Chapter 2
Chemical Bonding

What is Chemical Bonding?

- Chemical Bonding refers to the formation of a chemical bond between two or more atoms, molecules, or ions to give rise to a chemical compound. These chemical bonds are what keep the atoms together in the resulting compound.
- The attractive force which holds various constituents (atom, ions, etc.) together and stabilizes them by the overall loss of energy is known as chemical bonding. Therefore, it can be understood that chemical compounds are reliant on the strength of the chemical bonds between its constituents; The stronger the bonding between the constituents, the more stable the resulting compound would be.
- The opposite also holds true; if the chemical bonding between the constituents is weak, the resulting compound would lack stability and would easily undergo another reaction to give a more stable chemical compound (containing

stronger bonds). To find stability, the atoms try to lose their energy.

- Whenever matter interacts with another form of matter, a force is exerted on one by the other. When the forces are attractive in nature, the energy decreases. When the forces are repulsive in nature, the energy increases. The attractive force that binds two atoms together is known as the chemical bond.

- When an atom's outer electron shell is completely full, it is stable and will not react with other atoms.
- All of the Noble Gases are inert, and will not naturally react with other elements.
- However when an atoms' outermost shell is not completely filled, it is unstable hence it reacts with other atoms.
- A chemical Bond may be defined as the force of attraction between any two atoms in a molecule, to maintain stability.
- There are three types of Chemical Bonds:

- Electrovalent(ionic) Bond is formed as a result of the transfer of electrons from one atom of an element to one atom of another element.
  2) Covalent Bond: The chemical bond formed between two combining atoms by mutual sharing of one or more pairs of electrons. Compound formed due to this bond is called covalent compound.
  3) Coordinate bond is the bond formed between two atoms by sharing a pair of electrons, provided entirely by one of the combining atoms but shared by both .

- Introduction of Ionic Bond

- Ionic bond is a kind of chemical bond which involves an electrostatic attraction between two oppositely charged ions because of the complete transfer of valence electrons between them. As for example: metals such as sodium losses electrons to to become positive ion, whereas non-metal such as chlorine accepts electrons to become a negative ion. The metal that gives electrons is called donor and the non-metal that accepts electrons is called acceptor.

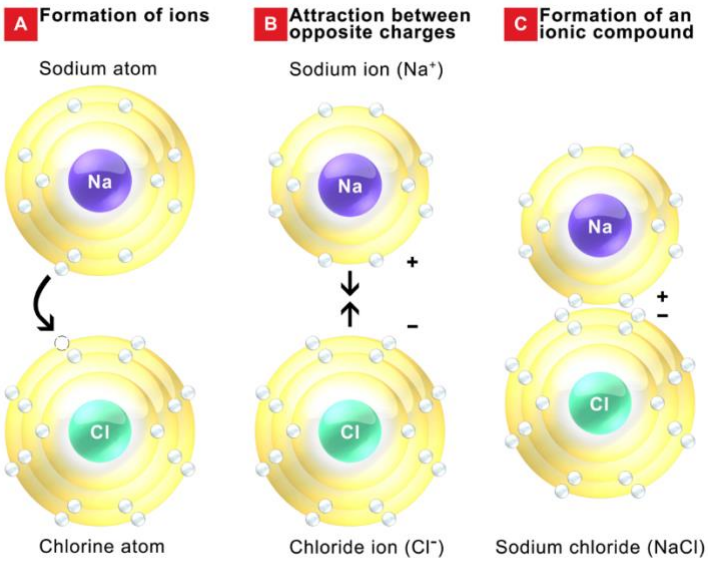
- Formation

- Ionic bond occurs between metals and non-metals because the metals have only few electrons in its outermost shell. Thus it likes to give away these electron to achieve the noble gas configuration and satisfy the octet rule. The number of electrons, a metal loses is the number of positive charge it achieves to form the ionic bond.

- On other hand to fulfill the octet rule, non metals accepts the electrons and charged negatively. The number of electrons it accepts, is the number of negative charge it gains. As a result an electrostatic force occurs between these two oppositely and equally charged atoms to form an ionic bond.

