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2.1 DISCOVERY OF SUB-ATOMIC PARTICLES

An insight into the structure of atom was obtained from the experiments on electrical discharge through gases. Before we discuss these results, let us keep in mind a basic rule regarding the behaviour of charged particles: "Like charges repel each other and unlike charges attract each other".

2.1.1 Discovery of Electrons

In 1890, Michael Faraday showed that if electricity is passed through a solution of an electrolyte, chemical reactions occurred at the electrodes, which resulted in the liberation and deposition of matter at the electrodes. He formulated certain laws which you will study in class XII. These results suggested the particulate nature of electricity.

In mid 1850s many scientists mainly Faraday began to study electrical discharge in partially evacuated tubes, known as **cathode ray discharge tubes**. It is depicted in Fig. 2.1. A cathode ray tube is made of glass containing two thin pieces of metal, called electrodes, sealed in it. The electrical discharge through the gases could be observed only at very low pressures and at very high voltages. The pressure of different gases could be adjusted by evacuation of the glass tubes. When sufficiently high voltage is applied across the electrodes, current starts flowing through a stream of particles, moving in the tube from the negative electrode (cathode) to the positive electrode (anode). These were called **cathode rays** or **cathode ray particles**. The flow of current from cathode to anode was further checked by making a hole in the anode and coating the tube behind anode with phosphorescent material like sulphur. When these rays, after passing through anode, strike the zinc sulphide coating, a bright spot is developed on the coating (Fig. 2.1(b)).

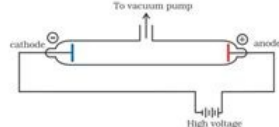


Fig. 2.1(a) A cathode ray discharge tube

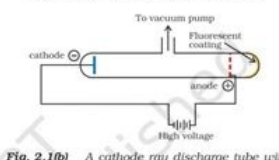
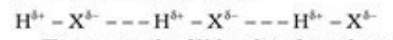


Fig. 2.1(b) A cathode ray discharge tube with phosphorescent coating

The results of these experiments are summarised below:

- The cathode rays start from cathode and move towards the anode.
- These rays themselves are not visible but their behaviour can be observed with the help of certain kind of materials (phosphorescent or phosphorescent) which glow when hit by them. Television picture tubes are cathode ray tubes and television pictures result, due to fluorescence on the television screen coated with certain fluorescent or phosphorescent materials.
- In the absence of electrical or magnetic field, these rays travel in straight lines (Fig. 2.2).
- In the presence of electrical or magnetic field, the behaviour of cathode rays are similar to that expected from negatively charged particles, suggesting that the cathode rays consist of negatively charged particles, called **electrons**.
- The characteristics of cathode rays (electron) do not depend upon the

(5). This results in the formation of a polar molecule having electrostatic force of attraction which can be represented as:



The magnitude of H-bonding depends on the physical state of the compound. It is maximum in the solid state and minimum in the gaseous state. Thus, the hydrogen bonds have strong influence on the structure and properties of the compounds.

4.9.2 Types of H-Bonds

There are two types of H-bonds

- Intermolecular hydrogen bond
- Intramolecular hydrogen bond

(1) **Intramolecular hydrogen bond** : It is formed between two different molecules of the same or different compounds. For example, H-

bond in case of HF molecule, alcohol or water molecules, etc.

(2) **Intramolecular hydrogen bond** : It is formed when hydrogen atom is in between the two highly electronegative (F, O, N) atoms present within the same molecule. For example, in o-nitrophenol the hydrogen is in between the two oxygen atoms.

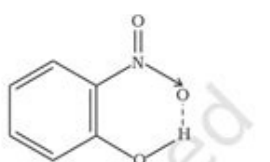


Fig. 4.22 Intramolecular hydrogen bonding in o-nitrophenol molecule

SUMMARY

Kössel's first insight into the mechanism of formation of electropositive and electronegative ions related the process to the attainment of noble gas configurations by the respective ions. Electrostatic attraction between ions is the cause for their stability. This gives the concept of **electrovalency**.

