, 3+, and 5+
- N_2 gas is very stable, but its compounds are not
- TNT and dynamite are made with N_2
- Liquid N_2 has extensive industrial use
- Ammonium nitrate is used as fertilizer or explosives
- Phosphoric acid is used to make fertilizer and other applications
- Organic compounds of phosphorus are vital to living organisms

Nitrogen and Phosphorus group 15

- **Nitrogen occurs in all oxidation states ranging from 3- to 5+ phosphorus shows only 3- 0 3+ & 5+**
  - **Nitrogen gas is extremely stable N_2**
  - **Most Nitrogen compounds are unstable**
  - **Amino acids have proteins in them**
- **Phosphorus**
  - **Two allotropes**
    - **Red**
    - **White**

Chalcogen

- oxygen (**O**), sulfur (**S**), selenium (**Se**), tellurium (**Te**), the radioactive polonium (**Po**), and the synthetic ununhexium (**Uuh**).
- Oxygen is needed for respiration
- Commonly minerals
- Oxygen and sulfur are nonmetals
- polonium, selenium and tellurium are metalloid semiconductors
- common as minerals

Chalcogens continued

- Oxygen is the most plentiful element in Earth's crust
- Oxygen reacts by gaining 2 electrons or by sharing electrons
- O_2 has several allotropes. Their properties are similar to that of sulfur
- S can form long chain ions such as $S_6{}^{2-}$
- Other members of the group: Se, Te, and Po

Oxygen Family

- **Oxygen**
  - **Two allotropes**
  - **Diatomic O_2 and Ozone O_3**
- **Sulfur**
  - **Similar and character to Oxygen, just not as reactive**
  - **Two allotropes of white sulfur and yellow sulfur**

Halogen

- fluorine, F, chlorine, Cl, bromine, Br, iodine, I, astatine
- Very reactive
- Volatile, diatomic non metals
- Always found combined with another element in nature
- Used as disinfectants and to strengthen teeth
- nonmetal elements
- found in the environment only in compounds or as ions.
- also be found as natural products in living organisms

Halogens

- Halogens react by forming negative ions or by sharing electrons
- F is the most reactive chemical element
- Cl forms chlorides readily. The primary use of Cl is to make other chemicals
- only periodic table group exhibiting all three states of matter.
- harmful or lethal to biological organisms in sufficient quantities
- all form binary compounds with hydrogen

Noble Gases

- Group 18 (VIIIA) contains very stable gases, because all outer electrons are filled
- Helium, Neon, Argon, Krypton, Xenon, Radon
- Highly unreactive monatomic gases
- Used in neon signs
- Used in blimps
- Have a full valence shell
- occur as odorless, colorless, monatomic gases

Noble Gases

- rarely react with other elements
- no conventional compounds of helium or neon have yet been prepared.
- Chemically, noble gases are not inert
- Xe, Kr, and Rn compounds have been made
- Ar is used to fill light bulbs to protect the filament
- Ne, Kr, and Xe are used to fill brightly colored gas discharge tubes for advertising

Noble Gases (Continued)

- high ionization energies and negligible electro negativities
- weak inter-atomic forces of attraction, and consequently very low melting points and boiling points.
- Krypton is also used in lasers, and are used by doctors for eye surgery

Chemical bonding

Electronegativity

- **The relative tendency of an atom to attract electrons to itself when it bounds with another atom**
- **Bonds strength increases as the electronegativity increases**
- **Trends**
  - **Most active metals have low electronegativities**
  - **Most active nonmetals have high electronegativities**

Bond Character

- Electron transfer - when the difference electronegativity is high
- Electrons are shared when the difference is electronegativity is low
- Ionic bond results when the difference is 1.67 or greater
- Covalent bond results from ad difference of 1.67 or less

Ionic bonds

- **Electrostatic force holds two ions together due to their different charges**
- **Assigned oxidation numbers according to the number of electrons gained or lost**
- **Characteristics**
  a. **High melting points**
  b. **Soluble in water**
  c. **Well defined crystal**
  d. **Molten form conducts electricity**