- Example

- Sodium losses an electron to get positive charge and chlorine accepts that electron to achieve a negative charge. An electrostatic force holds these to atoms to together in a crystallographic lattice. Thus sodium chloride is formed.



- **Formation of an Ionic Bond**

- Another example of ionic bond is the formation of magnesium chloride by transferring two electrons from a magnesium atom to two chlorine atoms.

- $Mg + Cl2 \rightarrow Mg2+ + 2Cl– \rightarrow MgCl2$
- Stability of ionic compound

- Stability of an ionic compound depends on:

- The ionization energy
- Electron affinity
- The lattice energy
- Electronegativity

- The ionization energy (IE)

- The ionization energy is the energy required to remove a valence electron from the outermost shell of a metal atom. This required energy should be low to form an ionic bond.

- $A + IE \rightarrow A^+ + e^-$
- Electron Affinity (EA)

- Electron affinity (EA) is the energy released when an electron is added to a neutral atom in its gaseous state. To form an ionic bond, the electron affinity of a non metal atom should be high. So that the atom will have more tendency to accept the electron to release more energy to the nature and to become more stable ionic compound.

- $B + e^- \rightarrow B + EA$
- Lattice Energy (LE)

- To form ionic compound the lattice energy should be high.

- $A^+ + B^- \rightarrow AB + LE$

- Electronegativity

- The difference in electronegativity between the metal and non metal should be high enough to form an ionic compound. For example, the electronegativity of Sodium and chlorine in sodium chloride is:

- Na = 0.9 and Cl = 3.0.

- Here the difference is large enough to make an ionic compound.

- Properties of ionic bond

- Ionic bond has a very characteristic properties which can differentiate them from the covalent bond.

- Physical properties

- Ionic bonds are polar in nature.
- Ionic bond is stronger than covalent bond.
- Compounds with ionic bonds are mostly solid at room temperature.

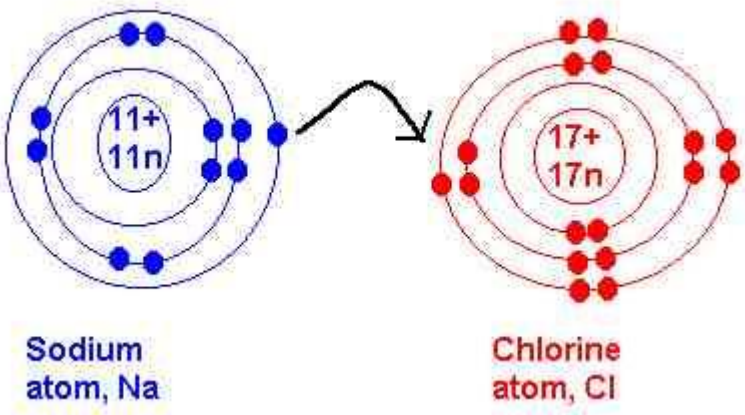
- Solid compounds with ionic bonds form lattice structure.
- It has high melting point and boiling point.
- Ionic compounds can conduct electricity only when it is melted or in aqueous solution.
- These are soluble in water and other polar solvent.
- They are not soluble in any non polar solvent.
- Chemical properties

- Ionic compounds are not reactive in its solid state.
- Ionic compounds show ionic reactions in aqueous solution.
- It is very reactive to other ionic compounds in aqueous solution.

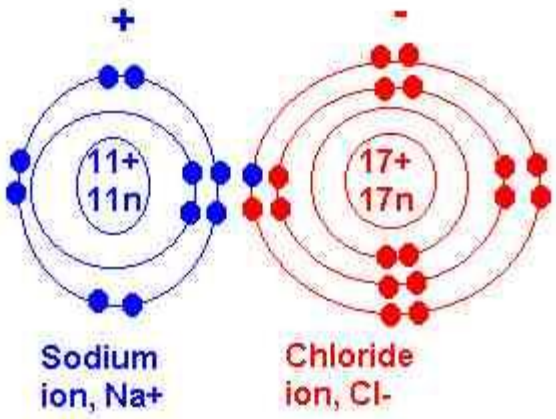
- Ionic bond formation in sodium chloride
- A sodium atom donates a valence electron to a chlorine atom to form a sodium ion and a chloride ion.
- A sodium atom has the electron configuration $1s^2\ 2s^2 2p^6\ 3s$. It can gain a noble

