BI 107

CHAP 2

Chemical Context of Life

Chemical Elements and Compounds

- Matter consists of chemical elements in pure form & in combinations called compounds
- Matter consists of anything that occupies space and has mass

Chemical Elements and Compounds cont.

- Elements – substances which cannot be broken down to other substances by chemical reactions
- 92 naturally occurring elements – each has a unique symbol
- Life requires about 25 chemical elements
- 4 elements – carbon, hydrogen, oxygen, nitrogen make up 96% of living matter
- 7 make up most of the rest
- Trace elements required in minute amounts – some needed by all living organisms and other trace elements needed by some organisms

Chemical Elements and Compounds cont.

- Compounds – substances consisting of 2 or more elements in fixed ratio – H_2O
- Emergent properties – compound has properties beyond those of combined elements – NaCl

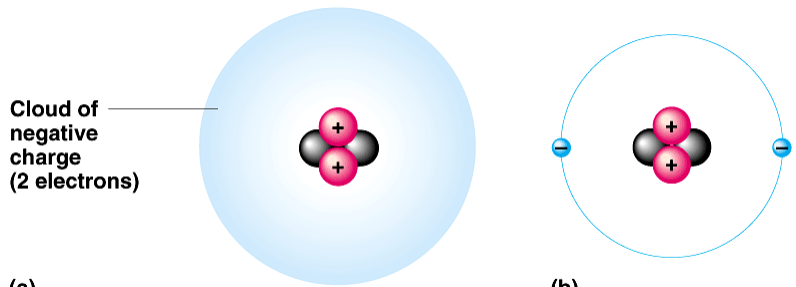
Atoms and Molecules

- Atoms – smallest unit of matter that retains properties of an element
- Atom of 1 element differs from atoms of all other elements
- Symbolize atoms with same letter used for the element

- Subatomic particles – protons, neutrons, electrons
- Protons and neutrons in dense core called nucleus
- Electrons circle in a cloud at about speed of light

Atoms and molecules cont.

- Electrons are negatively charged & protons are positively charged – neutrons are electrically neutral
- Neutron & proton – mass about equal at 1.7×10^{-24} gr. – called a Dalton – same as atomic mass unit



Atoms and Molecules cont.

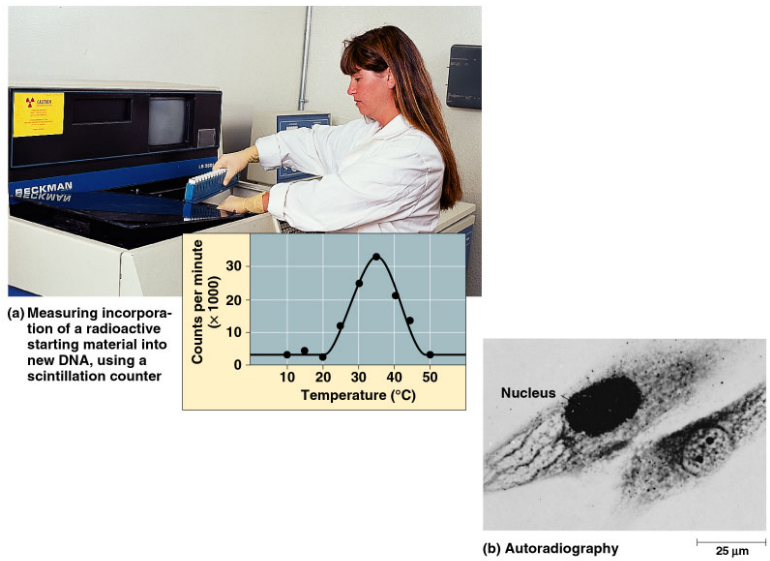
- Atomic number and atomic weight
- Atoms of different elements differ in number of subatomic particles
- All atoms of element

  have same number of protons in nucleus – called atomic number – left side subscript

- Atoms are neutral so have same number of electrons
- Mass number is sum of number of protons and neutrons – superscript to the left
- Atomic weight – approx. equal to sum of protons & neutrons

Atoms and Molecules cont.

- Isotopes – all atoms of an element have same number of protons in nucleus but can have differing number of neutrons – called isotopes – carbon 12, 13, 14 C14 is unstable or radioactive – nucleus decays spontaneously giving off particles and energy

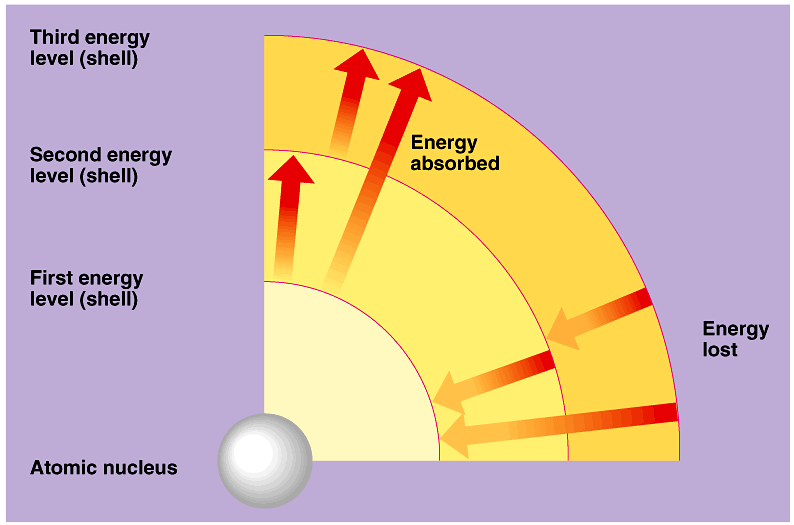


(a) Measuring incorporation of a radioactive starting material into new DNA, using a scintillation counter