The first description of **covalent bonding** was provided by Lewis in terms of the sharing of electron pairs between atoms and he related the process to the attainment of noble gas configurations by reacting atoms as a result of sharing of electrons. The Lewis dot symbols show the number of valence electrons of the atoms of a given element and Lewis dot structures show pictorial representations of bonding in molecules.

An ionic compound is pictured as a three-dimensional aggregation of positive and negative ions in an ordered arrangement called the crystal lattice. In a crystalline solid there is a charge balance between the positive and negative ions. The crystal lattice is stabilised by the **enthalpy of lattice formation**.

While a single covalent bond is formed by sharing of an electron pair between two atoms, multiple bonds result from the sharing of two or three electron pairs. Some bonded atoms have additional pairs of electrons not involved in bonding. These are called lone pairs of electrons. A Lewis dot structure shows the arrangement of bonded pairs and lone pairs around each atom in a molecule. **Important parameters, associated with chemical bonds, like bond length, bond angle, bond enthalpy, bond order and bond polarity have significant effect on the properties of compounds.**

A number of molecules and polyatomic ions cannot be described accurately by a single Lewis structure and a number of descriptions (representations) based on the same skeletal structure are written and these taken together represent the molecule or ion. This is a very important and extremely useful concept called **resonance**. The contributing structures or canonical forms taken together constitute the resonance hybrid which represents the molecule or ion.

4.1 KÖSSEL-LEWIS APPROACH TO CHEMICAL BONDING

In order to explain the formation of chemical bond in terms of electrons, a number of attempts were made, but it was only in 1916 when Kössel and Lewis succeeded independently in giving a satisfactory explanation. They were the first to provide some logical explanation of valence which was based on the inertness of noble gases.

Lewis pictured the atom in terms of a positively charged 'kernel' (the nucleus plus the inner electrons) and the outer shell that could accommodate a maximum of eight electrons. He, further assumed that these eight electrons occupy the corners of a cube which surround the 'kernel'. Thus the single outer shell electron of sodium would occupy one corner of the cube, while in the case of a noble gas all the eight corners would be occupied. This octet of electrons, represents a particularly stable electronic arrangement. **Lewis postulated that atoms achieve the stable octet when they are linked by chemical bonds.** In the case of sodium and chlorine, this can happen by the transfer of an electron from sodium to chlorine thereby giving the Na^+ and Cl^- ions. In the case of other molecules like Cl_2 , H_2 , F_2 , etc., the bond is formed by the sharing of a pair of electrons between the atoms. In the process each atom attains a **stable outer octet of electrons**.

Lewis Symbols: In the formation of a molecule, only the outer shell electrons take part in chemical combination and they are known as **valence electrons**. The inner shell electrons are well protected and are generally not involved in the combination process. G.N. Lewis, an American chemist introduced simple notations to represent valence electrons in an atom. These notations are called **Lewis symbols**. For example, the Lewis symbols for the elements of second period are as under:



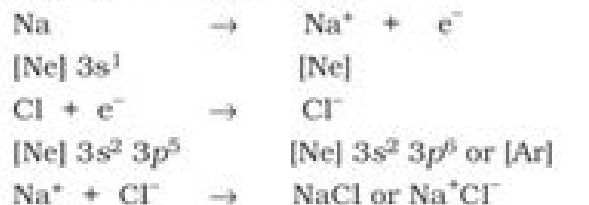
Significance of Lewis Symbols : The number of dots around the symbol represents

the number of valence electrons. This number of valence electrons helps to calculate the common or **group valence** of the element. The group valence of the elements is generally either equal to the number of dots in Lewis symbols or 8 minus the number of dots or valence electrons.

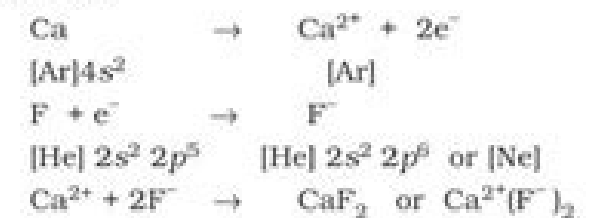
Kössel, in relation to chemical bonding, drew attention to the following facts:

- In the periodic table, the highly electronegative halogens and the highly electropositive alkali metals are separated by the noble gases;
- The formation of a negative ion from a halogen atom and a positive ion from an alkali metal atom is associated with the gain and loss of an electron by the respective atoms;
- The negative and positive ions thus formed attain stable noble gas electronic configurations. The noble gases (with the exception of helium which has a duplet of electrons) have a particularly stable outer shell configuration of eight (octet) electrons, $ns^2 np^6$.
- The negative and positive ions are stabilised by electrostatic attraction.

