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PAPER-IV: Fundamentals of Biochemistry

Lesson: Types and significance of chemical bonds

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Chapter: Types and significance of chemical bonds

Introduction

We see several things around us such as water, salt, sugar, carbon dioxide etc. Each one of these substances is not made up of single element rather they have two or more elements joined by a bond. To understand what a chemical bond is and how they are formed we should have some basic knowledge of atoms and their properties. There are 92 naturally occurring elements in the earth crust. The smallest particle or the entity of an element that cannot be broken down further or converted into other substances by chemical means, but retains its distinctive chemical property is known as atom. Chemical bonding is all about these atoms and it is important to understand the structure of an atom.

Structure of atom

Each atom itself is made up of three small subatomic particle known as protons, neutrons and electrons. An atom has a positively charged nucleus (containing protons and neutrons) surrounded by a cloud of negatively charged electrons. These electrons are arranged in a series of orbitals and held by electrostatic attraction to the nucleus. Since an atom as a whole is electrically neutral, the number of positively charged protons in the nucleus is equal to the negatively charged electrons surrounding the nucleus. The number of electrons in an atom gives the atomic number which is also equal to the number of proton in the nucleus. Neutrons of an atom are uncharged subatomic particle which gives stability to the nucleus. The atomic weight of an atom is equal to the atomic weight of protons plus neutrons. Electrons contribute almost nothing towards the atomic weight of the atom; however the electrons determine the chemical behavior of the atom.

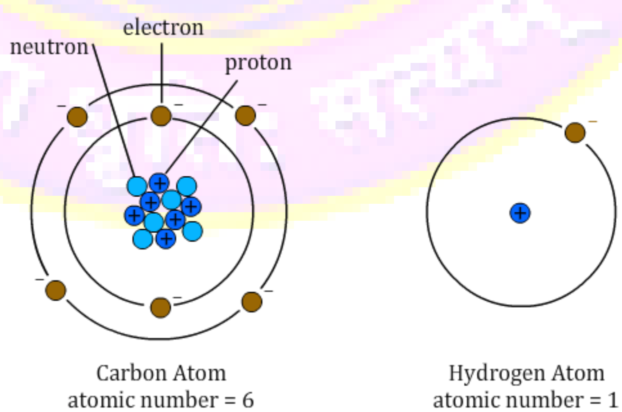


Figure: Structure of carbon and hydrogen atom. A carbon atom has six protons and six neutrons in the nucleus and six electrons arranged in two shells surrounding the nucleus. A hydrogen atom has only one proton and one electron.

Source: Author

Atomic Mass Unit

Even though atoms are very tiny pieces of matter, they have mass. Their masses are so small, however, that chemists often use a unit other than grams to express them—the atomic mass unit.

The atomic mass unit (abbreviated u, although amu is also used) is defined as 1/12 of the mass of a ^{12}C atom:

1 u=112 the mass of 12C atom

It is equal to 1.661×10^{-24} g.

Question: What is the average mass of a carbon atom in grams?

Solution:

1 u = 1.661×10^{-24} *g:*

12.01 u × 1.661×10−24 g1 u=1.995×10−23 g

This is an extremely small mass, which illustrates just how small individual atoms are.

Masses of other atoms are expressed with respect to the atomic mass unit. For example, the mass of an atom of ^{1}H is 1.008 u, the mass of an atom of ^{16}O is 15.995 u, and the mass of an atom of ^{32}S is 31.97 u. Note, however, that these masses are for particular isotopes of each element. Because most elements exist in nature as a mixture of isotopes, any sample of an element will actually be a mixture of atoms having slightly different masses (because neutrons have a significant effect on an atom's mass). How, then, do we describe the mass of a given element? By calculating an average of an element's atomic masses, weighted by the natural abundance of each isotope, we obtain a weighted average mass called the atomic mass (also commonly referred to as the *atomic weight*) of an element.

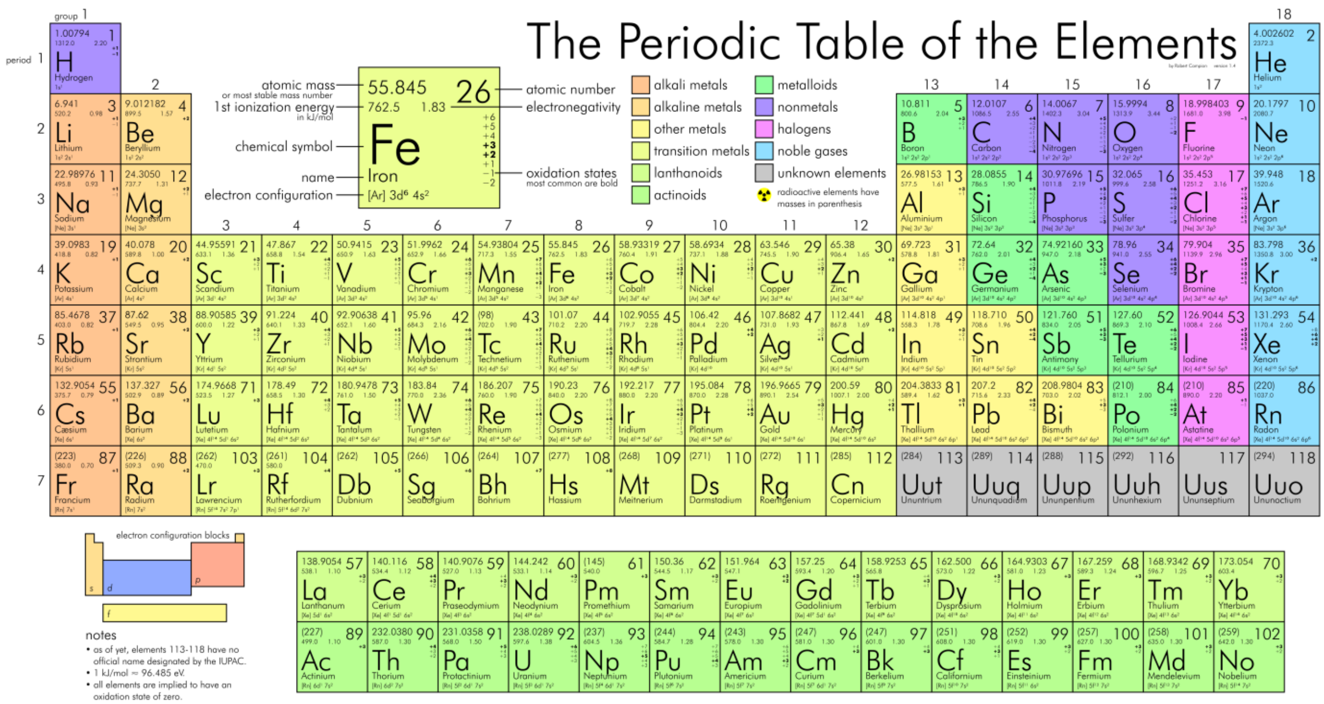
For example, boron exists as a mixture that is 19.9% ^{10}B and 80.1% ^{11}B. The atomic mass of boron would be calculated as (0.199 × 10.0 u) + (0.801 × 11.0 u) = 10.8 u. Similar average atomic masses can be calculated for other elements. Carbon exists on Earth as about 99% ^{12}C and about 1% ^{13}C, so the weighted average mass of carbon atoms is 12.01 u.
Source: http://2012books.lardbucket.org/books/introduction-to-chemistry-general-organic-and-biological/s05-05-atomic-masses.html (CC)

All naturally occurring elements differ from each other in number of protons and electrons in their atoms and therefore have different physical and chemical properties. Biological world is made up of only small number of these elements. Major elements of biological system include carbon, hydrogen, nitrogen and oxygen. Some other elements such as zinc, iron, calcium, sodium, potassium etc are known as minor elements as they are required in less amount. The composition of various elements in the living world is markedly different from that of the nonliving inorganic environment. Thus choice of elements in the living system does not depend upon their availability in the atmosphere rather the elements must be suitable or have chemical properties that are compatible with the biological system.