Table 12-6

Electronegativities

H 2.20																
Li 0.96	Be 1.50											B 2.02	C 2.56	N 2.81	O 3.37	F 4.00
Na 0.96	Mg 1.29											Al 1.63	Si 1.94	P 2.04	S 2.46	Cl 3.00
K 0.84	Ca 1.02	Sc 1.28	Ti 1.44	V 1.54	Cr 1.61	Mn 1.57	Fe 1.74	Co 1.79	Ni 1.83	Cu 1.67	Zn 1.60	Ga 1.86	Ge 1.93	As 2.12	Se 2.45	Br 2.82
Rb 0.85	Sr 0.97	Y 1.16	Zr 1.27	Nb 1.23	Mo 1.73	Tc 1.36	Ru 1.42	Rh 1.87	Pd 1.78	Ag 1.57	Cd 1.52	In 1.69	Sn 1.84	Sb 1.83	Te 2.03	I 2.48
Cs 0.82	Ba 0.93	*Lu 1.20	Hf 1.23	Ta 1.33	W 1.88	Re 1.46	Os 1.52	Ir 1.88	Pt 1.86	Au 1.98	Hg 1.72	Tl 1.74	Pb 1.87	Bi 1.76	Po 1.76	At 1.96
Fr 0.86	Ra 0.97	**														
	*La 1.09	Ce 1.09	Pr 1.10	Nd 1.10	Pm 1.07	Sm 1.12	Eu 1.01	Gd 1.15	Tb 1.10	Dy 1.16	Ho 1.16	Er 1.17	Tm 1.18	Yb 1.06		
	**Ac 1.00	Th 1.11	Pa 1.14	U 1.30	Np 1.29	Pu 1.25	Am 1.2 ←	Cm	Bk	Cf estimated	Es	Fm	Md → 1.2			