(b) Autoradiography

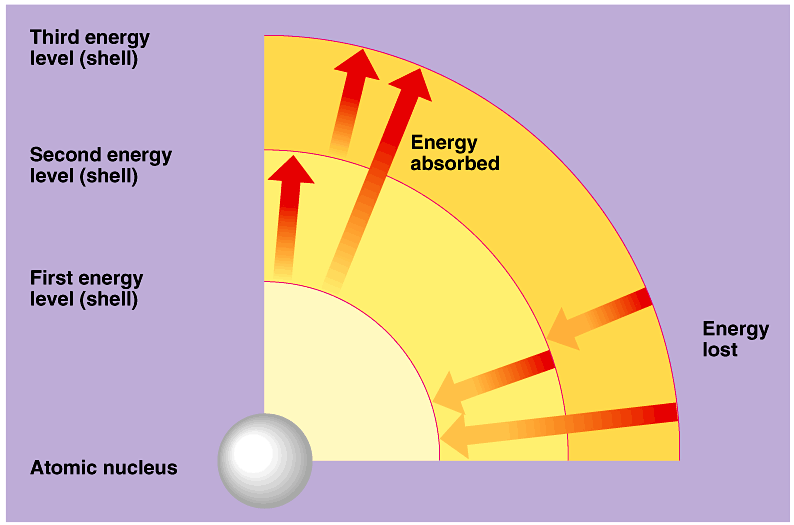
Atoms and Molecules cont. Energy levels of electrons

- Only electrons are directly involved in chemical reactions
- Electrons are far from the nucleus and vary in the amount of energy they have



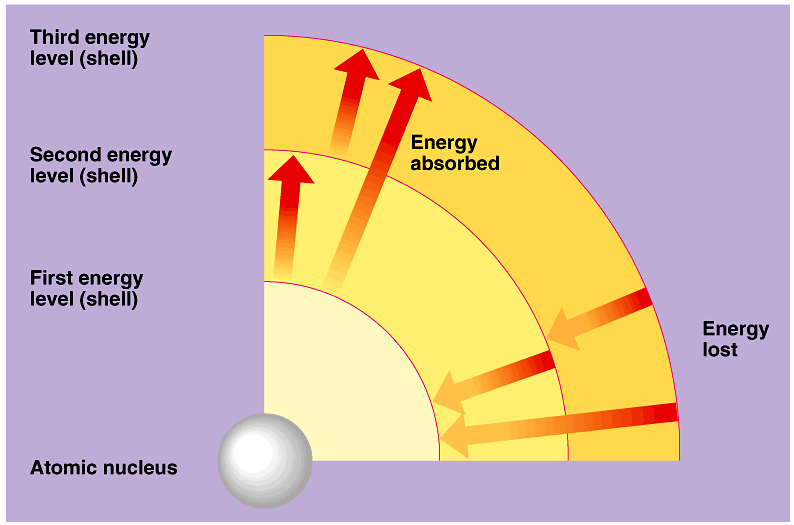
Energy Levels of Electrons cont.

- Energy – ability to do work
- Potential energy – energy that matter stores due to its position or location
- Matter – tendency to move to lowest state of potential energy & work must be done to restore used potential energy



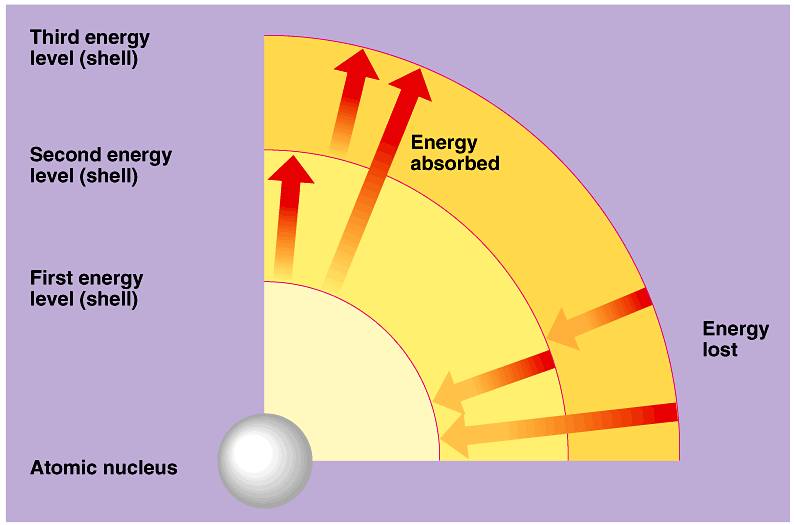
Energy levels of electrons cont.