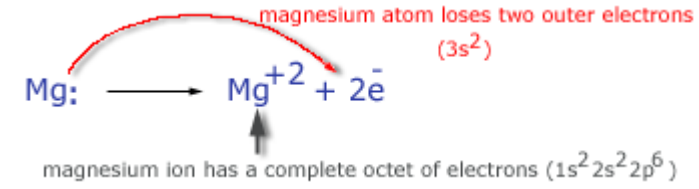
gas (s^2p^6) configuration by losing the 3s electron.

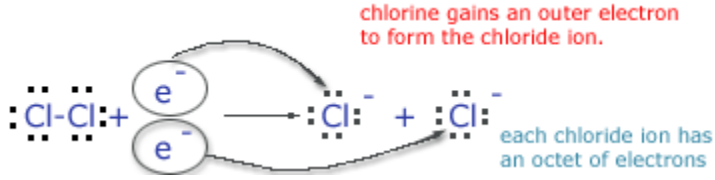
- A chlorine atom has the electron configuration $1s^2\ 2s^22p^6\ 3s^23p^5$. It can achieve a noble gas configuration by gaining an electron.
- If Na gives an electron to Cl, we get an Na^+ ion and a Cl^- ion. Each ion has a noble gas configuration.

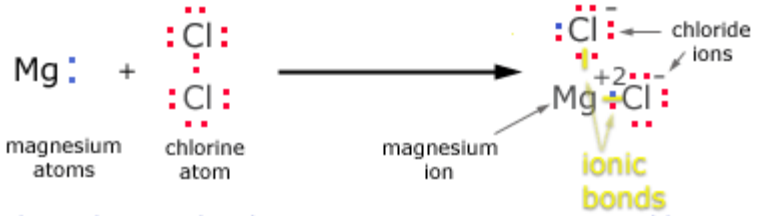


- The positive and negative ions attract each other to form the ionic bonds in sodium chloride.



- Ionic bond formation of magnesium chloride
- Mg forms ionic bond to Cl by donating its valence electrons to two Cl atoms.
- The electron configuration of Mg is $[Ne]3s^2$. It can achieve a complete octet by losing its two valence electrons to form Mg^{2+}.
- 

- The electron configuration of Cl is $[Ne]3s^23p^5$. It can achieve an octet by gaining one valence electron to form Cl^-.
- 

- The oppositely charges of the magnesium and chloride ions attract each other and form ionic bonds.
- 

The 2 electrons lost by a magnesium atom are gained by chlorine atoms to produce a magnesium ion and 2 chloride ions.
- Covalent bond

- A covalent bond in chemistry is a chemical link between two atoms or ions in which the electron pairs are shared between them. A covalent bond may also be termed a molecular bond. Covalent bonds form between two nonmetal atoms with identical or relatively close electronegativity values. This type of bond may also be found in other chemical species, such as radicals and macromolecules. The term "covalent bond" first came into use in 1939, although Irving Langmuir introduced the term "covalence" in 1919 to describe the number of electron pairs shared by neighboring atoms.

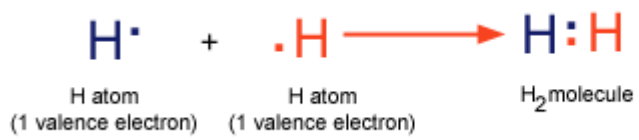
- The electron pairs that participate in a covalent bond are called bonding pairs or shared pairs. Typically, sharing bonding pairs allows each atom to achieve a stable outer electron shell, similar to that seen in noble gas atoms.
- Polar and Nonpolar Covalent Bonds
- Two important types of covalent bonds are nonpolar or pure covalent bonds and polar covalent bonds. Nonpolar bonds occur when atoms equally share electron pairs. Since only identical atoms (having the same

electronegativity) truly engage in equal sharing, the definition is expanded to include covalent bonding between any atoms with an electronegativity difference less than 0.4. Examples of molecules with nonpolar bonds are H2, N2, and CH4.