Why atoms interact and form bonds

As stated earlier protons and neutrons are tightly bound to one another in nucleus which seldom interacts with other atoms. Electrons are present outside the nucleus and undergo rearrangements. As electrons reside in specific orbital and there is a strict limit to the number of electrons that can be accommodated in an orbital of a given type so called **electron shell**. The shell closest to nucleus can accommodate a maximum of 2 electrons. The inner shell is also strongly attracted to the nucleus. The second shell is less tightly bound to nucleus and can hold up to eight electrons. Third shell can also hold 8 electrons, while 4th and 5th shell can hold 18 electrons each. The shell which is farthest from the nucleus is known as outermost shell or the valence shell and the number of electrons in this shell is known as **valence electrons**. Periodic table of elements shows the arrangement of elements in the table according to their atomic number. By looking at periodic table we can determine, how many electrons will be there in an outermost shell of an atom of a particular element. Elements in column 1A has a valency of 1 i.e. their outermost shell has one electron in it. While the elements in column VII A have 7 electrons in the outermost shell.

Elements of column 0 are known as noble gas or inert gas. They have 8 electrons in outermost shell thus have a completely filled outer shell and therefore they have a valency zero.



Source:http://upload.wikimedia.org/wikipedia/commons/3/39/Periodic_table_large.png CC)

How electrons occupy the space about the nucleus. Do they move around the nucleus at random, or do they exist in some ordered arrangement?
The modern theory of electron behavior is called **quantum mechanics**. It makes the following statements about electrons in atoms: • Electrons in atoms can have only certain specific energies. We say that the energies of the electrons are quantized. • Electrons are organized according to their energies into sets called **shells**. Generally **the higher the energy of a shell, the farther it is (on average) from the nucleus.** Shells do not have specific, fixed distances from the nucleus, but an electron in a higher-energy shell will spend more time farther from the nucleus than does an electron in a lower-energy shell. • Shells are further divided into subsets of electrons called **subshells**. The first shell

has only one subshell, the second shell has two subshells, the third shell has three subshells, and so on. The subshells of each shell are labeled, in order, with the letters *s*, *p*, *d*, and *f*. Thus, the first shell has only an *s* subshell, the second shell has an *s* and a *p* subshell, the third shell has *s*, *p*, and *d* subshells, and so forth.

- Different subshells hold a different maximum number of electrons. Any *s* subshell can hold up to 2 electrons; *p*, 6; *d*, 10; and *f*, 14.

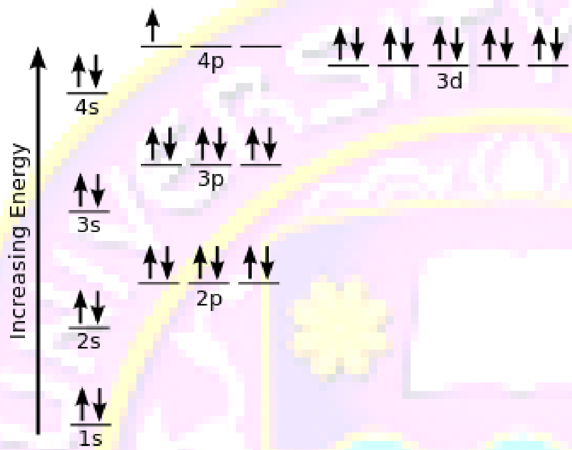


Figure: electronic configuration of gallium (Ga). It has 3 valence electrons and 28 core electrons.

Source: http://en.wikibooks.org/wiki/High_School_Chemistry/Electron_Configurations

We use numbers to indicate which shell an electron is in. The first shell, closest to the nucleus and with the lowest-energy electrons, is shell 1. This first shell has only one subshell, which is labeled *s* and can hold a maximum of 2 electrons. We combine the shell and subshell labels when referring to the organization of electrons about a nucleus and use a superscript to indicate how many electrons are in a subshell. Thus, because a hydrogen atom has its single electron in the *s* subshell of the first shell, we use $1s^1$ to describe the electronic structure of hydrogen. This structure is called an **electron configuration**. Electron configurations are shorthand descriptions of the arrangements of electrons in atoms. The electron configuration of a hydrogen atom is spoken out loud as “one-ess-one.”

Helium atoms have 2 electrons. Both electrons fit into the 1*s* subshell because *s* subshells can hold up to 2 electrons; therefore, the electron configuration for helium atoms is $1s^2$

(spoken as "one-ess-two").

The 1*s* subshell cannot hold 3 electrons (because an *s* subshell can hold a maximum of 2 electrons), so the electron configuration for a lithium atom cannot be $1s^3$. Two of the lithium electrons can fit into the 1*s* subshell, but the third electron must go into the second shell. The second shell has two subshells, *s* and *p*, which fill with electrons in that order. The 2*s* subshell holds a maximum of 2 electrons, and the 2*p* subshell holds a maximum of 6 electrons. Because lithium's final electron goes into the 2*s* subshell, we write the electron configuration of a lithium atom as $1s^22s^1$.

The next largest atom, beryllium, has 4 electrons, so its electron configuration is $1s^22s^2$. Now that the 2*s* subshell is filled, electrons in larger atoms start filling the 2*p* subshell. Thus, the electron configurations for the next six atoms are as follows:

B: $1s^22s^22p^1$

C: $1s^22s^22p^2$

N: $1s^22s^22p^3$

O: $1s^22s^22p^4$

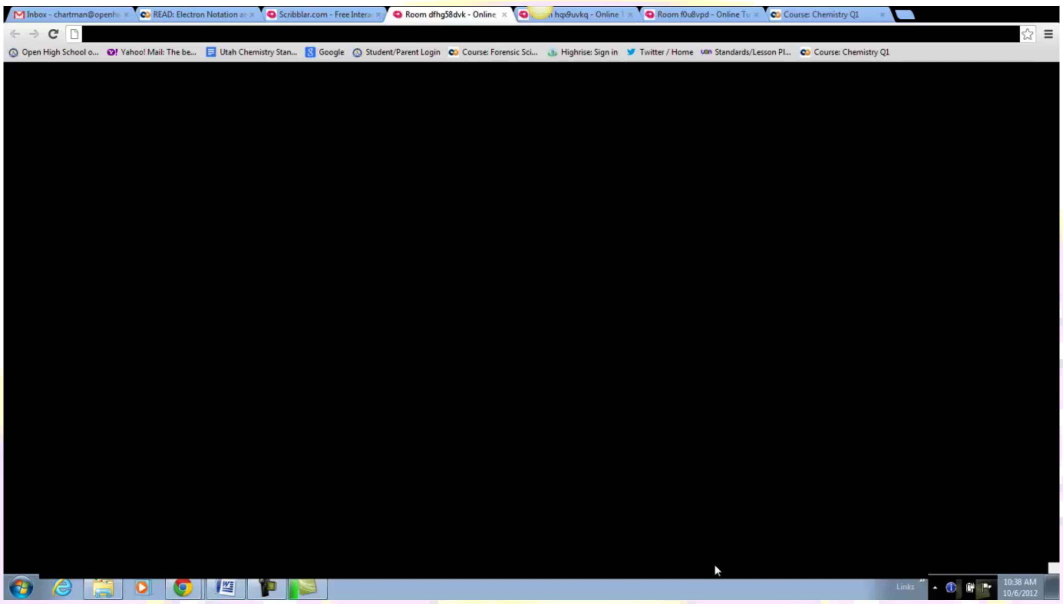
F: $1s^22s^22p^5$

Ne: $1s^22s^22p^6$

With neon, the 2*p* subshell is completely filled. Because the second shell has only two subshells, atoms with more electrons now must begin the third shell. The third shell has three subshells, labeled *s*, *p*, and *d*. The *d* subshell can hold a maximum of 10 electrons. The first two subshells of the third shell are filled in order—for example, the electron configuration of aluminum, with 13 electrons, is $1s^22s^22p^63s^23p^1$. However, a curious thing happens after the 3*p* subshell is filled: the 4*s* subshell begins to fill before the 3*d* subshell does. In fact, the exact ordering of subshells becomes more complicated at this point (after argon, with its 18 electrons), so we will not consider the electron configurations of larger atoms.