- Electrons have potential energy due to position in relation to nucleus
- Negative electrons attracted to positive nucleus & further from nucleus an electron is the greater the potential energy it has



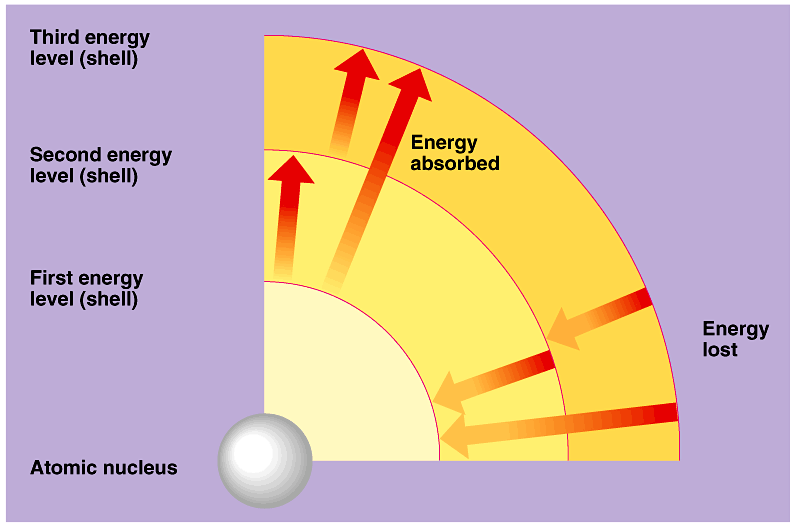
Energy Levels of Electrons cont.

- Changes in energy levels of electrons occur in discrete steps
- Different states of potential energy electrons have in the atom called energy levels or electron shells



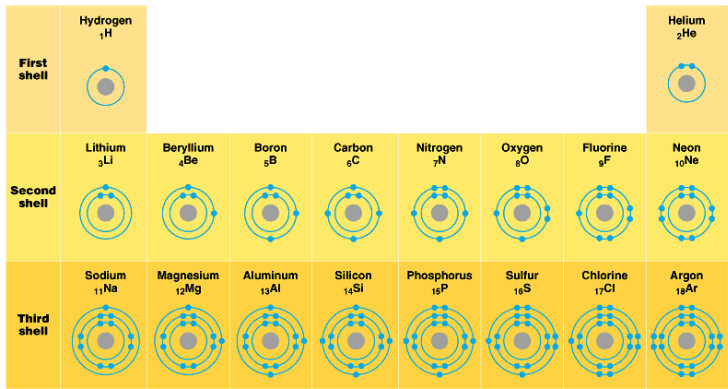
Energy Levels of Electrons cont.

- 1st shell closest to nucleus and has lowest energy more energy in 2nd shell & even more in 3rd shell
- Electron can change shell by adding or losing energy equal to difference in energy between old & new shell



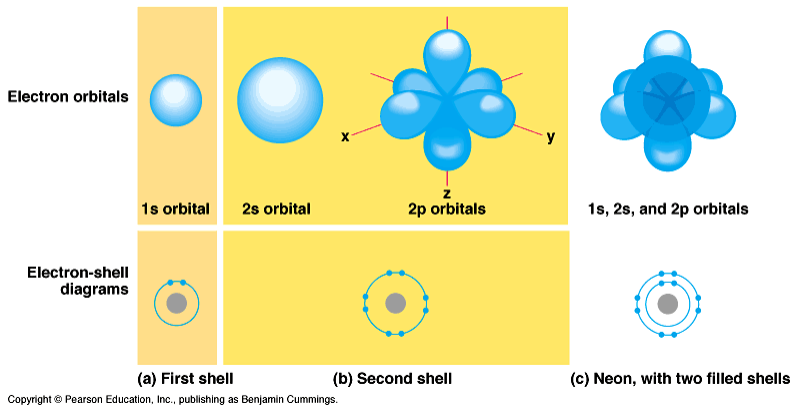
Electron Configuration & Chemical Properties

- Chemical behavior of an atom determined by electron configuration – distribution of electrons in electron shells of the atom
- Chemical behavior depends mostly on number of electrons in outermost shell – called valence shell and electrons called valence electrons



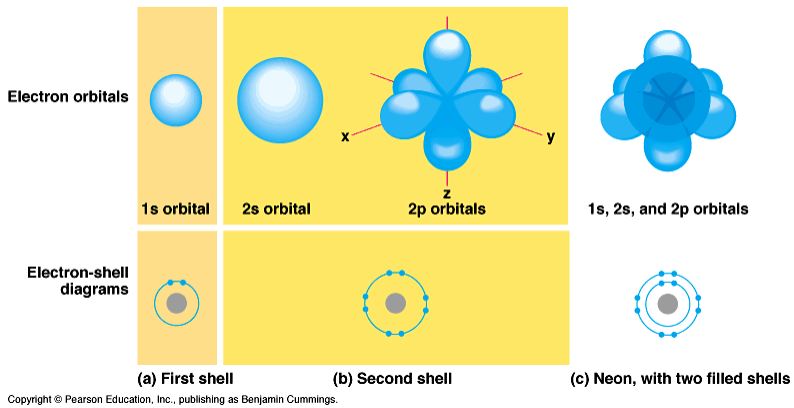
Electron Configuration & Chemical Properties cont.