For example, the formation of NaCl from sodium and chlorine, according to the above scheme, can be explained as:



Similarly the formation of CaF_2 may be shown as:



The bond formed, as a result of the electrostatic attraction between the positive and negative ions was termed as

layer structure in which planar BO_3 units are joined by hydrogen bonds as shown in Fig. 11.1.

Boric acid is a weak monobasic acid. It is not a protic acid but acts as a Lewis acid by accepting electrons from a hydroxyl ion: $\text{BO}_3 + 2\text{OH}^- \rightarrow [\text{B}(\text{OH})_4]^- + \text{H}_2\text{O}$

On heating, orthoboric acid above 370K forms metaboric acid, HBO_2 , which on further heating yields boric oxide, B_2O_3 .

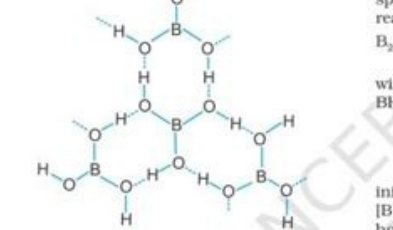
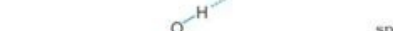


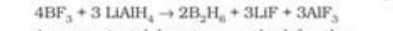
Fig. 11.1 Structure of boric acid; the dotted lines represent hydrogen bonds

Problem 11.4 Why is boric acid considered as a weak acid?

Solution Because it is not able to release H^+ ions on its own. It receives OH^- ions from water molecule to completely ionise and in turn releases H^+ ions.

11.3.3 Diborane, B_2H_6

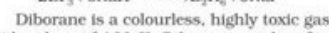
The simplest boron hydride known, is diborane. It is prepared by treating boron trichloride with LiAlH_4 in diethyl ether.



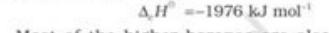
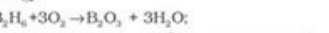
A convenient laboratory method for the preparation of diborane involves the oxidation of sodium borohydride with iodine.

$2\text{NaBH}_4 + \text{I}_2 \rightarrow \text{B}_2\text{H}_6 + 2\text{NaI} + \text{H}_2$

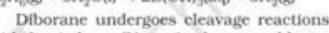
Diborane is produced as an industrial scale by the reaction of BF_3 with sodium hydride.



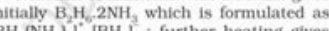
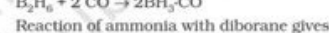
Diborane is a colourless, highly toxic gas with a b.p. of 180 K. Diborane catches fire spontaneously upon exposure to air. It burns in oxygen releasing an enormous amount of energy.



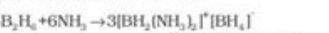
Most of the higher boranes are also spontaneously flammable in air. Boranes are readily hydrolysed by water to give boric acid.



Diborane undergoes cleavage reactions with Lewis bases (L) to give borane adducts, BH_3L .



Reaction of borane with diborane gives initially $\text{B}_2\text{H}_6\text{B}_2\text{H}_6$ which is formulated as $[\text{BH}_2(\text{NH})_2]_2$. [BH] is further heating gives borazine, $\text{B}_3\text{N}_3\text{H}_6$ known as "inorganic benzene" in view of its ring structure with alternating BH and NH groups.



