## 1. Details of Module and its structure

| Module Detail | |
|---|---|
| **Subject Name** | **Physics** |
| **Course Name** | **Physics 02 (Physics Part-2, Class XI)** |
| **Module Name/Title** | **Unit 7, Module 1, Bulk Properties of Matter (overview of the unit)**<br>**Chapter 9, Mechanical Properties of Solids** |
| **Module Id** | **keph_20901_eContent** |
| **Pre-requisites** | **Atoms, Molecules, states of matter** |
| **Objectives** | **After going through the module, the students will be able to:**<br>• **Visualize** the arrangement of atoms and molecules in solids<br>• **Logically deduce** the existence of intermolecular and inter-atomic forces also appreciate that they can be both attractive and repulsive in nature<br>• **Understand** existence of matter in different states (solid, liquid and gas)<br>• **Get an overview** of the unit under study<br>• **Outline study of few selected properties of matter**<br>Elastic behavior of solids<br>Stationary Fluid properties: pressure, up thrust<br>Stationary liquid property: surface tension and its effects<br>Flowing fluids: viscosity<br>Effects of heat |
| **Keywords** | **Bulk properties of matter, intermolecular forces** |

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## 1. UNIT SYLLABUS

**UNIT 7: PROPERTIES OF BULK MATTER: 24 periods**

**Syllabus**

**Chapter–9: Mechanical Properties of Solids:**

Elastic behaviour, Stress-strain relationship, Hooke's law, Young's modulus, bulk modulus, shear modulus of rigidity, Poisson's ratio; elastic energy.

**Chapter–10: Mechanical Properties of Fluids:**

Pressure due to a fluid column ; Pascal's law and its applications (hydraulic lift and hydraulic brakes), effect of gravity on fluid pressure. Viscosity, Stokes' law, terminal velocity, streamline and turbulent flow, critical velocity, Bernoulli's theorem and its applications. Surface energy and surface tension, angle of contact, excess of pressure across a curved surface, application of surface tension ideas to drops, bubbles and capillary rise

**Chapter–11: Thermal Properties of Matter:**

Heat, temperature, thermal expansion; thermal expansion of solids, liquids and gases, anomalous expansion of water; specific heat capacity; Cp, Cv- calorimetry; change of state - latent heat capacity. Heat transfer-conduction, convection and radiation, thermal conductivity, qualitative ideas of Blackbody radiation, Wien's displacement Law, Stefan's law, Greenhouse effect.

## 2. MODULE-WISE DISTRIBUTION OF UNIT SYLLABUS 17 MODULES

**The above unit is divided into 17 modules for better understanding**

| | |
|---|---|
| **Module 1** | • Forces between atoms and molecules making up the bulk matter<br>• Reasons to believe that intermolecular and interatomic forces exist<br>• Overview of the unit<br>• State of matter<br>• Study of a few selected properties of matter<br>• Study of elastic behaviour of solids<br>• Stationary fluid property: pressure and viscosity<br>• Stationary liquid property: surface tension<br>• Properties of Flowing fluids<br>• Effect of heat on matter |
| **Module 2** | • Idea of deformation by external force<br>• Elastic nature of materials<br>• Elastic behaviour<br>• Plastic behaviour<br>• Tensile stress<br>• Longitudinal Stress and longitudinal strain<br>• Relation between stress and strain<br>• Hooke's law<br>• Young's modulus of elasticity 'Y' |
| **Module 3** | • Searle's apparatus<br>• Experiment to determine Young's modulus of the material of a wire in the laboratory<br>• What do we learn from the experiment? |
| **Module 4** | • Volumetric strain<br>• Volumetric stress<br>• Hydraulic stress<br>• Bulk modulus K<br>• Fish ,aquatic life on seabed ,deep sea diver suits and submarines |
| **Module 5** | • Shear strain<br>• Shear stress |