- When valence shell completely filled with electrons then atom is inert and not reactive
- 3D space where electron spends 90% of time called an orbital
- No more than 2 electrons can occupy an orbital



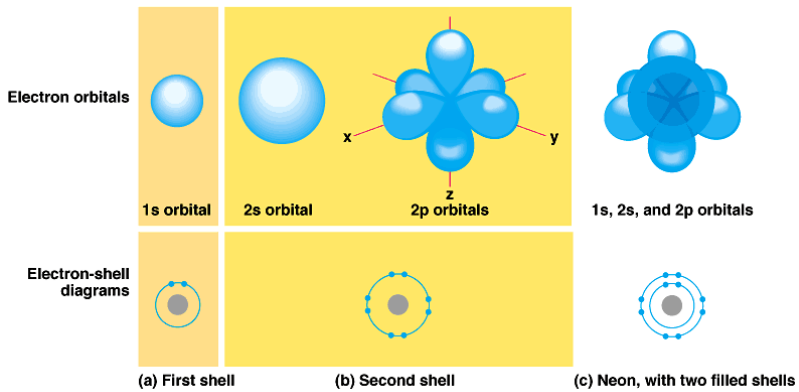
Electron Configuration & Chemical Properties cont.

- Each electron shell has specific number of orbitals of specific shapes
- 1st electron shell has 1 orbital and can hold 2 electrons – orbital is spherical and called 1s orbital



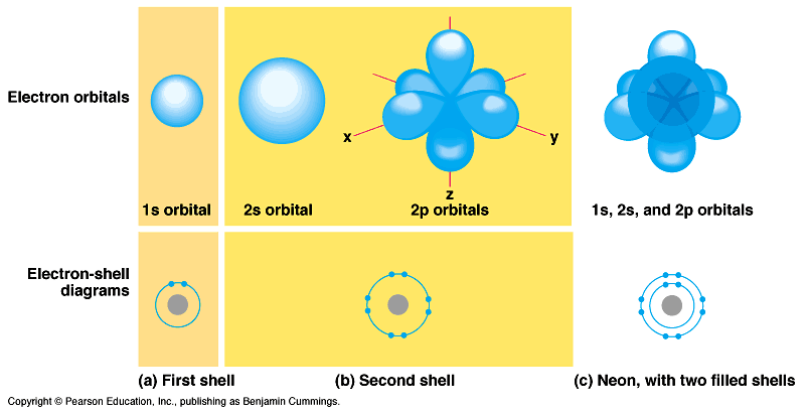
Electron Configuration & Chemical Properties cont.

- 2^{nd} shell has 4 orbitals & can hold 8 electrons
- Electrons in 4 orbitals have same energy but move in different volumes of space – 2s is spherical & 2p orbitals are dumbbell shaped



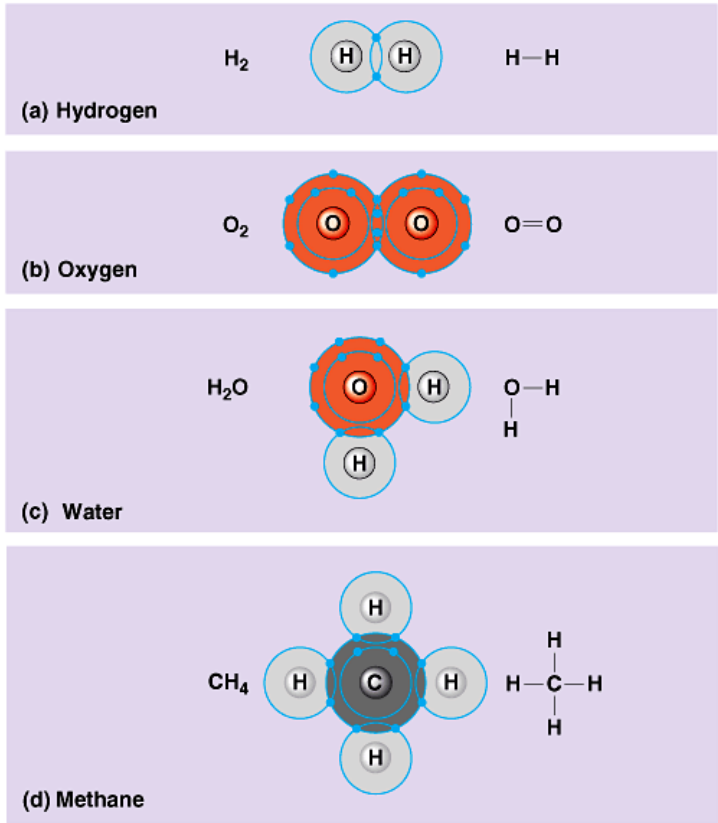
Electron Configuration & Chemical Properties cont.