- As the electronegativity difference increases, the electron pair in a bond is more closely associated with one nucleus than the other. If the electronegativity difference is between 0.4 and 1.7, the bond is polar. If the electronegativity difference is greater than 1.7, the bond is ionic.
- Covalent Bond Examples
- There is a covalent bond between the oxygen and each hydrogen in a water molecule (H2O). Each of the covalent bonds contains two electrons, one from a hydrogen atom and one from the oxygen atom. Both atoms share the electrons.
- A hydrogen molecule, H2, consists of two hydrogen atoms joined by a covalent bond. Each hydrogen atom needs two electrons to achieve a stable outer electron shell. The pair of electrons is attracted to the positive charge of both atomic nuclei, holding the molecule together.

- Phosphorus can form either PCl3 or PCl5. In both cases, the phosphorus and chlorine atoms are connected by covalent bonds. PCl3 assumes the expected noble gas structure, in which the atoms achieve complete outer electron shells. Yet PCl5 is also stable, so it's important to remember covalent bonds in chemistry don't always abide by the octet rule.
- Formation of hydrogen molecule by covalent bond

- Each H atom has 1 valence electron.
- When two H atoms react, they share a pair of electrons. In the sharing of a pair of electrons a



chemical bond is formed. Because the bond involves sha ring of electrons, it is called a covalent bond.

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- The driving force behind the formation of a H2 molecul e is that in the sharing arrangemen t, each H atom in the
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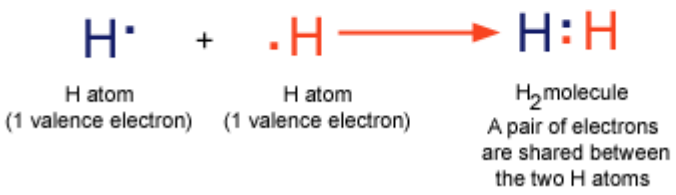
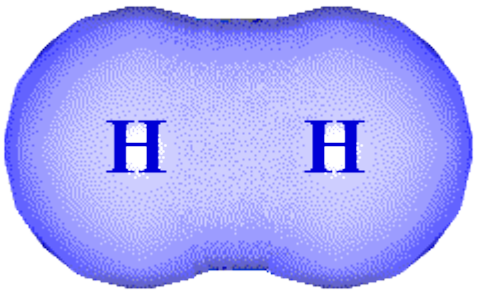


H2 molecule is able to achieve a stable arrangement of a filled shell.
Put your mouse over and click on the image on the right to have a closer look.

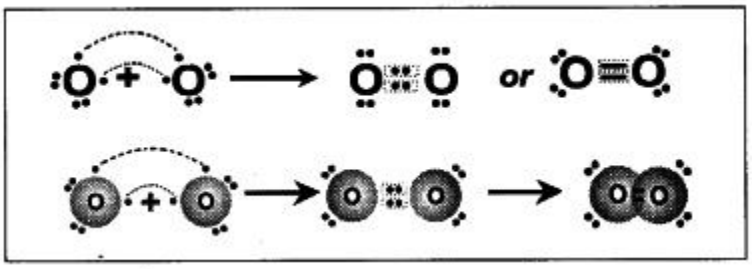
- Electrons are not really dots. Let's take a look at another look at this covalent bond in the following representation of electrons.

- 

- This is a representation of the electron cloud about the hydrogen atoms. The identical electron clouds about each hydrogen atom indicate that in the hydrogen molecule, the electrons are shared equally between the two hydrogen nuclei because both H atoms have the same electronegativity. The bond that forms between the hydrogen nuclei is said to be a nonpolar covalent bond

- Formation Of Double Bond (Oxygen Molecule)

- Two oxygen atoms combine to form oxygen molecule by sharing two electron pairs. Each oxygen atom (2, 6) has six electrons in the valence shell. It required two electrons to acquire nearest noble gas configuration. Therefore, both the atoms contribute two electrons each for sharing to form oxygen molecule. In the molecule, two electron pairs are shared and hence there is a double bond between the oxygen atoms