The structure of diborane is shown in Fig. 11.2(a). The four terminal hydrogen atoms and the two boron atoms lie in one plane, above and below this plane, there are two bridging hydrogen atoms. The four terminal B-H bonds are regular two centre two electron bonds while the two bridge (B-H-B) bonds are different and can be described in terms of three

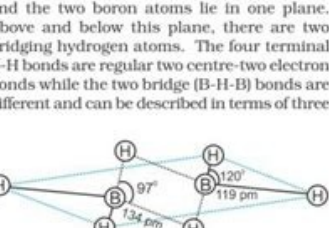


Fig. 11.2(a) The structure of diborane, B_2H_6

chloride solution of same molar concentration. For a buffer solution formed by ammonium chloride and ammonium hydroxide, equation (7.42) becomes:

$$\text{pH} = 9.25 + \log \frac{[\text{Conjugate acid, BH}^+]}{[\text{Base, B}]}$$

pH of the buffer solution is not affected by dilution because ratio under the logarithmic term remains unchanged.

7.13 SOLUBILITY EQUILIBRIA OF SPARINGLY SOLUBLE SALTS

We have already known that the solubility of ionic solids in water varies a great deal. Some of these (like calcium chloride) are so soluble that they are hygroscopic in nature and even absorb water vapour from atmosphere. Others (such as lithium fluoride) have so little solubility that they are commonly termed as insoluble. The solubility depends on a number of factors important amongst which are the lattice enthalpy of the salt and the solvation enthalpy of the ions in a solution. For a salt to dissolve in a solvent the strong forces of attraction between its ions (lattice enthalpy) must be overcome by the ion-solvent interactions. The solvation enthalpy of ions is referred to in terms of solvation which is always negative i.e. energy is released in the process of solvation. The amount of solvation enthalpy depends on the nature of the solvent. In case of a non-polar (covalent) solvent, solvation enthalpy is small and hence, not sufficient to overcome lattice enthalpy of the salt. Consequently, the salt does not dissolve in non-polar solvent. As a general rule, for a salt to be able to dissolve in a particular solvent its solvation enthalpy must be greater than its lattice enthalpy so that the latter may be overcome by former. Each salt has its characteristic solubility which depends on temperature. We classify salts on the basis of their solubility in the following three categories.

Category I	Soluble	Solubility > 0.1M
Category II	Slightly Soluble	0.01M<Solubility< 0.1M
Category III	Sparingly Soluble	Solubility < 0.01M

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We shall now consider the equilibrium between the sparingly soluble ionic salt and its saturated aqueous solution.

7.13.1 Solubility Product Constant

Let us now have a solid like barium sulphate in contact with its saturated aqueous solution. The equilibrium between the undissolved solid and the ions in a saturated solution can be represented by the equation:



The equilibrium constant is given by the equation:

$$K = \frac{[\text{Ba}^{2+}][\text{SO}_4^{2-}]}{[\text{BaSO}_4]}$$

For a pure solid substance the concentration remains constant and we can write

$$K_{sp} = K[\text{BaSO}_4] = [\text{Ba}^{2+}][\text{SO}_4^{2-}] \quad (7.43)$$

We call K_{sp} the *solubility product constant* or simply *solubility product*. The experimental value of K_{sp} in above equation at 298K is 1.1×10^{-10} . This means that for solid barium sulphate in equilibrium with its saturated solution, the product of the concentrations of barium and sulphate ions is equal to its solubility product constant. The concentrations of the two ions will be equal to the molar solubility of the barium sulphate. If molar solubility is S, then

$$1.1 \times 10^{-10} = (\text{S})(\text{S}) = \text{S}^2$$

$$\text{or} \quad \text{S} = 1.05 \times 10^{-5}.$$

Thus, molar solubility of barium sulphate will be equal to $1.05 \times 10^{-5} \text{ mol L}^{-1}$.