- Reactivity comes from having unpaired electrons in 1 or more orbitals of valence shell
- Electrons fill orbitals 1 at a time
- Atoms interact to complete valence shells & unpaired electrons react



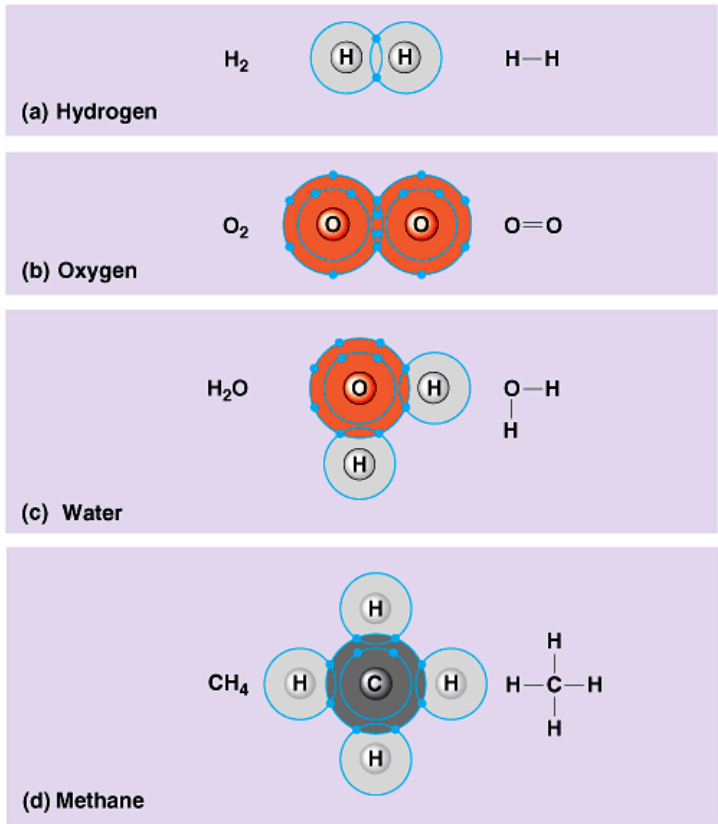
Atoms combine by Chemical Bonding to Form Molecules

- Atoms with incomplete valence shells interact with other atoms so valence shells completed – by sharing or transferring electrons
- Atoms held close together by attractions called chemical bonds



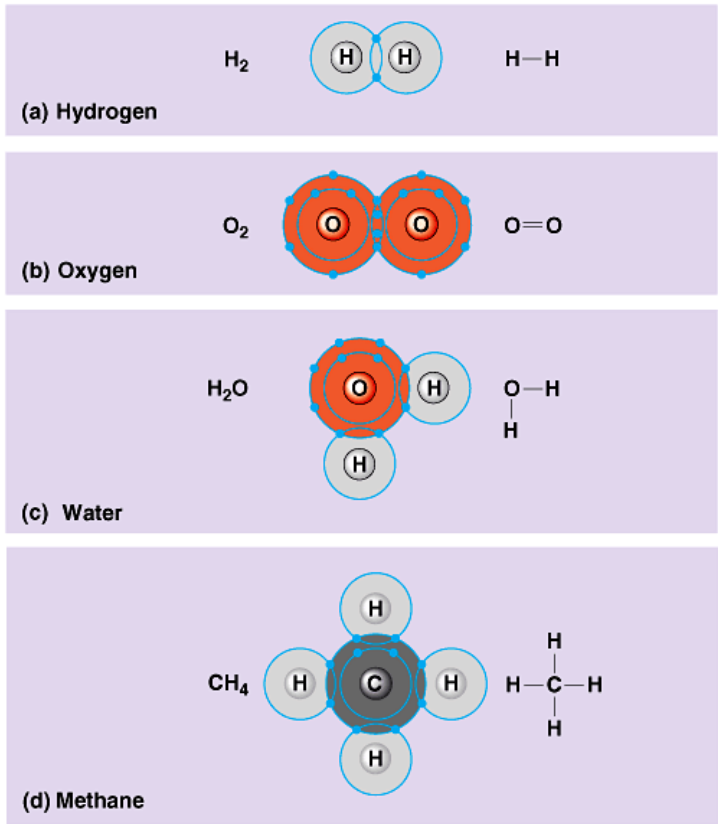
Chemical Bonds cont.

- 2 strongest types of chemical bonds are covalent and ionic
- Covalent bonds – electrons are shared – 1 pair of electrons shared is a single bond, 2 pairs of electrons gives a double bond, 3 pairs shared gives triple bond



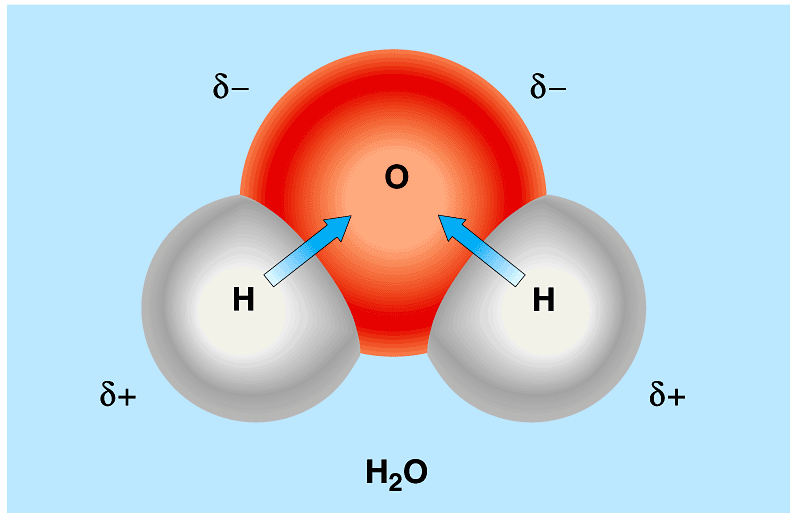
Chemical Bonds cont.