A fourth subshell, the *f* subshell, is needed to complete the electron configurations for all

elements. An *f* subshell can hold up to 14 electrons.
Source: http://2012books.lardbucket.org/books/introduction-to-chemistry-general-organic-and-biological/s05-06-arrangements-of-electrons.html



Video: How to find valance electrons on the periodic table.

Source: http://vimeo.com/50892319

An atom which has an unfilled outer electron shell is less stable than an atom whose electron shells are completely filled. Therefore atoms with incomplete outer shell have a strong tendency to interact with other atoms in a way that can cause them to either gain or lose enough electrons to achieve a completed outermost shell. The forces that hold atoms together are called **chemical bond**. Thus chemical bond is a manifestation of a force of attraction. The inert gas do not interact with other atoms as their outer electron shell is completely filled. Thus we see that atoms interact with each other to gain stability.

Types of bond

There are generally two strategies by which a chemical bond can form between atoms. Atom with incomplete outer shell can achieve stable configuration either by transferring electrons from one atom to another or by sharing electrons between two atoms. The transfer of electrons results in the formation of an ionic bond, while the sharing of electrons results in the formation of a covalent bond. Whether an atom will form an ionic bond or a covalent bond will depend upon the electronegativity and metallic/no metallic character of that atom. Electronegativity of an atom is defined as the ability of an atom to attract electrons in a bond. In a periodic table electronegativity increases from left to right and it decreases as we move top to bottom in a column. In general metallic elements have low electronegativity and non-metallic elements have high electronegativity. Two elements close to each other will have similar electronegativity. Elements in column 0 s have 0 electronegativity as they are stable.

Pauling Electronegativities of the Elements

in their most common states

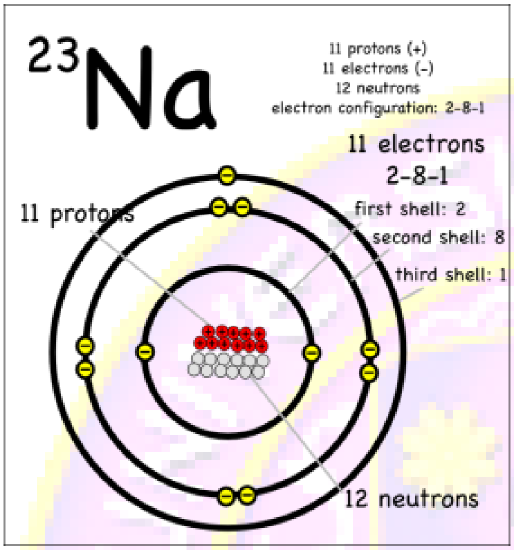
	1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	0
1	1 H 2.20																	2 He
2	3 Li 0.98	4 Be 1.57											5 B 2.04	6 C 2.55	7 N 3.04	8 O 3.44	9 F 3.98	10 Ne
3	11 Na 0.93	12 Mg 1.31											13 Al 1.61	14 Si 1.90	15 P 2.19	16 S 2.58	17 Cl 3.16	18 Ar
4	19 K 0.82	20 Ca 1.00	21 Sc 1.36	22 Ti 1.54	23 V 1.63	24 Cr 1.66	25 Mn 1.55	26 Fe 1.83	27 Co 1.88	28 Ni 1.91	29 Cu 1.90	30 Zn 1.65	31 Ga 1.81	32 Ge 2.01	33 As 2.18	34 Se 2.55	35 Br 2.96	36 Kr 3.00
5	37 Rb 0.82	38 Sr 0.95	39 Y 1.22	40 Zr 1.33	41 Nb 1.6	42 Mo 2.16	43 Tc 1.9	44 Ru 2.2	45 Rh 2.28	46 Pd 2.20	47 Ag 1.93	48 Cd 1.69	49 In 1.78	50 Sn 1.96	51 Sb 2.05	52 Te 2.1	53 I 2.66	54 Xe 2.60
6	55 Cs 0.79	56 Ba 0.89	57 La	72 Hf 1.3	73 Ta 1.5	74 W 2.36	75 Re 1.9	76 Os 2.2	77 Ir 2.20	78 Pt 2.28	79 Au 2.54	80 Hg 2.00	81 Tl 1.62	82 Pb 1.87	83 Bi 2.02	84 Po 2.0	85 At 2.2	86 Ra 2.2
7	87 Fr 0.7	88 Ra 0.9	89 Ac	104 Rf	105 Ha	106	107	108	109									

Figure: Electronegativity of elements in the periodic table

Source: www.uic.edu/classes/bios/bios100/lecturesf04am/lect02.htm

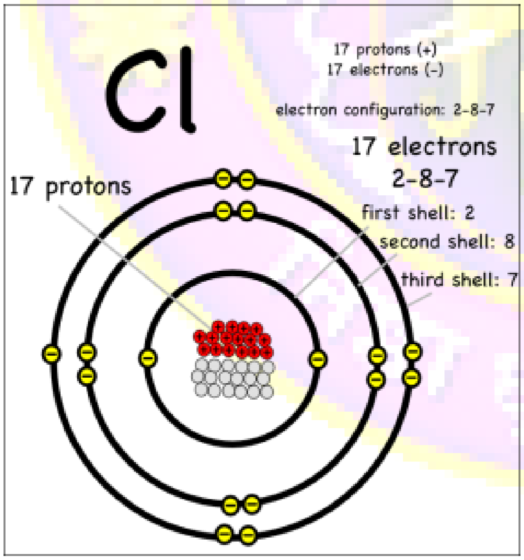
Ionic bond

Ionic bonds are formed by complete transfer of electrons from one atom to another. These bonds are formed most likely by the atoms that have just one or two electrons in the outermost shell in addition to a filled inner shell or are just one or two electrons short of acquiring a filled outer shell. Thus metals which have one or two electrons in outer shell forms ionic bond with the non-metals which are short of one or two electrons. Another criteria for ionic bond is that the electronegativity difference between the two atoms should be more than 1.8. For example a sodium (Na) atom, with atomic number 11, has one electron in its outermost shell, it can attain a filled shell configuration by giving up this single electron.



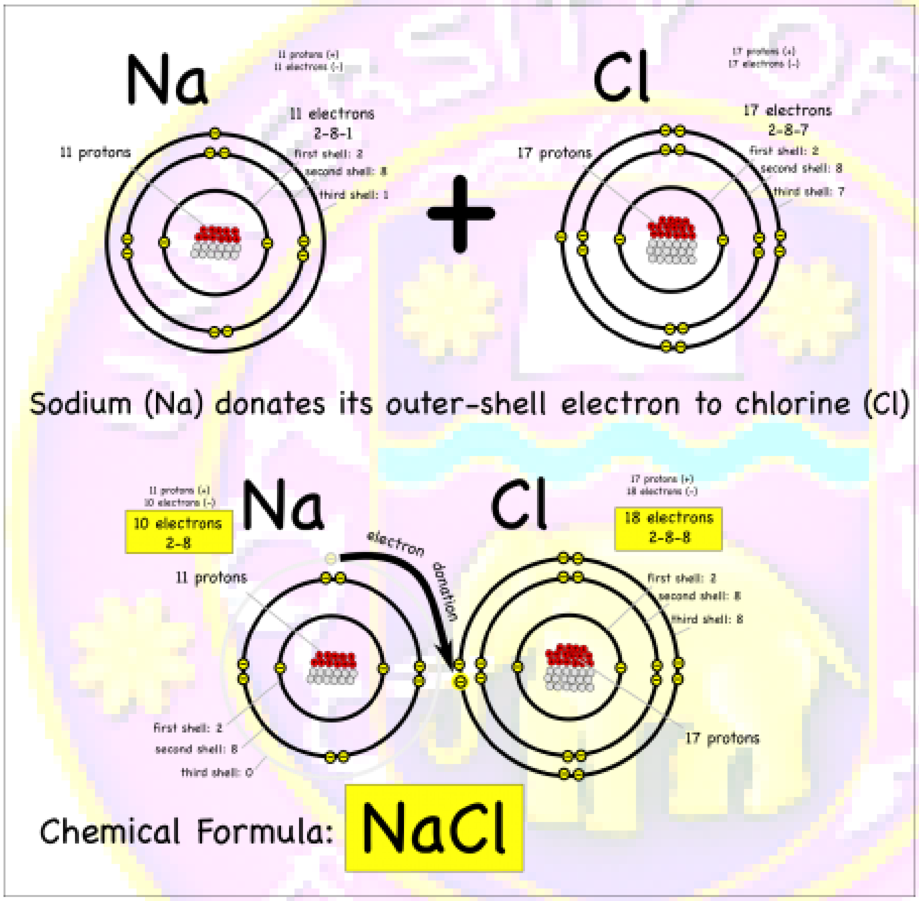
Source: http://montessorimuddle.org/2013/02/21/an-introduction-to-ionic-bonding/ (CC)