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- Formation of triple bond (Nitrogen molecule)

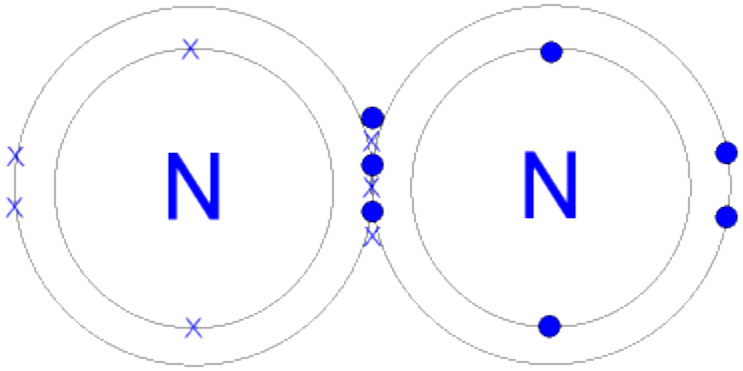
- Nitrogen is a non-metal.

A nitrogen atom has 5 electrons in its outer shell.

Nitrogen is in group 5 of the periodic table.

Two nitrogen atoms will each share three electrons to form
three covalent bonds and make
a nitrogen molecule (N2).

- This is a picture of a nitrogen molecule.



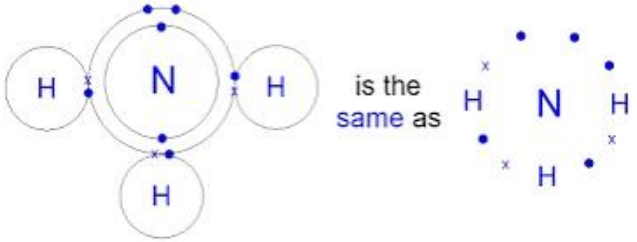
- By sharing the six electrons where the shells touch
each nitrogen atom can count 8 electrons in its outer shell.
These full outer shells with their shared electrons are now stable.
The N2 molecule will not react further with other nitrogen atoms.
- Note the 3 pairs (6 electrons) shared between the atoms.
Each electron pair is one bond.
Nitrogen has three bonds between its atoms.
This is called a triple bond.
The triple bond is very strong

and this is what
makes nitrogen so unreactive (stable).

- The structural formula of an nitrogen molecule is written

$$N \equiv N$$

- Formation of Ammonia(NH3)

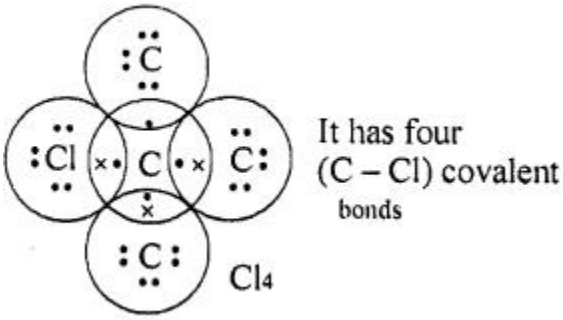


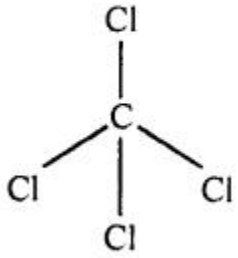
- Ammonia is a covalent molecules with 3 covalent bonds. In a simple molecular structure, the nitrogen atom has three unpaired electrons that they can share with 3 hydrogen atoms that has one valence electrons to achieve a stable noble gas configuration for both nitrogen and hydrogen atoms.