- Bonding capacity – number of covalent bonds an atom can form – called its valence and usually equals number of unpaired electrons in outermost shell
- Hydrogen – 1, carbon – 4



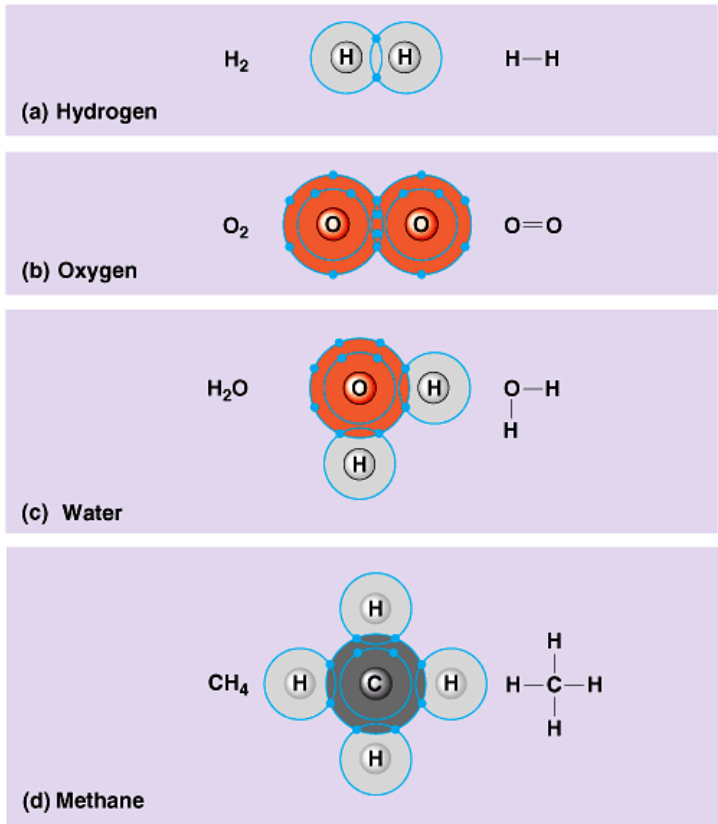
Chemical Bonds cont.

- Nonpolar and polar covalent bonds
- Attraction of an atom for the electrons of a covalent bond called its electronegativity
- Some atoms more electronegative than other atoms so pull the shared electrons strongly to themselves



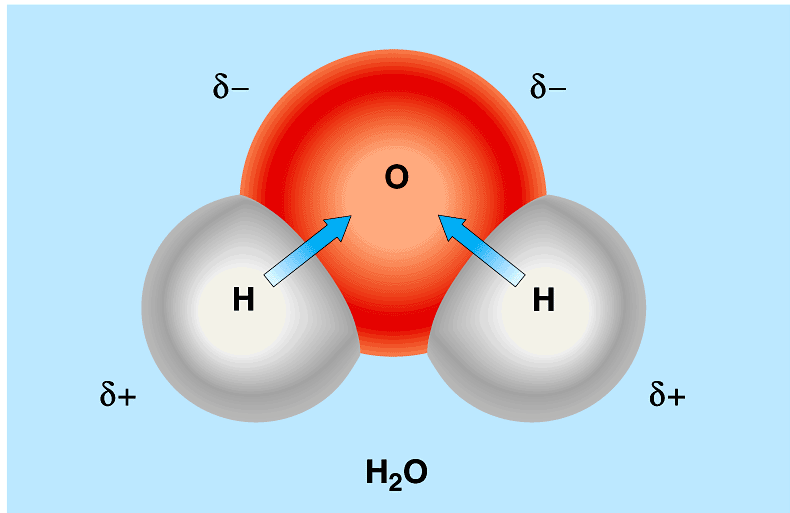
Chemical Bonds cont.

- If pull is equal because electronegativity is equal then electrons shared equally & called nonpolar covalent bond
- H-H of hydrogen molecule and CH_4 of methane gas



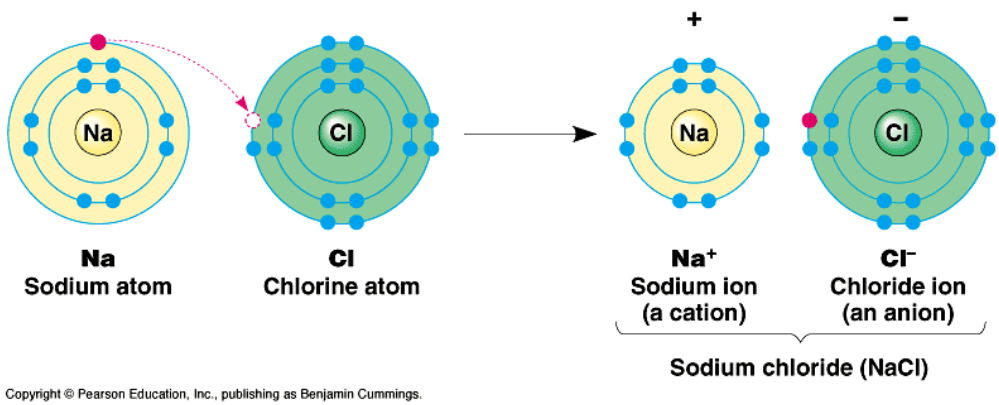
Chemical Bonds cont.