By contrast, a chlorine (Cl) atom, with atomic number 17, can complete its outer shell by gaining just one electron.



Source: http://montessorimuddle.org/2013/02/21/an-introduction-to-ionic-bonding/ (CC)

Thus when a Na atom encounters a Cl atom, an electron from the Na atom can jump to the Cl and both the atoms will have completed outer shells. Because of large electronegativity difference between the two atoms (2.1) chlorine is able to completely pull the electrons from the sodium. When Na atom gives an electron it becomes positively charged and is known as cation while the chlorine atom after accepting one electron becomes negatively charged and known as anion. Because of their opposite charges Na^+ and Cl- are attracted to each other and are held together in an ionic bond.



Source: http://montessorimuddle.org/2013/02/21/an-introduction-to-ionic-bonding/(CC)

The properties of the compound are completely different from the individual atoms. Sodium is a metal while chlorine is a toxic gas but when these two combines they result in the formation of non toxic table salt.

Source:http://chemistry4gcms2011.wikispaces.com/Chemical+Bonding(Peavy)

Other examples of ionic compounds are Magnesium chloride, Sodium fluoride, Potassium nitrite etc. When ionic compounds are dissolved in water they completely dissociates into their constituent ions each surrounded by several water molecules.

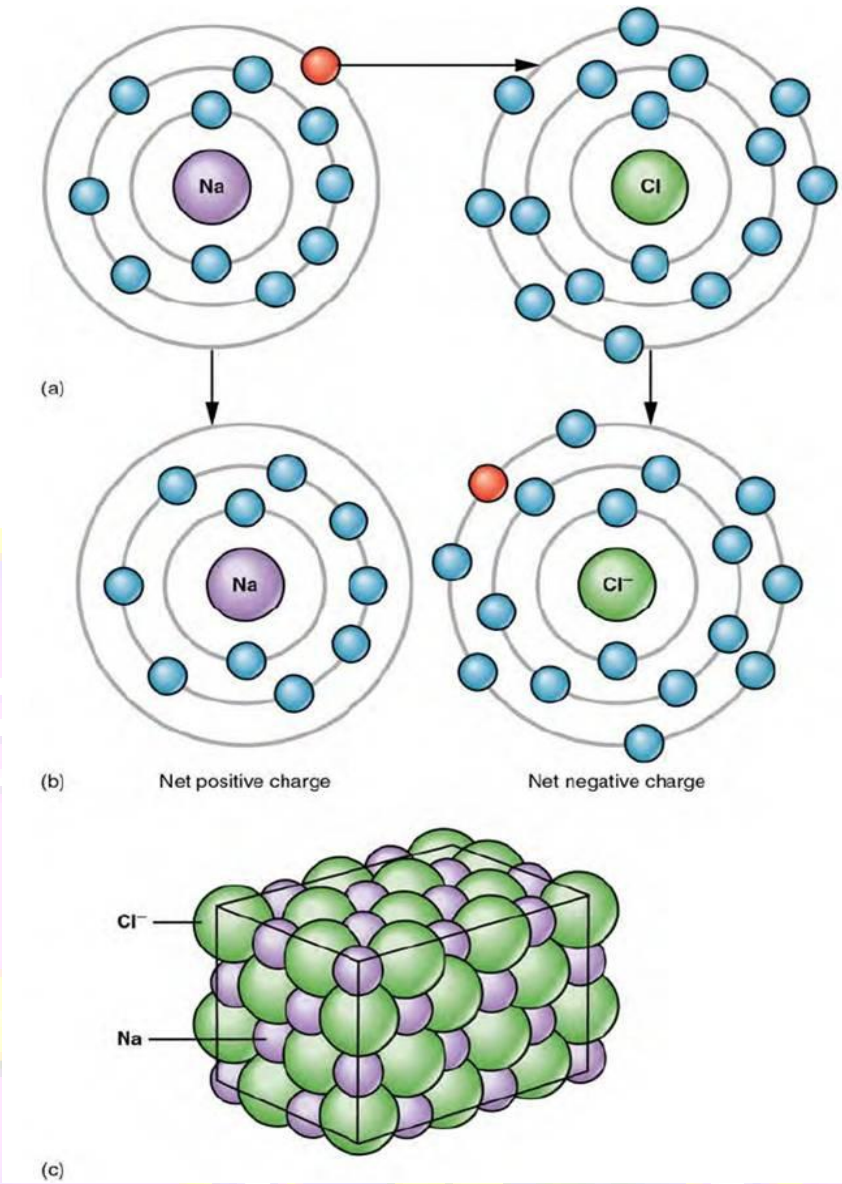
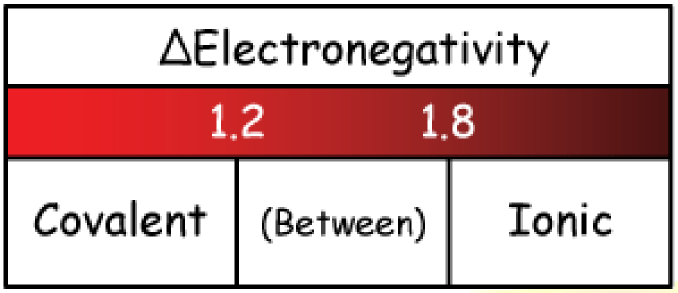


Figure: Ionic bond formation between sodium and chloride

Source: Openstax college, anatomy and physiology. Open stax college.19 june 2103.<http:/cnx.org/content/col11496/latest/> (CC)

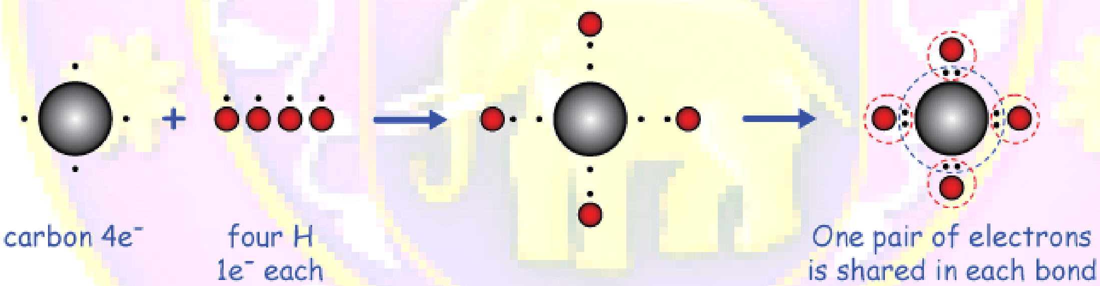
Covalent bond

Covalent bond is formed when electrons are shared between atoms to complete the outer shell rather than being transferred between them. When the electronegativity difference between the two atoms is less than 1.8 they forms a covalent bond.