Ionic Radii

- Internuclear distance sum of 2 radii of ions in the bond

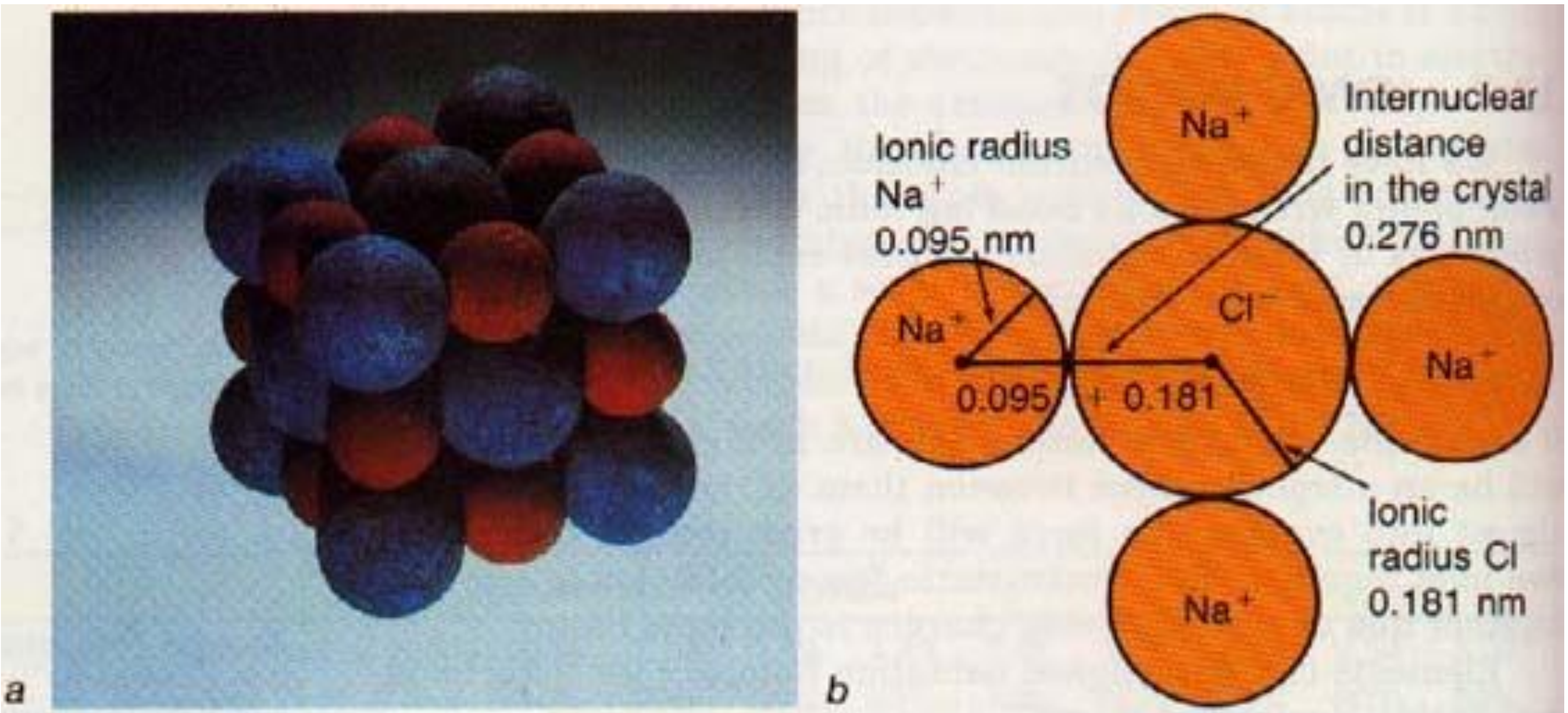


FIGURE 12-7. Sodium chloride consists of a regular arrangement of sodium and chloride ions as shown by the model (a). The ionic radius is the sum of the radii for both ions (b).

Molecule

- is a particle formed from a covalent bond
- Bond axis is a line joining the nuclei of 2 bonded atoms
- Bond angle is the angle between a 2 bond axis
- Bond length is the distance between 2 nuclei along the bond axis
  - This fluctuates
  - Not constant, because it undergoes bending wagging and rotational vibration

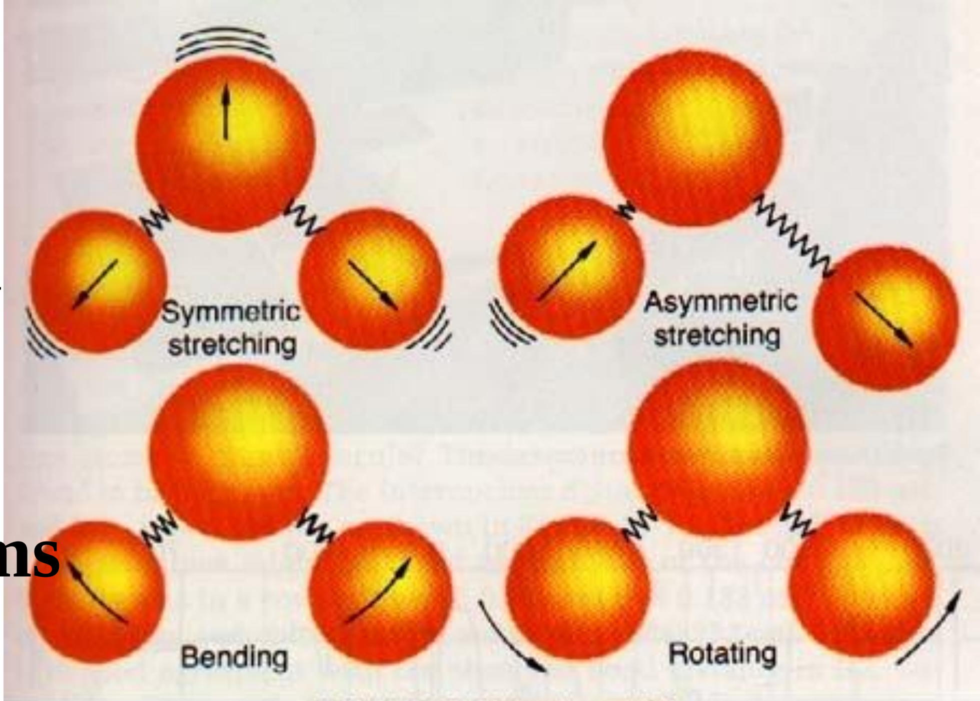


FIGURE 12-8. Molecules exhibit a variety of motions. Therefore, bond lengths and bond angles should be considered as average values.