| | |
|---|---|
| | • Modulus of Rigidity G<br>• Poisson's ratio<br>• Elastic energy<br>• To study the effect of load on depression of a suitably clamped meter scale loaded at i)its ends ii)in the middle<br>• Height of sand heaps , height of mountains |
| Module 6 | • Fluids-liquids and gases<br>• Stationary and flowing fluids<br>• Pressure due to a fluid column<br>• Pressure exerted by solids , liquids and gases<br>• Direction of Pressure exerted by solids , liquids and gases |
| Module 7 | • Viscosity- coefficient of viscosity<br>• Stokes' Law<br>• Terminal velocity<br>• Examples<br>• Determine the coefficient of viscosity of a given viscous liquid by measuring terminal velocity of a given spherical body in the laboratory |
| Module 8 | • Streamline and turbulent flow<br>• Critical velocity<br>• Reynolds number<br>• Obtaining the Reynolds number formula using method of dimensions<br>• Need for Reynolds number and factors effecting its value<br>• Equation of continuity for fluid flow<br>• Examples |
| Module 9 | • Bernoulli's theorem<br>• To observe the decrease in pressure with increase in velocity of a fluid<br>• Magnus effect<br>• Applications of Bernoulli's theorem<br>• Examples<br>• Doppler test for blockage in arteries |
| Module 10 | • Liquid surface<br>• Surface energy<br>• Surface tension defined through force and through energy<br>• Angle of contact<br>• Measuring surface tension |
| Module 11 | • Effects of surface tension in daily life |

| | |
|---|---|
| | • Excess pressure across a curved liquid surface<br>• Application of surface tension to drops, bubbles<br>• Capillarity<br>• Determination of surface tension of water by capillary rise method in the laboratory<br>• To study the effect of detergent on surface tension of water through observations on capillary rise. |
| **Module 12** | • Thermal properties of matter<br>• Heat<br>• Temperature<br>• Thermometers |
| **Module 13** | • Thermal expansion<br>• To observe and explain the effect of heating on a bi-metallic strip<br>• Practical applications of bimetallic strips<br>• Expansion of solids, liquids and gases<br>• To note the change in the level of liquid in a container on heating and to interpret the results<br>• Anomalous expansion of water |
| **Module 14** | • Rise in temperature<br>• Heat capacity of a body<br>• Specific heat capacity of a material<br>• Calorimetry<br>• To determine specific heat capacity of a given solid material by the method of mixtures<br>• Heat capacities of a gas have a large range<br>• Specific heat at constant volume $C_V$<br>• Specific heat capacity at constant pressure $C_P$ |
| **Module 15** | • Change of state<br>• To observe change of state and plot a cooling curve for molten wax.<br>• Melting point, Regelation, Evaporation, boiling point, sublimation<br>• Triple point of water<br>• Latent heat of fusion<br>• Latent heat of vaporisation<br>• Calorimetry and determination of specific latent heat capacity |
| **Module 16** | • Heat Transfer |

| | |
|---|---|
| | • Conduction, convection, radiation<br>• Coefficient of thermal conductivity<br>• Convection |
| **Module 17** | • Black body<br>• Black body radiation<br>• Wien's displacement law<br>• Stefan's law<br>• Newton's law of cooling ,<br>• To study the temperature, time relation for a hot body by plotting its cooling curve<br>• To study the factors affecting the rate of loss of heat of a liquid<br>• Greenhouse effect |

## MODULE 1

## 3. WORDS YOU MUST KNOW

**Matter:** Anything, that has mass and occupies space, is known as matter. This includes atoms and all things made up of these.

**Mass:** is a property of a physical body. It is the measure of an object's opposition to acceleration (a change in its state of motion) when a net external force acts on it. The basic SI unit of mass is the kilogram (kg).

**Volume:** is the amount of three-dimensional space occupied by an object. All substances (solid, liquid, gas, or plasma) occupy some space, i.e.,have a volume of their own.