Source: http://www.drcruzan.com/CovalentBonding.html (CC)

Covalent bonding occurs between atoms which are unable to donate or accept electron to complete their outermost shell and therefore shared electrons to have a stable configuration. For example carbon has four electrons in its valence shell and it can share its four electrons with four hydrogen molecule which need only one electron to complete its outer shell to form a molecule of methane. Whereas an H atom can form single covalent bond because it has only one electron in its outer shell, the other common atoms that form bond in the cells- O,N,S and as well as all important C atom can form more than one covalent bond. The outermost shell of these atoms as we have seen can accommodate up to eight electrons and they form covalent bonds with as many as other atoms as necessary to complete their outer shell.



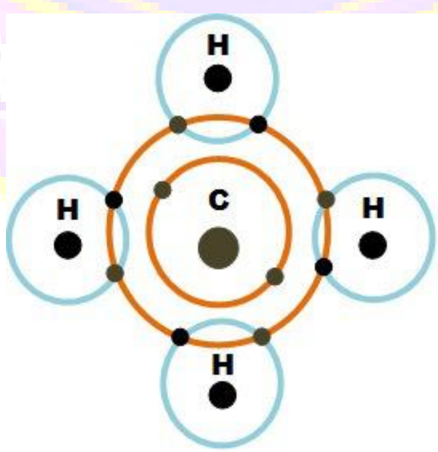


Figure: A molecule of methane in which carbon atom is forming single covalent bond with four hydrogen atoms

Source: http://www.drcruzan.com/CovalentBonding.html (CC);
http://bsclarified.wordpress.com/2011/09/20/would-you-wear-a-graphite-ring/

More than one electron can be shared between atoms to complete their outermost shell. A double bond is formed when two electrons from each atom is shared while a triple bond is formed when three electrons are shared between two atoms. Double bond and triple bonds are stronger than the single bond.

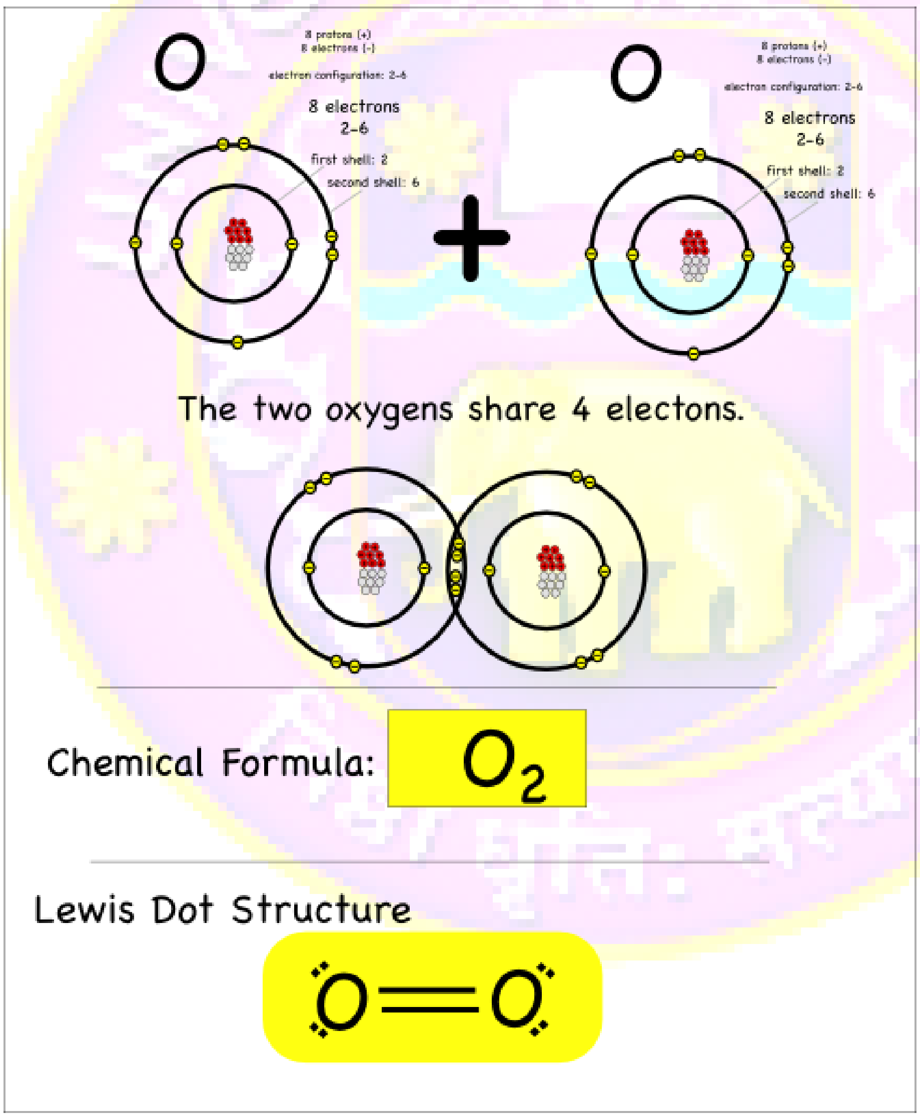


Figure: A molecule of oxygen formed by sharing of two electrons from each atom forming a double bond

Source: http://montessorimuddle.org/wp-content/uploads/2013/02/Oxygen-gas-490.png

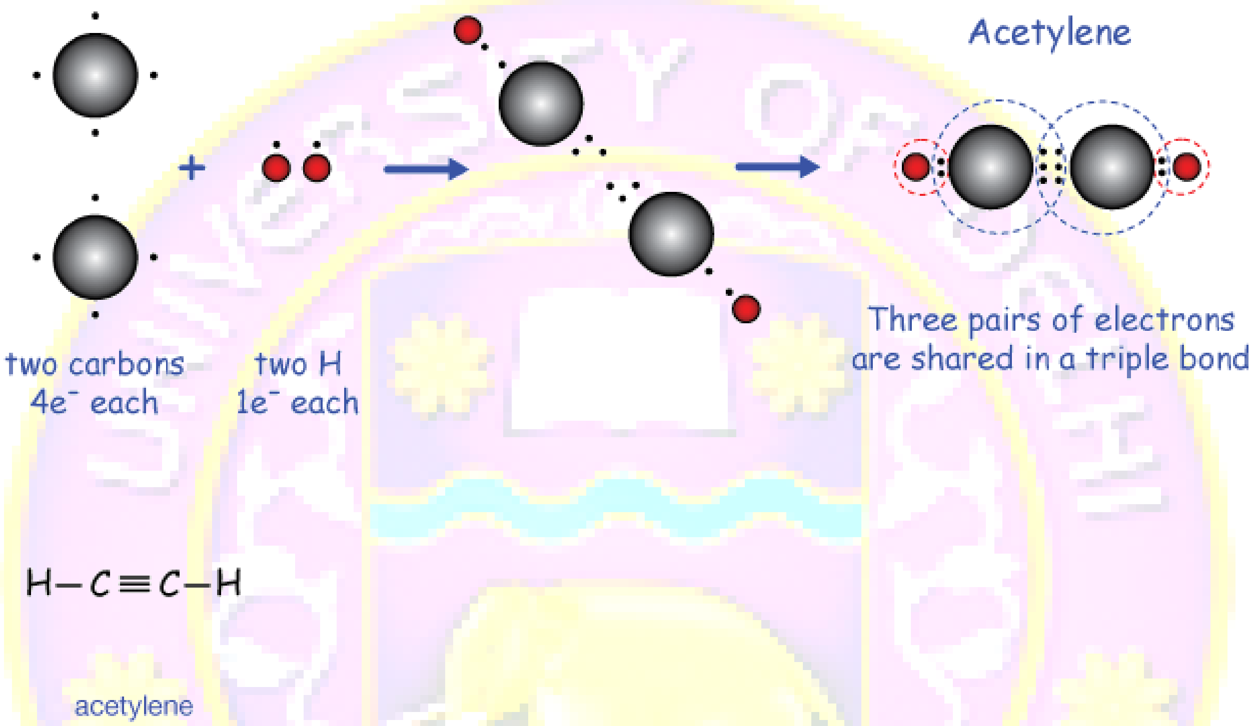


Figure: Acetylene molecule is formed when carbon shares three of its electrons with another carbon atom while the fourth one with the hydrogen atom, as a result each of the atom now has a completely filled outer shell.