Molecules

- **Near the same electronegativity**
- **Covalent bond**
  - **Character**
    - a. **Low melting points**
    - b. **Does not conduct electricity**
    - c. **Brittle**

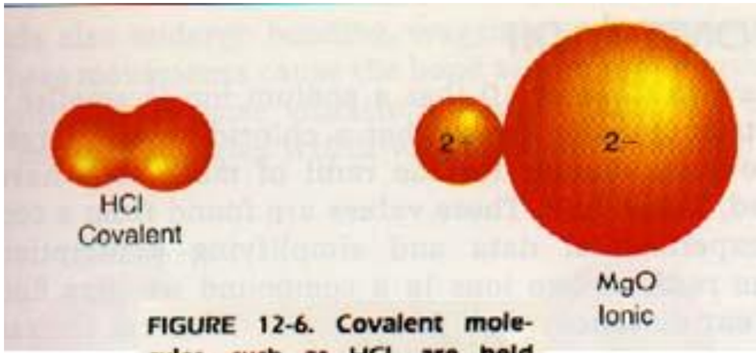


FIGURE 12-6. Covalent molecules, such as HCl, are held together by a mutual sharing of electrons. Note there is an overlap of the electron clouds. Ionic substances, such as MgO, are held together by the attractive force between oppositely-charged ions.