**Density:** or more precisely, the **volumetric mass density**, of a substance is its mass per unit volume. Its SI unit is $kgm^{-3}$ The symbol most often used for density is $\rho$ (the lower case Greek letter rho).

**Rigid body:** is a solid body in which any deformation (due to an external force) is zero or is negligibly small. The distance between any two given points on a rigid body, remains constant in time regardless of external forces exerted on it. A rigid body is an idealization; it usually considered as a continuous distribution of mass.

**States of matter:** are the distinct forms in which matter can exist. The three states of matter usually observable in everyday life, are solid, liquid and gas. We can also have fourth state of matter, known as plasma.

**Atom:** is the smallest constituent unit of an element that has the chemical properties of that element. Every solid, liquid, gas, or plasma is composed of neutral or ionized atoms. Atoms are very small; typical sizes are around 100 picometers (a ten-billionth of a meter, in the short scale).

**Molecule:** is an electrically neutral group of two or more atoms held together by chemical bonds. Molecules are distinguished from ions through the absence of any net charge on them.

**Bonds:** may be viewed as a lasting attraction between atoms, ions or molecules that enables the formation of chemical compounds. The bond may result from the electrostatic force of attraction between oppositely charged ions ( ionic bonds) or through the sharing of electrons between atoms (covalent bonds). The strength of chemical bonds varies considerably; there are "strong bonds", or "primary bonds" (such as metallic, covalent or ionic bonds) and "weak bonds" or "secondary bonds" such as dipole-dipole interaction and hydrogen bonding.

**Force:** An agency that can change the shape, position of rest or uniform motion .

**Force of attraction:** is a **force** that makes an object move towards, or closer to, the 'cause', of that force. There are many attractive **forces** existing in nature. Some of them are gravitational **force**, electrostatic/electric **force**, magnetic **force**.

**Interatomic and inter molecular force of attraction** **force** between atoms and molecules which keeps matter in solid or liquid state

**Force of repulsion:** is a force that makes an object move, away from the 'cause', of that force. Force between like charges, or like magnetic poles, are the most well-known examples of repulsive forces.

**Interatomic and inter molecular force of repulsion** force between atoms and molecules which does not allow collapse of matter in solid, tending to reduce its volume to zero

## 4. INTRODUCTION

Matter, as we understand is anything that has mass and occupies space. Objects, materials, that we see around us may be of different sizes and have different internal structures. We also know that matter can usually exist in three states solid, liquid or gaseous. Sometimes, fourth state called plasma is also considered. Materials are used on the basis of their properties and there behaviour when subjected to external forces. **The**

**bulk properties imply the behaviour of bulk matter under the influence of external variations in applied force, heat pressure etc.**

**In our course, we will study only some of the, many bulk properties of matter.**

**For solids**, we will only consider the

- **Property of Elasticity**.

**For liquids/fluids** state we would restrict our study to stationary fluids and slowly flowing fluids, the main properties we will consider here, would be

- **Pressure exerted by fluids,**
- **Buoyancy and Archimedes principle,**
- **Streamline flow**
- **Bernoulli's principle,**
- **Viscosity and**
- **Surface Tension.**

**The last of those is a property unique to liquids.**

We would also study to unique **thermal properties** for matter in solids, liquid and gaseous state.

We will also study the importance of **gaseous state** and the behaviour of a fixed mass of gas under external changes in temperature, pressure or volume.

**For understanding all these, we first need to understand the basic details of the atomic constitution of matter.**

## 5. INTERATOMIC AND INTERMOLECULAR FORCES:

**The atoms, in a solid or liquid are known to 'stay-together'. What is it that 'holds' these atoms/molecules together?**

Evidently there must exist some inter-atomic or intermolecular forces that keep them bound. However, the detailed nature of these forces is rather complex. In this section we shall, therefore, present only a **qualitative description** of these forces and see how various physical properties of matter can be understood in terms of this qualitative description.