Source:http://www.drcruzan.com/Images/Chemistry/CovalentBonding/CarbonToAcetyleneReaction.png

The shared electrons of the two atoms form a cloud of negative charge which is densest between the two positively charged nuclei and helps to hold them together, in opposition to the mutual repulsion between like charges that would otherwise force them apart. These attractive and repulsive forces are balanced when the two nuclei are separated by a particular distance. This distance is defined as bond length. Thus covalent bonds between two particular atoms have a specific bond length. Another important property of a bond (covalent or non covalent) is its strength. Bond strength is measured by the amount of energy that must be supplied to break the bond.

When one atom forms covalent bonds with several other, these bonds have definite orientation in space relative to one another. Covalent bonds between multiple atoms are therefore characterized by specific bond angles as well as bond lengths and bond energies.

Polar covalent bond

Polar covalent bond is formed when there is unequal sharing of electrons between the two atoms in a covalent bond.

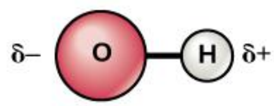
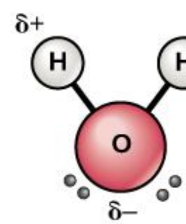
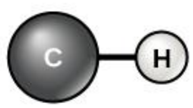
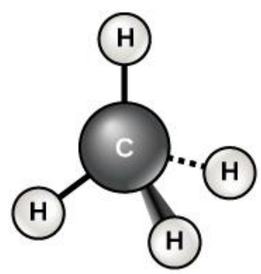
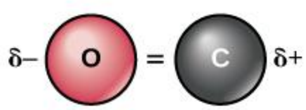
	Bond type	**Molecular shape**	**Molecular type**
Water	 Polar covalent	 Bent	Polar
Methane	 Nonpolar covalent	 Tetrahedral	Nonpolar
Carbon dioxide	 Polar covalent	 Linear	Nonpolar

Figure: Types of covalent bond.

Source: https://www.boundless.com/image/fig-ch02_01_11/ (CC)

As discussed earlier that elements in the periodic table have different electronegativity (ability to attract electrons).When two different atoms are bonded covalently the shared electrons are attracted to the more electronegative atom of the bond, resulting in a shift of electron density towards the more electronegative atom. Such a covalent bond is known as polar covalent bond and will have a dipole (one end is positive and the other end is negative).

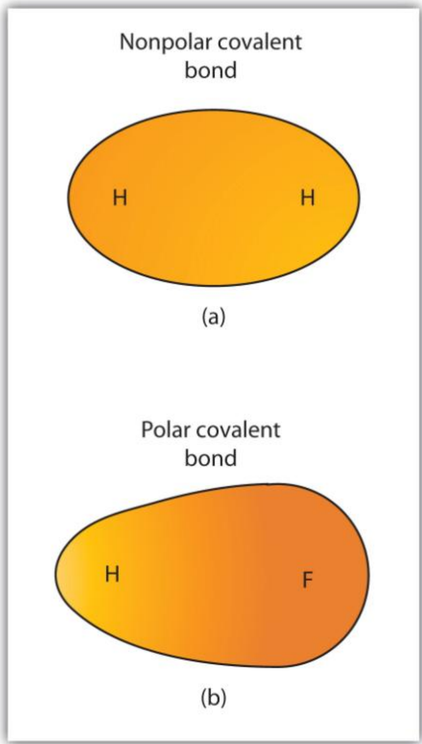


Figure: (a) The electrons in the covalent bond are equally shared by both hydrogen atoms. This is a nonpolar covalent bond. (b) The fluorine atom attracts the electrons in the bond more than the hydrogen atom does, leading to an imbalance in the electron distribution. This is a polar covalent bond.

Source: http://2012books.lardbucket.org/books/introduction-to-chemistry-general-organic-and-biological/s07-04-characteristics-of-covalent-bo.html (CC)

Water is a good example of a polar covalent bond, as oxygen is more electronegative than hydrogen it attracts the electrons from the shared pair and thus has a partial negative charge on it while the hydrogen atom will have a slightly positive charge. The degree of polarity and magnitude of the bond dipole will be proportional to difference in electronegativity of the bonded atoms. The charges on the atoms are written as delta plus and delta minus to differentiate it from the cations and anions.

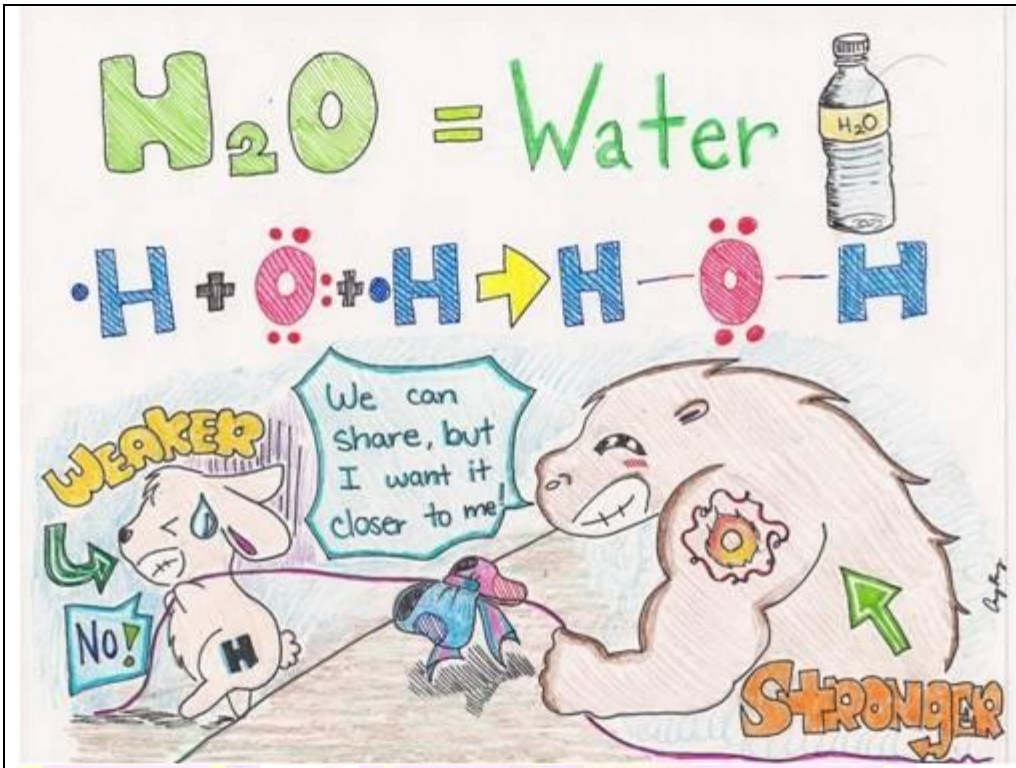
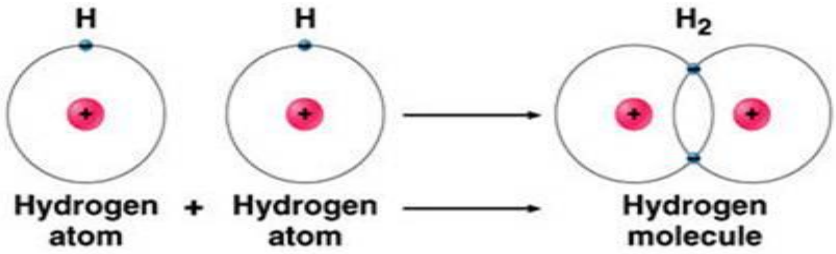


Figure: Oxygen is the big buff creature with the tattoo of "O" on its arm. The little bunny represents a Hydrogen atom. The blue and red bow tied in the middle of the rope, pulled by the two creatures represents - the shared pair of electrons--a single bond. Because the Hydrogen atom is weaker, the shared pair of electrons will be pulled closer to the Oxygen atom.