- Formation of carbontetrachloride(CCl4)

- Carbon atoms has four electrons in the outermost shell. In the formation of carbon tetrachloride, it shares four electrons with four chlorine atoms. In turn four chlorine atoms share

one electron each with one carbon atom. Thus in all, one carbon atom and four chlorine atoms complete their octet by mutual sharing of electrons and carbon tetrachloride containing four covalent bonds is formed as shown





- Difference between electrovalent compounds and covalent bonds:-

- Comparison chart

- Covalent Bonds versus Ionic Bonds comparison chart

•	• Covalent Bonds	• Ionic Bonds
• Polarity	• Low	• High

- Covalent Bonds versus Ionic Bonds comparison chart

•	• Covalent Bonds	• Ionic Bonds
• Formation	• A covalent bond is formed between two non-metals that have similar electronegativities. Neither atom is "strong" enough to attract electrons from the other. For stabilization, they share their electrons from outer molecular	• An ionic bond is formed between a metal and a non-metal. Non-metals(-ve ion) are "stronger" than the metal(+ve ion) and can get electrons very easily

- Covalent Bonds versus Ionic Bonds comparison chart

•	• Covalent Bonds	• Ionic Bonds
	orbit with others.	from the metal. These two opposite ions attract each other and form the ionic bond.
• Shape	• Definite shape	• No definite shape
• What is it?	• Covalent bonding is a form of chemical	• Ionic bond, also known as electrovale

- Covalent Bonds versus Ionic Bonds comparison chart

•	• Covalent Bonds	• Ionic Bonds
	bonding between two non metallic atoms which is characterized by the sharing of pairs of electrons between atoms and other covalent bonds.	nt bond is a type of bond formed from the electrostatic attraction between oppositely charged ions in a chemical compound. These kinds of bonds

- Covalent Bonds versus Ionic Bonds comparison chart

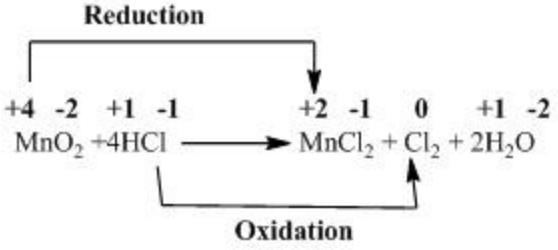
•	• Covalent Bonds	• Ionic Bonds
		occur mainly between a metallic and a non metallic atom.
• Melting point	• low	• High
• Examples	• Methane (CH4), Hydro Chloric acid (HCl)	• Sodium chloride (NaCl), Sulphuric Acid (H2SO4)

- Covalent Bonds versus Ionic Bonds comparison chart

•	• Covalent Bonds	• Ionic Bonds
• Occurs between	• Two non-metals	• One metal and one non-metal
• Boiling point	• Low	• High
• State at room temperature	• Liquid or gaseous	• Solid
•	•	•

- Oxidation- Reduction reaction
- A reaction in which one reactant undergoes oxidation whereas the other gets reduced during the course of reaction are termed as oxidation-reduction reactions or redox reactions. Oxidation refers to the loss of electrons or increase in

oxidation state by a molecule, atom, or ion. Reduction refers to the gain of electrons or decrease in oxidation state by a molecule, atom, or ion.

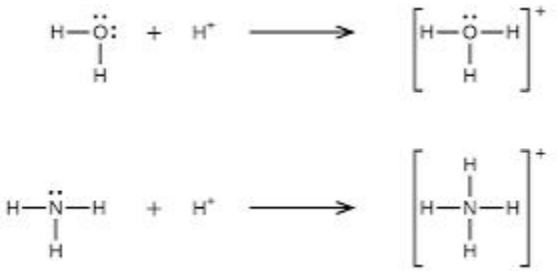
- Consider the following redox reaction.
- Burning sugars, such as glucose (C6H12O6) and the fatty acids in the fats we eat.
- C6H12O6(aq) + 6 O2(g) --
  > 6 CO2(g) + 6 H2O(l)
- Reaction of Manganese dioxide with hydrochloric acid involves redox reaction.
- 

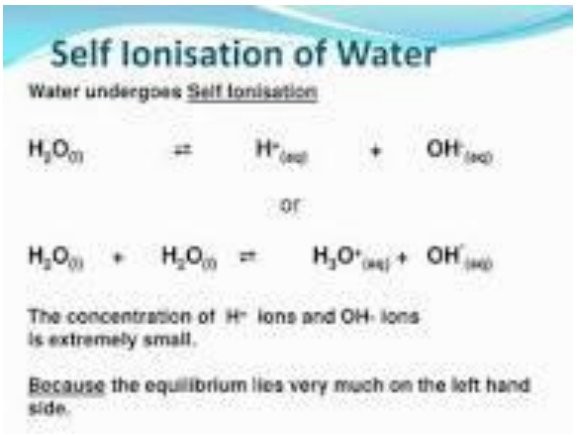
- Reaction of zinc oxide and carbon.
- ZnO + C --> Zn + CO
- In this reaction carbon is oxidised to CO and ZnO is reduced to Zn.
- COORDINATE BOND