We know that solids are characterized by their shape and size; large deforming forces are required to bring about any change in their shape and /or size. Similarly, liquids have a definite size (or volume) but no definite shape, they can also easily flow. The gases, on the other hand do not have any definite shape or size(volume).

These observational facts suggest that the inter-atomic, or intermolecular forces, are perhaps strongest in solids and weakest in the gases.

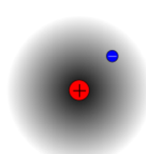
**These forces are usually attractive and depend on the inter-atomic or intermolecular separation. But if they are always attractive and their strength increases with decreasing separation, the matter should collapse when the atoms are brought closer and closer**. **This is contrary to observation**. It is also known that the solids are highly incompressible. These suggest that the nature of inter-atomic forces changes when the atoms are brought too close, they must become repulsive rather than attractive when they are brought very closer to each other, to avoid a collapse.

**The inter-atomic/intermolecular forces are electrical in nature.**

**We are now going to just try and understand how bulk matter is formed and what keeps it together. We would do this before we learn about the different properties manifested by bulk matter. This is important because selection of any material for any useful purpose depends upon the changes that may result because of the application of external changes on the material. For example- you would not be able to draw wires, strings, ropes using wood.**

As you know atoms consist of very small positively charged nuclei (**size ≈ $10^{-15}$m**) and negatively charged electrons distributed over a distance of about **$10^{-10}$ m** (atomic size) around it. Each atom is electrically neutral. Now, if they are electrically neutral, how do they attract each other? Strictly speaking atoms and molecules are not hard spheres; they do not have sharp boundaries.

**For example**, the electron in a hydrogen atom (with only one proton and one electron), could be at different (permitted) locations in the three dimensional space around the nucleus.



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So we can say that, the atom has around its nucleus, a distribution of negative (electron) charge, that may be like a **'cloud'**. the electron at any instant will be at a certain location within the cloud space . **There are rules which we know as of now, which suggest the location of the electrons in the electron cloud using quantum mechanics** . The atomic size is the 'size' of this cloud or distribution. Each atom or molecule undergoes fluctuating distortions in its shape. Such a distortion produces a relative shift between the centres of positive and negative charges in each atom. The **interaction energy** between them is found experimentally to vary as $R^{-6}$.where R is the interatomic separation. This leads to an attractive interaction between two atoms (or molecules), this is called **van der walls attraction** in honour of the **Dutch physicist C.F. van der Waals** (who postulated such an attractive force from his study of liquefaction of gases.)

All matter is made up of atoms and molecules. In elements, like copper or sodium, the molecules are simply atoms characteristic of the elements. Hydrogen, Oxygen commonly exist as molecules with two atoms each. The molecule of a chemical compound may consist of a number of atoms of different elements in close combination, the bonding are strong. For example, a molecule of carbon dioxide contains one atom of carbon and two of oxygen. Polymers, on the other hand, are long chains consisting of hundreds or thousands of atoms. Clearly, there are quite a variety of ways in which combinations of atoms stay as elements or become molecules.

**Atoms and molecules are neutral even though they are made up of charged protons and electrons.**

In your earlier study in science courses, you have studied that

- **All the elements, known till date, have been classified, according to their electronic configuration in the periodic table.**
- **Electrons in atoms have discrete energy states and tend to occupy the lowest available energy levels.**
- **The electronic structure of atoms governs their interaction with other atoms.**
- **Filled outer shells ,as in noble inert gases result in a stable configuration.**
- **Atoms with incomplete outer shells strive to reach this noble gas configuration for maximum stability by sharing or transferring electrons among one another.**

This is called bonding

**There are two main types of this bonding:**

**1) Primary bonding**

**2) Secondary bonding**

Primary bonding results from electron sharing or transfer. There are three types of **primary bonding**

a) **Ionic,**
b) **Covalent,**
c) **Metallic**

**Ionic Bonding:**

In ionic bonding, atoms behave like either positive or negative ions and are bound by attractive forces.