- If 1 atom is more electronegative it pulls or attracts electrons to greater extent resulting in unequal sharing of electrons
- Leads to molecule having regions with negative aspect and regions with positive aspects
- Called polar covalent bonds



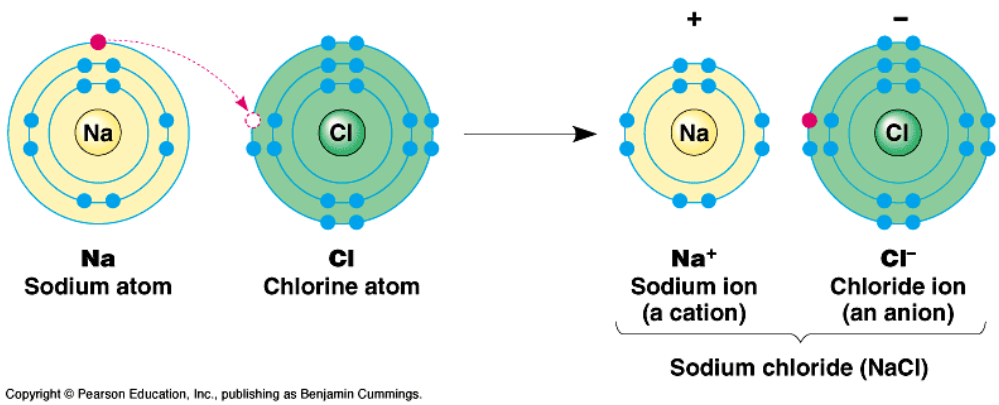
Chemical Bonds cont.

- Ionic bonds – 2 or more atoms differ tremendously in attraction for valence electrons the more electronegative atom removes an electron – electron is transferred



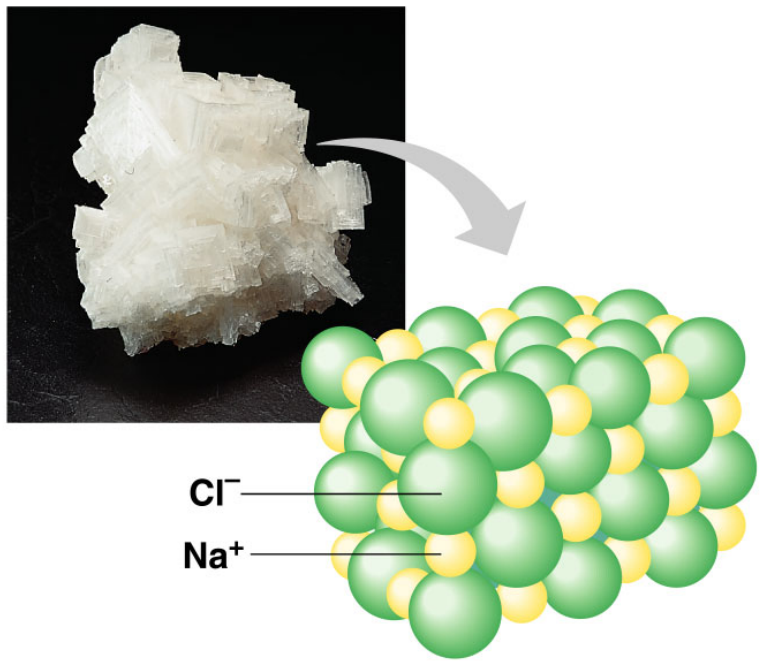
Chemical Bonds cont.

- Atoms start as electrically neutral as number of positive protons equals number of electrons
- Transfer of electron causes atom to become postively charged – called a cation other atom gains an electron and becomes negatively charged – called an anion



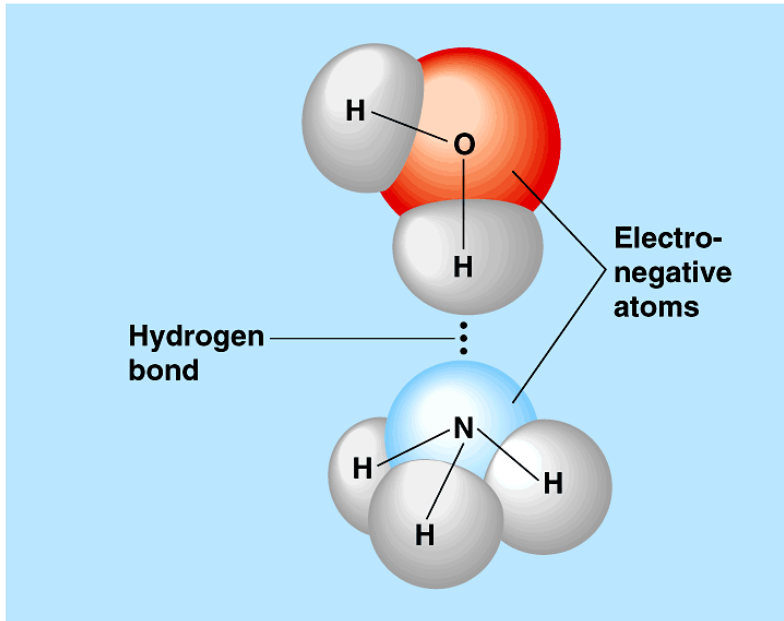
Chemical Bonding cont.