Source:http://chemwiki.ucdavis.edu/Theoretical_Chemistry/Chemical_Bonding/General_Principles/Covalent_Bonds (CC)

Non polar covalent bond

Non polar covalent bonds are formed between same atoms or atoms which have a very small difference in the electronegativity. The electrons are shared equally between the two partners and the bond is non polar covalent bond. For example H_2, O_2.



Source:http://legacy.owensboro.kctcs.edu/gcaplan/bio/notes/BIO%20Notes%20C%20Molecules%20and%20Compounds.htm

Intermolecular attraction

Hydrogen Bond

A hydrogen bond is formed when a partially positively charged hydrogen atom already bonded to one electronegative atom (for example, the oxygen in the water molecule) is attracted to another electronegative atom from another molecule. A hydrogen bond always involves a hydrogen atom in a covalent linkage with a more electronegative atom such as oxygen, nitrogen and fluorine. When hydrogen atom forms a covalent bond with a very electronegative atom such as oxygen and nitrogen there is a partial positive charge on the hydrogen atom because of difference in electronegativity. This partially positive charged hydrogen atom is electrostatically to another more electronegative atom having a lone pair of electrons (electrons not involved in covalent bonding) of the same or other molecule. Water is a very good example of hydrogen bonding.

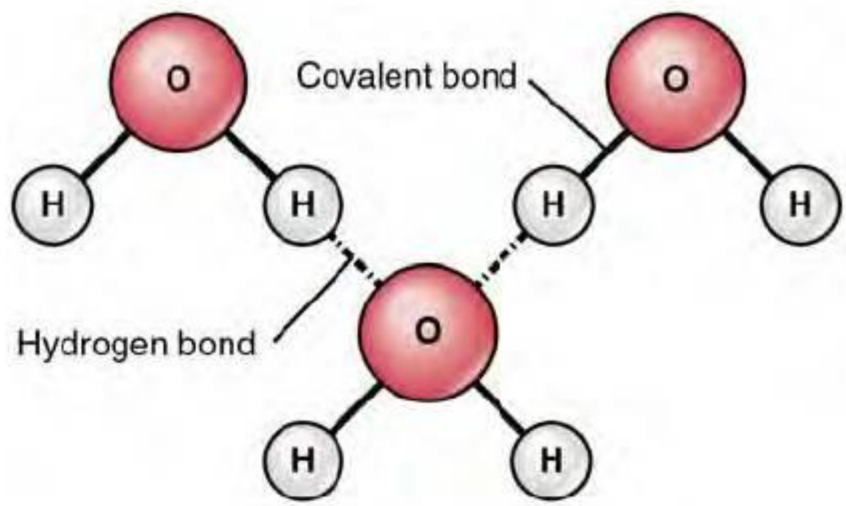


Figure: Molecules of water are joined to one another by hydrogen bonds

Source: Openstax college, anatomy and physiology. Open stax college.19 june 2103.<http:/cnx.org/content/col11496/latest/>

Hydrogen bond is weaker than a covalent bond and an ionic bond but multiple hydrogen bonding between molecules has significant effect on the properties of that molecule. The extensive hydrogen bonding between water molecules accounts for many of the key properties of this compound, including its unusually high melting and boiling points and its ability to interact with many other molecules. In general, molecules with polar bonds that easily form hydrogen bonds with water can readily dissolve in water; that is, they are hydrophilic. Hydrogen bonds are of great significance in the living world, these bonds are important for maintaining the structure of various biomolecules. For example, hydrogen bonding between amino acids in a linear protein determines the way it folds up into its functional configuration. Similarly hydrogen bonding between the nucleotides of two DNA molecules gives rise to the double helical structure of DNA which is very important for the transmission of genetic information. Hydrogen bonding is also the basis for various kinds of interaction that occur in the biological world such as enzyme substrate interaction, antigen antibody interaction, DNA protein interaction.

Dipole-Dipole interaction

There are several molecules which exists as electric dipoles i.e. they have a net negative charge on one part of the molecule and net positive charge on another part of molecule. Therefore when these molecules come together the opposite charges attract each other among different molecules while the like charge would repel. Therefore these kinds of interaction help molecules to arrange in a three dimensional structure such that the repulsion is less and attraction is more. Dipole- Dipole interactions are weaker than hydrogen bonds which is a special kind of Dipole interaction which involves hydrogen in linkage with oxygen, nitrogen and fluorine only.

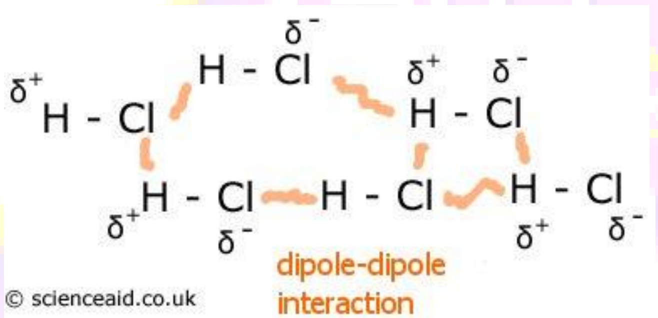


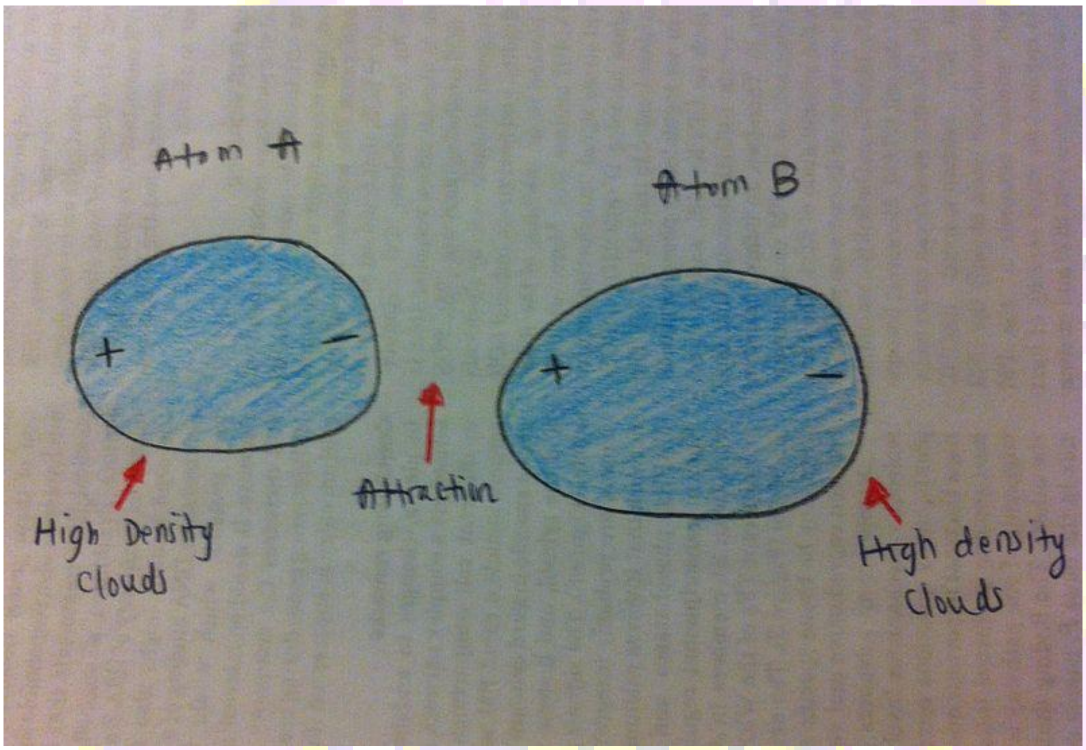
Figure: Dipole interaction between hydrogen chloride molecules. Hydrogen has a partial positive charge while chlorine has a partial negative charge. These opposite charges attract each other and keeps the molecules together.