https://upload.wikimedia.org/wikipedia/commons/e/e3/NaCl_ionic_bond.GIF

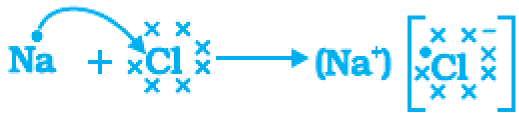
Recall the table showing Electronic configuration of some elements

| Type of element | Element | Atomic number | Number of electrons in shells | | | |
|---|---|---|---|---|---|---|
| | | | K | L | M | N |
| Noble gases | Helium (He) | 2 | 2 | | | |
| | Neon (Ne) | 10 | 2 | 8 | | |
| | Argon (Ar) | 18 | 2 | 8 | 8 | |
| Metals | Sodium (Na) | 11 | 2 | 8 | 1 | |
| | Magnesium (Mg) | 12 | 2 | 8 | 2 | |
| | Aluminium (Al) | 13 | 2 | 8 | 3 | |
| | Potassium (K) | 19 | 2 | 8 | 8 | 1 |
| | Calcium (Ca) | 20 | 2 | 8 | 8 | 2 |
| Non-metals | Nitrogen (N) | 7 | 2 | 5 | | |
| | Oxygen (O) | 8 | 2 | 6 | | |
| | Fluorine (F) | 9 | 2 | 7 | | |
| | Phosphorus (P) | 15 | 2 | 8 | 5 | |
| | Sulphur (S) | 16 | 2 | 8 | 6 | |
| | Chlorine (Cl) | 17 | 2 | 8 | 7 | |

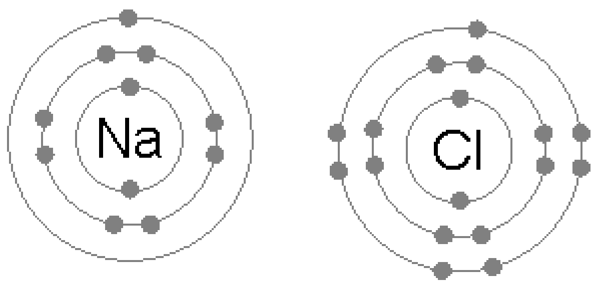
**You will understand how a single molecule of sodium chloride is formed .**

$$\underset{2,8,1}{Na} \rightarrow \underset{\substack{2,8 \\ \text{(Sodium cation)}}}{Na^{+}} + e^{-}$$

$$\underset{2,8,7}{Cl} + e^{-} \rightarrow \underset{\substack{2,8,8 \\ \text{(Chloride anion)}}}{Cl^{-}}$$




**Formation of sodium chloride (NCERT Class 10 Science)**

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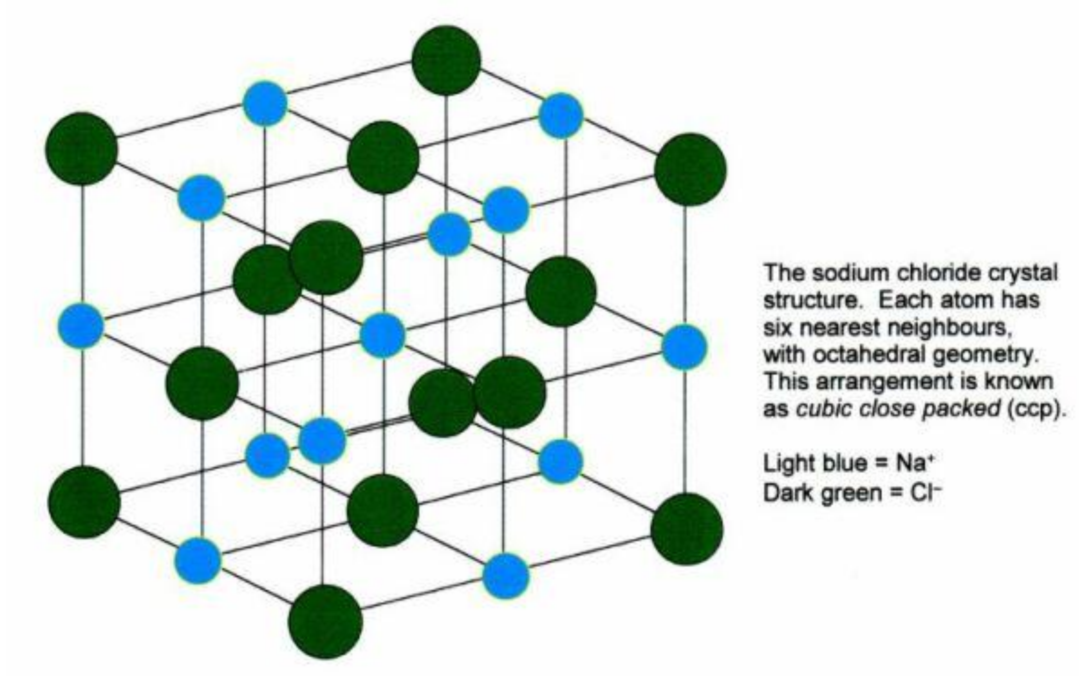
**Click to see the formation of the bond**