A salt may give on dissociation two or more than two anions and cations carrying different charges. For example, consider a salt like *zirconium phosphate* of molecular formula $(\text{Zr}^{4+})_3(\text{PO}_4^{3-})_4$. It dissociates into 3 zirconium cations of charge +4 and 4 phosphate anions of charge -3. If the molar solubility of zirconium phosphate is S, then it can be seen from the stoichiometry of the compound that

$$[\text{Zr}^{4+}] = 3\text{S} \text{ and } [\text{PO}_4^{3-}] = 4\text{S}$$

$$\text{and } K_{sp} = (3\text{S})^3 (4\text{S})^4 = 6912 (\text{S})^7$$

$$\text{or } \text{S} = [K_{sp} / (3^3 \times 4^4)]^{1/7} = (K_{sp} / 6912)^{1/7}$$

Eric E.Saint Louis UniversityI had a test for orgo in exactly one week. And after each video, you can solve practice questions to check your understanding to see if you're ready to move onto more advanced topics.Basic Analytical Chemistry - University of TokyoThe University of Tokyo's Basic Analytical Chemistry Course is designed for students and researchers who are interested in learning the basic concepts of analytical chemistry. Courtney E.Central Washington UniversityI stumbled across this website a couple years ago, seeking help in preparation for my general chemistry ACS exam, and it was helpful then so I've remembered it again and again for other classes, and am glad I can use it again now for organic chemistry. You'll also be able to give a detailed summary of the history and development of atomic theory as well as identify nuclear fission and fusion processes. 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Then it goes into more detail about some important analytical techniques including chromatography, spectroscopy, and electrochemistry.This course covers all these topics in detail, step by step. This site is that friend. By going through this introductory course you will gain a solid foundation on which you can build your knowledge of chemistry later on.This course will introduce students to the fundamental principles of chemistry, including atomic structure, chemical bonding, and reaction mechanisms, solutions and phases of matter, thermodynamics, electrochemistry, nuclear chemistry (radioactivity), spectroscopy (including infrared and ultraviolet-visible absorption spectra), kinetics (experimental methods) and equilibrium.The goal is for students taking this course to develop an appreciation for what chemists do as well as an understanding of concepts that can help them succeed in future courses such as organic chemistry.If you are interested in learning more about chemistry but have no background at all, then this is the perfect place to start. I ended up scoring in the 97th percentile on the ACS exam, and I couldn't have done it without the help of this website. Keep up the good work! 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It is aimed at those who have little or no background in the subject but would like to learn more about it.This course covers fundamental concepts such as chemical reactions, stoichiometry, and thermodynamics that form the basis of modern analytical methods used today - with a special emphasis on their applications in life sciences, environmental sciences, and geochemistry fields. Manuel E. I was able to score a 54/70 on a final where the class average was 20/70. Steve K.St. Joseph's UniversityI'm a biologist who has worked in chem labs most of my career. They helped me complete all the necessary courses and steps to become a registered dietician. You'll learn how compounds are formed using functional groups as building blocks. If you want a free organic chemistry course, Udemymy your best bet. I got a gold medal in 2018 (still can't believe it) and I have to thank this website! 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The sheer volume of terminology, the complexity of the reactions, and the difficulty in memorizing all those formulas make it hard for students to succeed.This course will give you a good understanding of organic chemistry by breaking down each concept into its simplest elements. This online learning platform offers millions of classes across diverse subjects from chemistry to physics and thousands of other topics.Click Here Now To Take The Free Organic Chemistry Course on Udemymy I just wish I found it earlier! Would've helped me so much on my midterm. Thank you so much! Morgan M.West Chester UniversityI recently purchased the organic chemistry guide. This is a great way for students to fill in any knowledge gaps they might have and prepare themselves for further study in this area.Advanced Chemistry is a free online course that teaches the fundamentals of organic chemistry. It covers topics such as structural biology, protein engineering techniques, fluorescent proteins for tracking live cells, fluorescence imaging applications, and much more.This course will teach you about some very fundamental concepts in biochemistry that are essential to any research or business project related to this field. Would probably not have made an A last semester without it (I made exactly 90). The instructors have made it as comprehensive as possible while keeping it fun and interesting