- The definition of a coordinate bond is a chemical bond between two atoms when one of the atoms shares a pair of electrons.
- An example of a coordinate bond is the relationship between hydrogen chloride and ammonia when the ammonium ions are formed by the transfer of a hydrogen ion to the pair of electrons in the ammonia molecule.
- Coordinate bond is formed when the shared pair of electrons is provided by one of the two atoms and it is shared by both the atoms. The conditions necessary for the formation of coordinate bond are:
- (1). One of the atoms should have a lone pair of electron to share which is known as donor atom.
- (2). The other atom must have an incomplete outermost shell which shares the electron pair is known as the acceptor atom.
- The hydronium ion is formed by the combination of a water molecule and a proton.
- The water molecule has and oxygen atom bonded to two hydrogen atoms via covalent

bonds. Now this oxygen atom has two lone pairs of electrons so when it has a proton in its vicinity it donates one of its lone pairs to the proton to form a hydronium ion and the overall molecule gets a +1 net charge due to the proton.

- Now this bond between the oxygen and the proton is called a coordinate bond or dative bond and is different from your regular covalent bond as in this case both the electrons of the bond come from oxygen atom as opposed to one from oxygen and one from hydrogen in a covalent bond.
- So the hydronium ion has 2 covalent bonds and one coordinate bond.





- QUESTIONS

. A. In covalent compounds, the bond is formed due to the _____ electrons.

Electrovalent compounds have a _____ B.P.

a molecule of _____ contains a triple bond.

By drawing an electron dot diagram, show the lone pair effect leading to the formation of

ammonium ion from ammonia gas and hydrogen ion.

Give reasons why HCl can be termed as a polar covalent compound.

2. Consider the section of the Periodic table given below:

Group number	IA	IIA	IIIA	IVA	VA	VIA	VIIA	0 group
	1	2	13	14	15	16	17	18
	Li		D			O	J	Ne
	A	Mg	E	Si		H	K	
	B	C		F	G			L

Some elements are given in their own symbols and position in the P.table while others are shown with a letter. With reference to the above table, answer the following questions:

Which is the most electronegative element?

How many valence electrons are present in G?

Write the formula of the compound between B and H.

In the compound between F and J, what type of bond will be formed?

Draw electron-dot structure for the compound formed between C and K.

3. Methane is the first member of alkane family when it is treated with excess of Cl2 in the

presence of diffused sunlight if forms Carbon tetrachloride. Draw appropriate formula of

Carbon tetrachloride and state the type of bond present in it.

4. A. Name the charged particles which attracts one another to form electrovalent

compounds.

B. In the formation of electrovalent compounds, electrons are transferred from one element

to another. How are electrons involved in the formation of a covalent compound

C. The electronic configuration of Nis 2,5. How many electrons in the outer shell of a N atom

are not involved in the formation of a nitrogen molecule?

D. In the formation of $MgCl_2$, name the substance that is oxidized and the substance that is

reduced.

5. A. Acids dissolve in water to produce positively charged ions. Draw the structure of these

positively charged
ions.

B. Explain why carbon tetrachloride does not dissolve in water.

C. Elements Q and S react together to form an ionic compound. Under normal conditions,

which physical state will the compound QS exist in? Can Q and S, both be metals? Justify your answer.

6. Element X is a metal with a valency 2. Element Y is a non metal with a valency 3.

Write the chemical equations to show how X and Y form ions.

If Y is a diatomic gas, write the chemical equation for the direct combination of X and Y

to form a
compound.

If the compound formed between X and Y is melted and an electric current passed

through the molten compound, the element will be obtained at the _____ and Y at

the _____ of the electrolytic cell.