Covalent Radii

- **Internuclear distance or the sum of the radii of the two atoms**

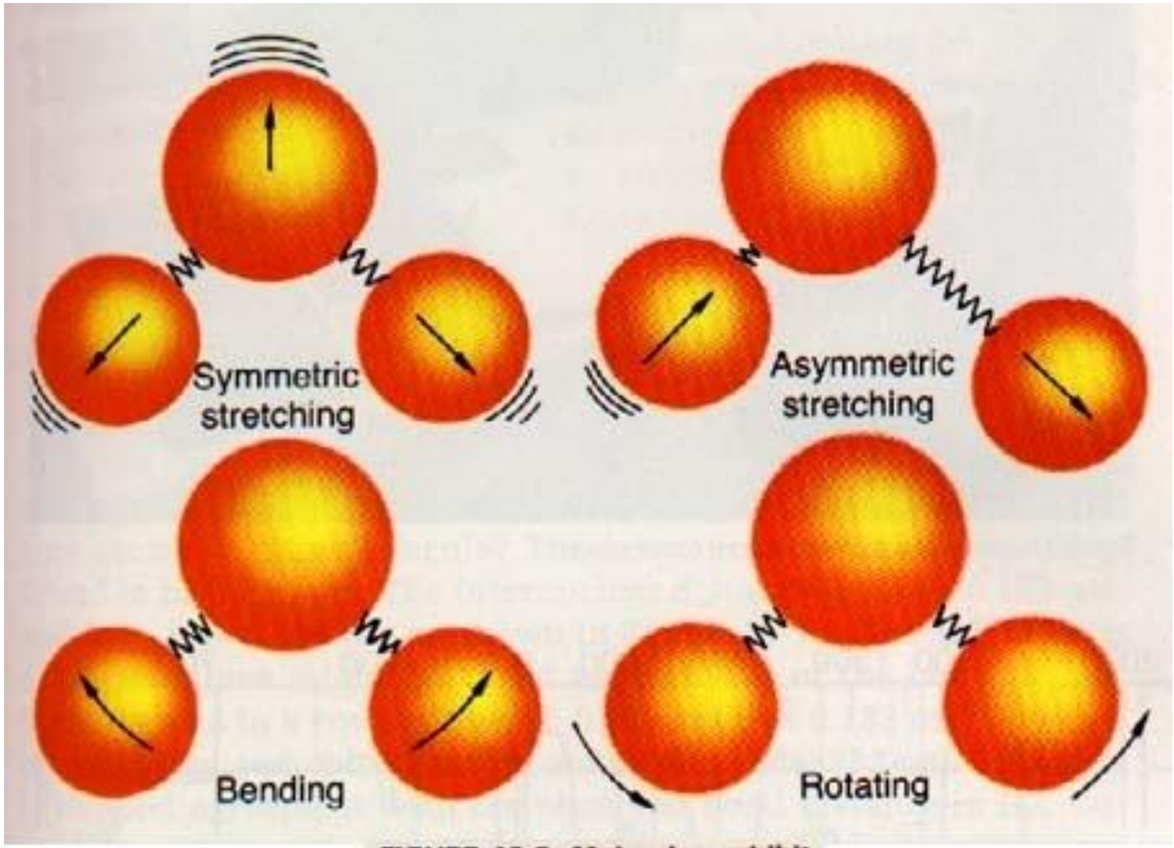


FIGURE 12-8. Molecules exhibit a variety of motions. Therefore, bond lengths and bond angles should be considered as average values.

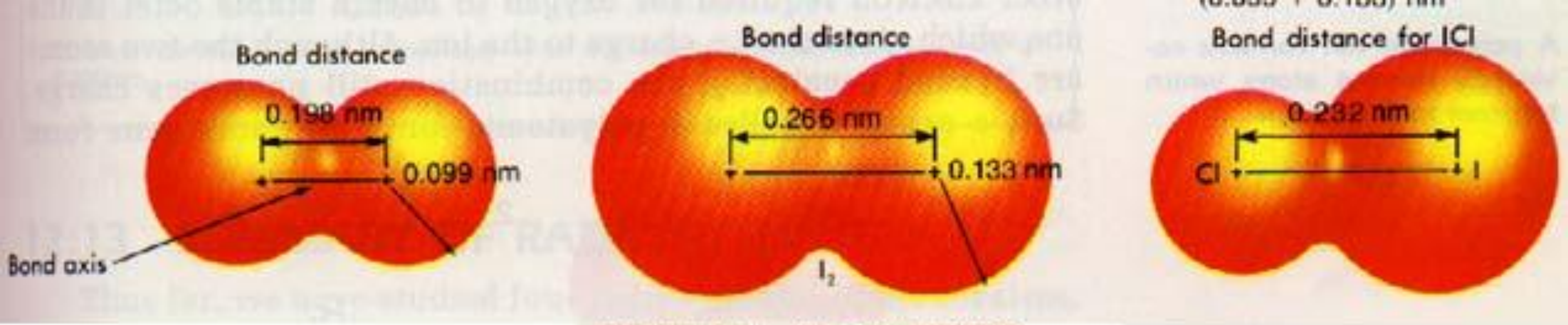


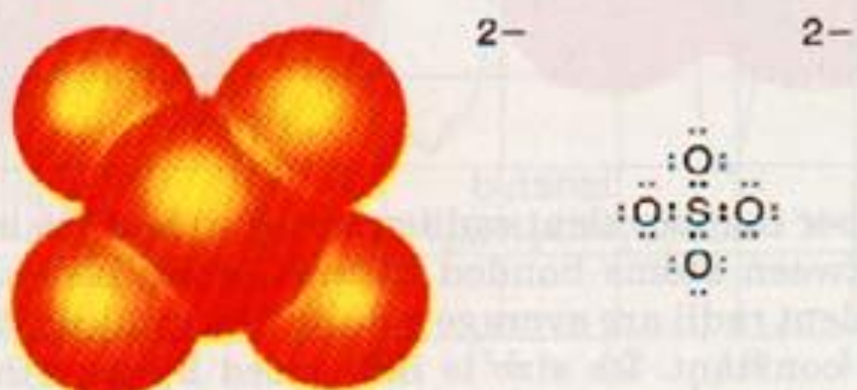
FIGURE 12-11. The internuclear distance is the sum of the covalent radii for each atom. Recall that bond distances are not fixed values.