throughout the entire series with videos, quizzes, and other interactive features so that everyone can enjoy learning about these topics.Advanced Chemistry - Organic and Analytical Chemistry - AlisonAlison's Advanced Chemistry - Organic and Analytical Chemistry provides intermediate-level college students with the perfect bridge between high school and more advanced classes like organic chemistry or biochemistry. I joined about 2 weeks before finals and ended up getting an A in the class! Mujtaba H.Wayne State UniversityThank you, not only for preventing OChem from being a "weeder" class for me, but also for making it an enjoyable journey. This makes naming organic compounds an incredibly frustrating experience for many students.Mastering the IUPAC nomenclature rules will not only make your life easier, but it will also help you master other concepts of chemistry such as drawing structures from their names or vice-versa.This course contains videos covering all the IUPAC rules, step by step. The course is broken up into 8 video lectures with 1h 48m of videos total. Finally, you'll be able to describe energy conversions.This course has been designed for anyone who wants to understand more about organic and analytical chemistry or even just brush up on what they already know. You'll learn how to identify elements, their origin, the Mass-Mole relationship, acids and bases, laboratory titrations, rates of reactions, and the factors affecting them. And after each video, you can solve practice questions to check your understanding. If so, then this post will be perfect for you. You don't need prior knowledge or experience in order to take this class; if anything, it's better if you're an absolute beginner because that means you'll be able to build up your knowledge from scratch.ConclusionWith all the resources that are available to us nowadays, it's no surprise there are so many courses and tutorials for every subject imaginable. I did it with the more difficult organic professor too! Paul G.Cincinnati Public High SchoolI am a high school teacher in Cincinnati. The course covers topics such as chemical kinetics, equilibrium, and thermodynamics. It also includes interactive simulations and quizzes to help you learn more about these concepts.This university-level course provides access to an extensive range of resources, including lecture notes, quizzes, assignments, and exams. I always start my class on MOC. All of these courses are great options if your school doesn't offer an organic chemistry course or if you need help understanding your current organic chemistry curriculum.Best Free Online Organic Chemistry CourseThe Organic Chemistry Course - Udemymy This Free Organic Chemistry Course covers all of the basics of OC in 9 lectures and 1.5 hours of video, and it covers everything from hydrocarbons to nitrogen compounds. Rafael S.Binghamton U.These guides are awesome. It's perfect for students studying science at school or university level but it can also help people with jobs related to these topics. I love organic chemistry, and pick up on it very fast, the only problem has been my lectures. Over 400+ blog posts to guide you through introductory Organic Chemistry, organized by subject.Gen Chem and Organic Chem: How are they different? How Gen Chem Relates to Organic Chem, Pt. 1 - The AtomFrom Gen Chem to Organic Chem, Pt. 2 - Electrons and OrbitalsFrom Gen Chem to Organic Chem, Pt. 3 - Effective Nuclear ChargeFrom Gen Chem to Organic Chem, Pt. 4 - Chemical BondingFrom Gen Chem to Organic Chem, Pt. 5 - Understanding Periodic TrendsFrom Gen Chem to Org Chem, Pt. 6 - Lewis Structures, A ParableFrom Gen Chem to Org Chem, Pt. 7 - Lewis StructuresFrom Gen Chem to Org Chem, Pt. 8 - Ionic and Covalent BondingFrom Gen Chem to Org Chem, Pt. 9 - Acids and BasesFrom Gen Chem to Organic Chem, Pt. 10 - Hess' LawFrom Gen Chem to Organic Chem, Pt. 11 - The Second LawFrom Gen Chem to Org Chem Pt. 12 - KineticsFrom Gen Chem to Organic Chem, Pt. 13 - EquilibriaFrom Gen Chem to Organic Chem, Part 14: Wrapup Abby M.Lee UniversityI made an A in my Organic 2 class - this website was an invaluable resource!! Thanks so much. It's also useful if you just want a better understanding of what goes on inside your body. Kaitlyn M.Penn State UniversityA friend at my university informed me about this website and said it was the only reason he passed organic chemistry! Leah S.University of PittsburghMOC was my best friend this past semester. Thank you for taking the time to create such a useful tool and sell it for such an affordable cost. (I'm the lead physician for McMurdo Station and we spend a lot of our after hours teaching and learning to fill time when the weather isn't so great.) From the bottom of the world - thanks! Luke D.LaMar UniversityThe cheat sheets have been a great reference for my studies, as well as the reaction guide. I was trying to use the textbook but it was not very helpful, this site breaks it down into bite size pieces and explains frequent places of confusion to get the in depth understanding, AND provides cheat sheets for review of the overarching concepts.

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