Source: http://scienceaid.co.uk/chemistry/fundamental/inter.html

Van der Waals Interactions

Van der Waals attraction are very weak attraction between two molecules in close proximity with each other whether polar or non polar. These intermolecular forces are named after dutch physicist Johannes van der Waals, who first postulated these forces in 1873. These nonspecific interactions result from the momentary random fluctuations in the distribution of the electrons of any atom, giving rise to a transient unequal distribution of electrons. When two non covalently bonded atoms come close together, electrons of one atom perturbs the electrons of the other resulting in the generation of transient dipole in other atom. These dipole than attract each other weakly. Similarly, a polar covalent bond in one molecule will attract an oppositely oriented dipole in another.

The strength of van der Waals interactions decreases as the distance is increased between two atoms; thus these non covalent bonds can form only when atoms are quite close to one another. However, if atoms get too close together, they become repelled by the negative charges of their electrons. When the van der Waals attraction between two atoms exactly balances the repulsion between their two electron clouds, the atoms are said to be in van der Waals contact. The strength of the van der Waals interaction is about 1 kcal/mol, weaker than typical hydrogen bonds and only slightly higher than the average thermal energy of molecules at 25 ºC. Thus multiple van der Waals interactions, a van der Waals interaction in conjunction with other noncovalent interactions, or both are required to significantly influence intermolecular contacts.



Source: http://commons.wikimedia.org/wiki/File:VanderwaalsAttraction.JPG

Hydrophobic interaction

As non polar molecules molecules do not contain charged groups, or have a dipole moment, they cannot be hydrated by the water molecules. These non-polar molecules are therefore insoluble or almost insoluble in water; that is, they are hydrophobic. Therefore in a polar environment these on polar molecule or the non-polar portion of the molecule tends to aggregate with each other and the effect is known as hydrophobic effect. The interaction between these nonpolar molecules are called hydrophobic interaction. Rather than constituting an attractive force such as in hydrogen bonds, the hydrophobic effect results from an avoidance of an unstable state (extensive water cages around individual nonpolar molecules). There are some van der wall interactions also among non polar molecules. The net result of these interaction (hydrophobic and van der wall) is strong tendency of these molecules to stick with each other and not with water molecule. These hydrophobic interactions are the basis for the folding of protein in the three three dimensional structure or formation of phospholipid bilayer.

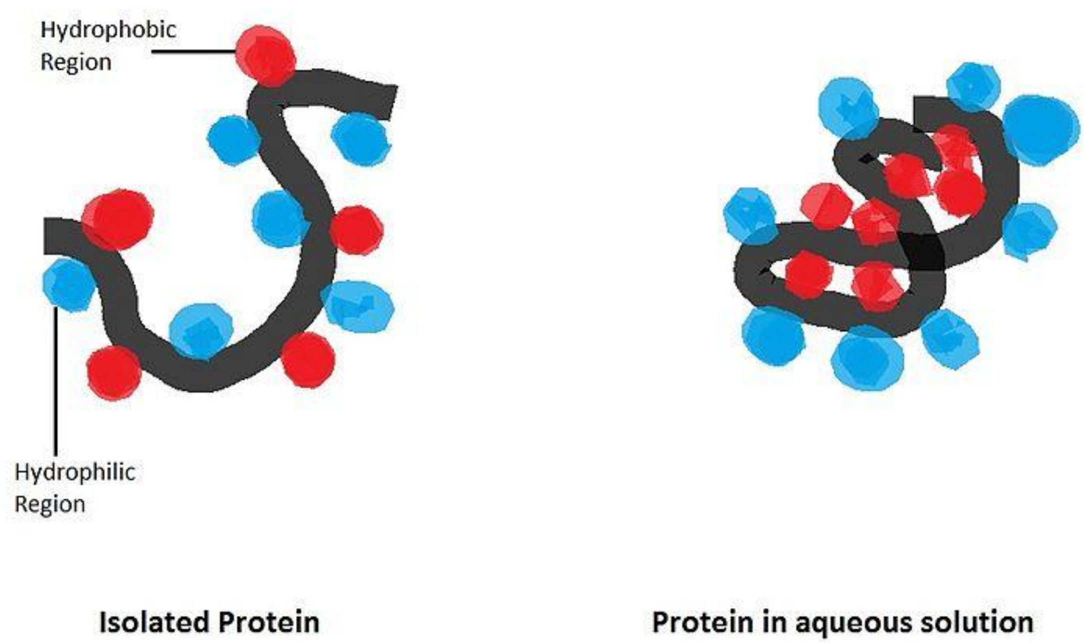


Figure: Hydrophobic interaction between the hydrophobic region of proteins derives the protein to fold in its three dimensional structure

Source:http://upload.wikimedia.org/wikipedia/commons/5/50/Cartoon_of_protein_hydrophobic_interaction.jpg

Significance of chemical bonds

Chemical bonds helps to keep the atoms together resulting in various comounds which are required in day to day life. These bonds are very important for the living systems. Biomolecules such as carbohydrate, proteins and nucleic acid are polymers of monomeric units which have atoms joined by the covalent bonds. Other than the covalent bonds, non covalent interactions plays very important role in the biological system. These non covalent interactions are necessary for maintaining the three dimensional structure of the biomolecules. Each non covalent interaction by itself is weak however when several of these interaction are present they governs the several biological processes.

Summary

- Formation of bonds between different atoms depends upon their valence electrons.
- Complete transfer of an electron from one atom to another results in the formation of an ionic bond between the two atom.
- Covalent bond formation between two atoms occurs by sharing of electrons between the two atoms. More than one electron pair could be shared among atoms leading to double and triple bond formation.
- Covalent bond can be polar or non polar depending on the electronegativity of two atoms forming the covalent bond
- Weak intermolecular bonds are formed between atoms of different molecule these include van der wall interaction, Hydrogen bond, Dipole – Dipole interaction and hydrophobic interaction.
- Non covalent weak interactions are important for maintaining the three dimensional structure of biological molecules such as DNA and protein.

Glossary

Atom: smallest unit of an element that retains the unique properties of that element

Atomic number: number of protons in the nucleus of an atom

Anion: atom with a negative charge

Bond: electrical force linking atoms

Cation: atom with a positive charge

Covalent bond: chemical bond in which two atoms share electrons, thereby completing their valence shells

Electron: subatomic particle having a negative charge and nearly no mass; found orbiting the atom's nucleus

Hydrogen bond: dipole-dipole bond in which a hydrogen atom covalently bonded to an electronegative atom is weakly attracted to a second electronegative atom

Ionic bond: attraction between an anion and a cation

Mass number: sum of the number of protons and neutrons in the nucleus of an atom

Neutron: heavy subatomic particle having no electrical charge and found in the atom's nucleus

Proton: heavy subatomic particle having a positive charge and found in the atom's nucleus

Valence shell: outermost electron shell of an atom

Exercises

1. Can two atoms of oxygen engage in ionic bonding? Why or why not?
2. How does octet rule applies to covalent bond
3. What property of the two atoms in a covalent bond determines whether or not the bond will be polar?
4. Hydrogen bond is a weak bond yet it plays an important role in the double stranded DNA molecule. Explain?
5. How hydrophobic interaction drives the folding of proteins?

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