**Notice the release of energy as the bond is made**.

**The molecules collectively stays together as salt, as we know, have seen, and have eaten in our food.**

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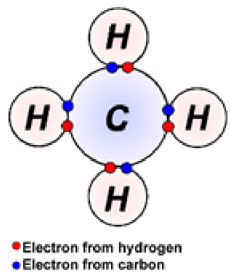
**A large difference in electronegativity between atoms is required for an ionic bond to be formed**.

The ionic bonding is non-directional, i.e., the magnitude of the strength of the bond is equal in all directions.

**In ceramics, (They are usually combinations of metals with oxygen, nitrogen or carbon (oxides, nitrides, and carbides)), the bonding is predominantly ionic. Ionic materials are hard and brittle due to electrically charged nature of component ions. And, furthermore they are electrical and thermal insulators due to absence of a large number of free electrons. (Examples: glass, porcelain, examples of other ceramic materials range from household items to high performance combustion engines which utilize both metals and ceramics.)**

**Covalent Bonding:**

In covalent bonding, electrons are shared between the molecules, to saturate the valency and to approach the 'noble gas configuration'.

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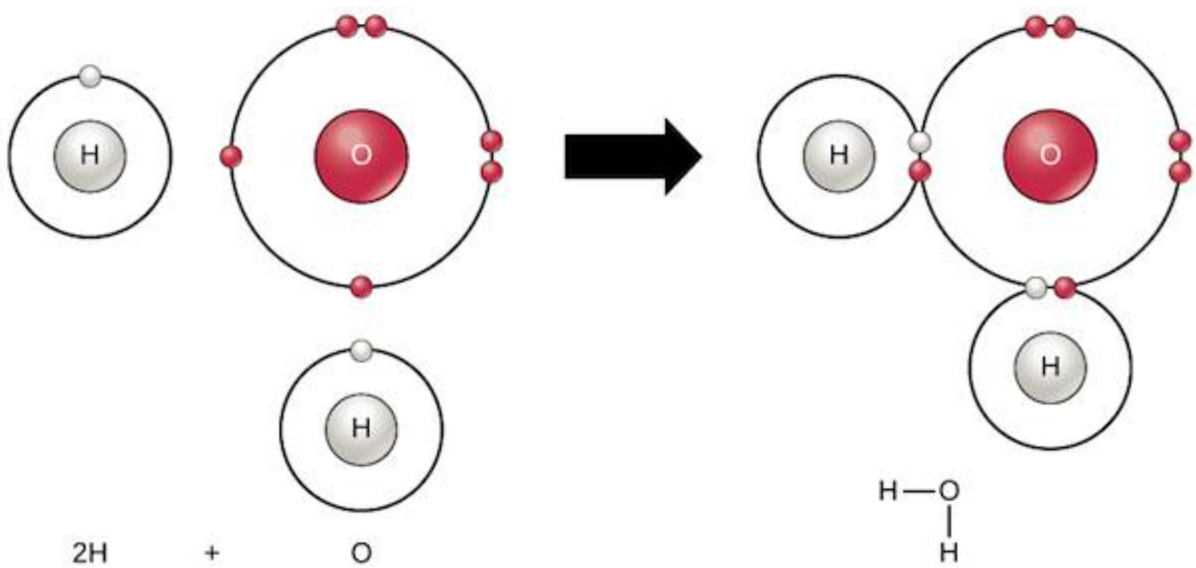
Covalent bonds are highly directional. The simplest example is the $SiO_2$ molecule. Their electrical properties depend strongly on the minute proportions of their contaminants. The three dimensional pictures help you imagine the insides of any such material. **All empty spaces are vacuum, and there are plenty of them.**