Table 12-8

Covalent Radii (in nanometers)			
Atom	Radius	Atom	Radius
Al	0.125	I	0.133
As	0.121	N	0.070
B	0.088	O	0.066
Be	0.089	P	0.110
Bi	0.152	Pb	0.144
Br	0.114	S	0.104
C	0.077	Sb	0.141
Cl	0.099	Se	0.117
F	0.064	Si	0.117
Ga	0.125	Sn	0.140
Ge	0.122	Te	0.140
H	0.037		

Table 12-9

Experimental Bond Lengths (in nanometers)		
Molecule	Bond	Length
BCl_3	B—Cl	0.174
B_2H_6	B—H	0.132
Diamond	C—C	0.154
CH_4	C—H	0.110
CH_3I	C—H	0.110
	C—I	0.221
ClBr	Cl—Br	0.214
HF	H—F	0.092
H_2O	H—O	0.096
NH_3	N—H	0.101
OF_2	O—F	0.141
O_3	O—O	0.128
H_2SAlBr_3	S—Al	0.243
$(H_3Si)_2NN(SiH_3)_2$	Si—N	0.173



Sulfate ion

FIGURE 12-12. The sulfate ion contains S—O covalent bonds. The electron dot structure shows a stable octet for each atom. However, the particle as a whole has a net negative charge.

Polyatomic ions

- **There are a large number of ionic compounds made of more than two elements.**
  - **In these compounds, one ion consists of two or more atoms covalently bonded.**
  - **However, the particle as a whole possesses an overall charge**.
- Hydroxide ion, OH^{-1}.
- Hydrogen atom contributes one electron to the octet of oxygen.
  - combination still possesses charge.

Van Der Walls Radii

- **Distance of closest approach of nonbonded atoms**
- Minimum distance must be maintained between atoms that are not bonded to each other.
  - This limitation exists because the electron cloud of one atom repels the electron cloud of other atoms.
- Colliding free atoms and molecules act as if they had a rigid outer shell.
  - This shell limits the closeness with which they may approach other atoms or molecules.
- **Since the covalent bond consists of shared electrons, bonded atoms can come closer than atoms which are not bonded**
- It is named for the Dutch 'physicist Johannes Van Der Waals.

Special properties of metals

- The properties of metals are not explained by any of the bonding properties already considered.
  - **One of these properties is the ability to conduct electricity quite readily.**
  - **Good electric conductivity indicates a ready source of electrons in metals.**
- We can use the following model to describe a piece of metal.
  - Imagine metal atoms without their outer level electrons.
  - These positive ions are packed together and their empty outer-level orbitals interact with each other.
  - Each outer level is split into closely spaced energy levels. These splits are so small that we actually have bands of possible energies.
  - **These energy bands are separated from each other by small energy gaps called forbidden zones**
  - **Conduction band is a group of extremely closely spaced energy levels which free electrons can occupy**
    - **Once the electrons are in the conduction band the can travel where ever they want**

Metalic Bonding

- **Delocalized electrons are electrons which can travel any where through out the substance**
  - **The number of electrons available for bonding determines properties of metals**
  - **The more delocalized electrons the stronger the metal**