- In ionic bonding atoms held together by attraction of positive cation with negative anion – the attraction called ionic bond
- Not as strong as covalent bond



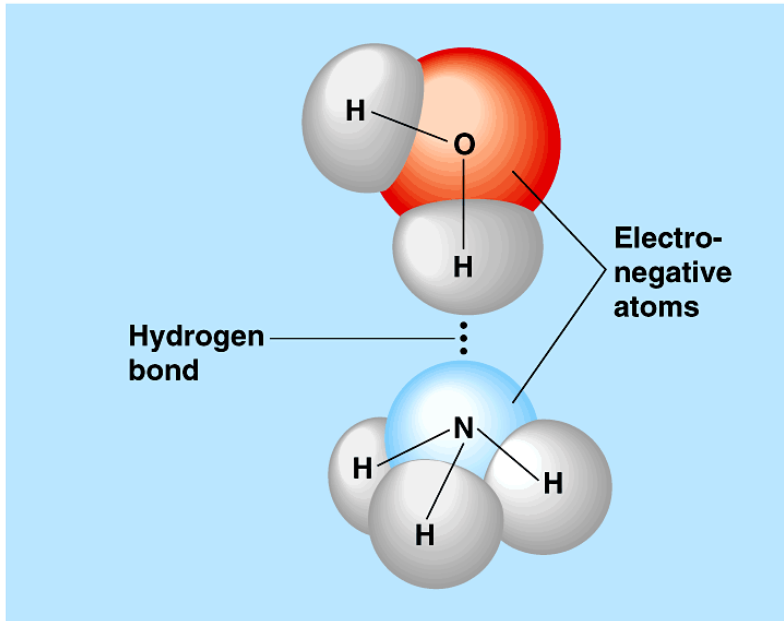
Weak Chemical Bonds Important in Biological Systems

- Strong chemical bonds are covalent bonds linking atoms to form molecules
- Bonding between molecules is also important – weak temporary bonds – important types – ionic, hydrogen, Van der Waals interactions



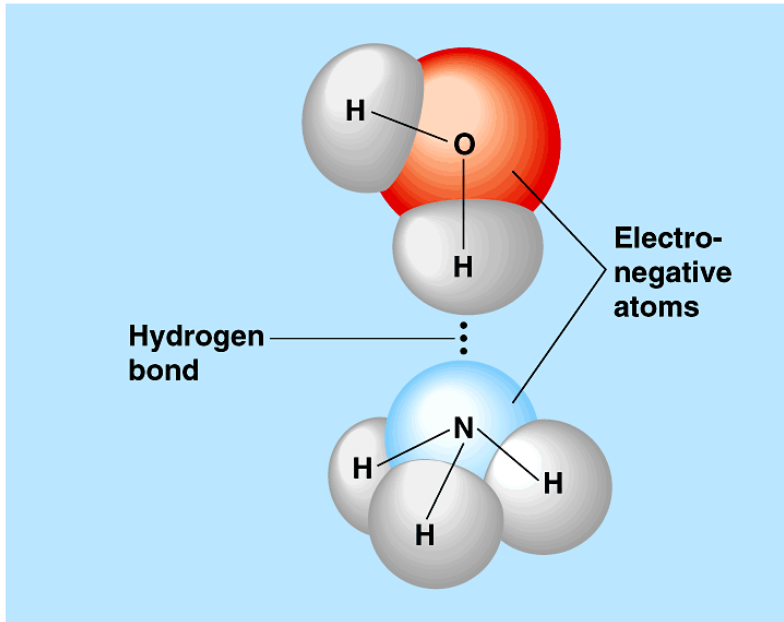
Weak Chemical Bonds cont.

- Hydrogen bond – positive region of 1 molecule attracted to negative region of another molecule – water to water or DNA double strands
- Ionic bond is weak in water



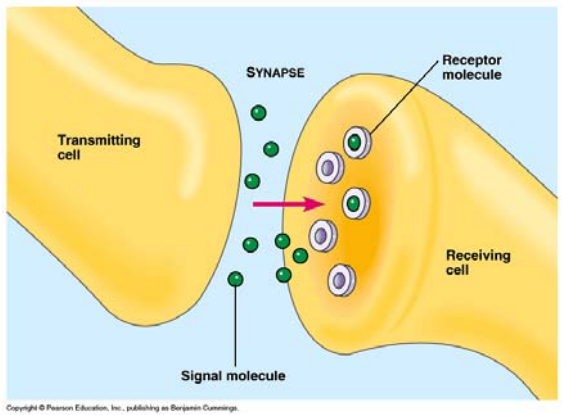
Weak Chemical Bonds cont.

- Van der Waals interactions – nonpolar molecules can temporarily have positive and negative regions which allow molecules and atoms to stick together temporarily



Weak Chemical Bonds cont.

- All weak bonds can form between regions of a single large molecule
- Leads to molecular shape – 3D shape – very important in biological function



Chemical Reactions Make & Break Chemical Bonds

- Reactants and products in a chemical reaction – break bonds in reactants and form bonds in products
- Most but not all chemical reactions are reversible
- Chemical equilibrium is where forward reaction goes at same rate as reverse reaction – dynamic equilibrium