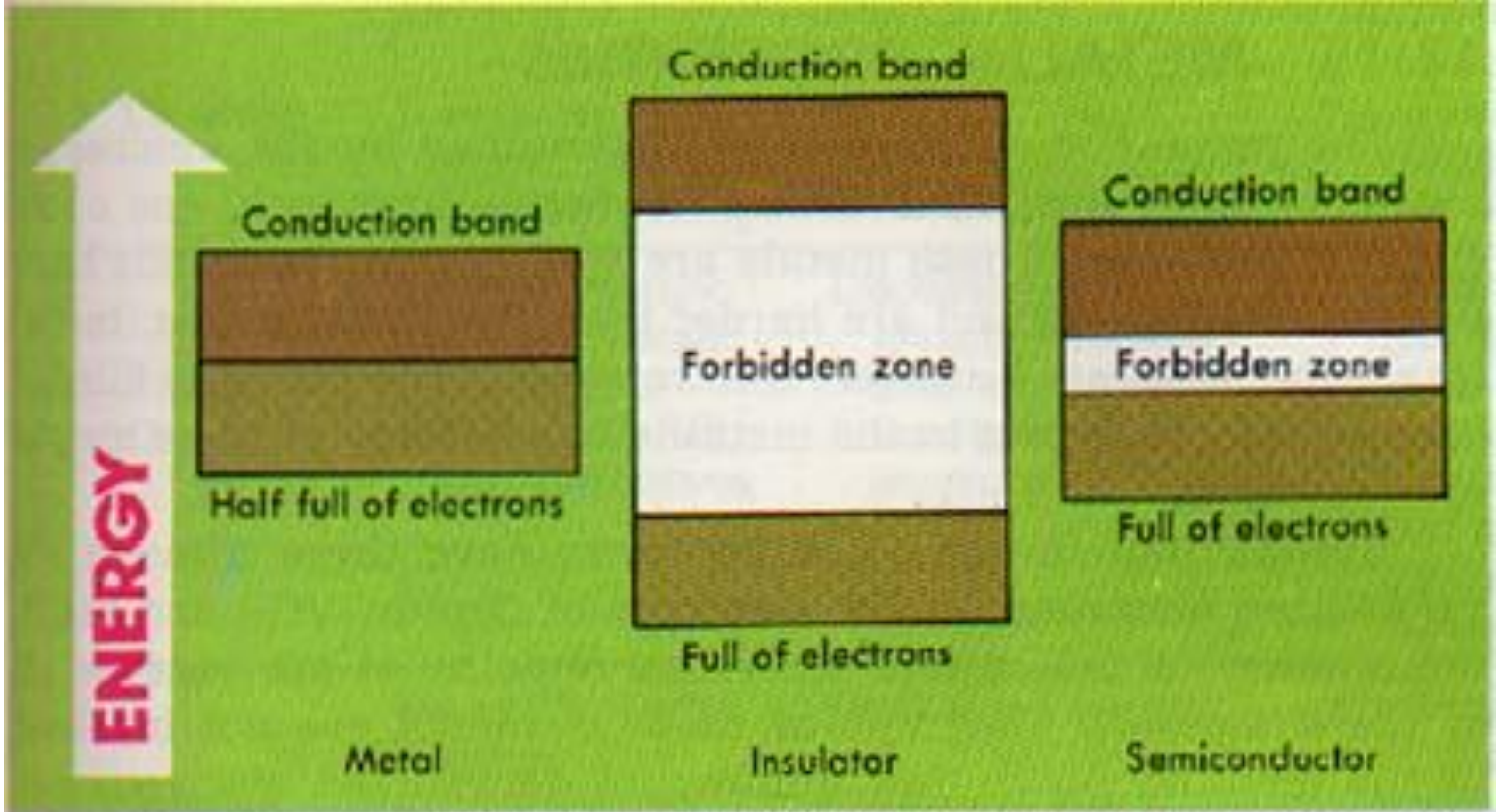


FIGURE 12-15. Metals are excellent conductors in that electrons can move easily to the conduction band. Insulators block the passage of current in that the forbidden zone represents too large an energy gap. Semiconductors can conduct if electrons receive enough energy to move past the forbidden zone to the conduction band.

METALLlC PROPERTIES

- The properties of metals are determined by the number outer electrons available.
  - Group IA metals have only one electron per atom. These metals are soft.
  - Group IIA metals two outer electrons and are harder than Group IA metals.
  - In the transition elements however, electrons from the partially filled **d** orbitals may take part in the metallic bond. Many of these metals are very hard.
    - The strong metallic bond of our structural metals, such as iron, chromium, and nickel, makes them hard and strong.
- In general, the transition elements are the hardest and strongest elements.
  - It is possible to strengthen some of the elements with fewer delocalized electrons by combining them with other metals to form **alloys**.
  - These alloys have properties different from those of pure elements.