For instance, covalent bonds are key to the structure of carbon-based organic molecules like our DNA and proteins. Covalent bonds are also found in smaller inorganic molecules. The more electrons that are shared between two atoms, the stronger their bond will be.

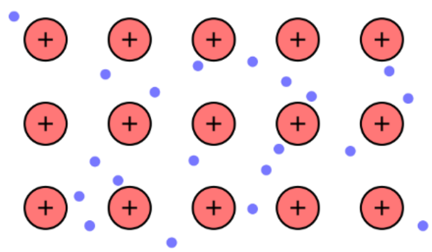
As an example of covalent bonding, let's look at water. A single water molecule consists of two hydrogen atoms bonded to one oxygen atom. Each hydrogen shares an electron with oxygen, and oxygen shares one of its electrons with each hydrogen:




**Hydrogen atoms sharing electrons with an oxygen atom to form covalent bonds, creating a water molecules.**

## Metallic Bonding:

In metals, valence electrons can get detached from atoms, they spread out as an 'electron gas 'or 'electron sea' that keeps the ions together.



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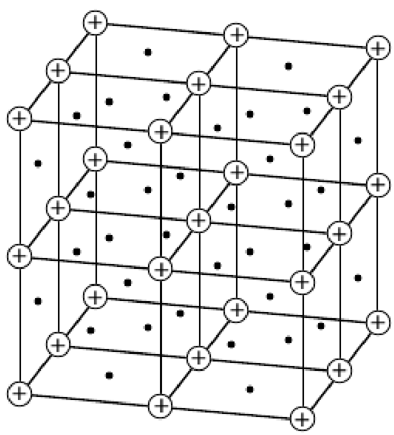
Imagine a 3 dimensional picture



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Metals and alloys exhibit four characteristic properties **(namely good ductility, high thermal conductivity, high electrical conductivity and metallic lustre)** due to their free electrons. Metallic bonding is non-directional and is rather insensitive to structure. As a result high ductility is observed in metals– examples of metals, with typical metallic bonding are Cu, Al, Au, Ag, etc.

**New words and their meaning**

**Ductile** a material may be stretched into a wire.

**Malleable** a material's ability to deform under pressure (compressive) to make different desired shapes

**Electronegativity is** a chemical property that describes the tendency of an atom to attract a shared pair of electrons (or electron density) towards itself. An atom's *electronegativity* is affected by both its atomic number and the distance at which its valence electrons reside from the charged nucleus.

**Alloy** An alloy is a mixture of metals or a mixture of a metal and another element. Alloys are defined by a metallic bonding character. An alloy may be a solid solution of metal elements

**Isotropic** having a physical property which has the same value when measured in different directions.

**Anisotropic properties** having a physical property which has the same value when measured in different directions.

**2) Secondary bonding:**

There is **no electron transfer or sharing in secondary bonding**. Secondary bonding, also called as Van der Waals bonding, is much weaker as compared to the primary bonding. It results from interaction between atoms or molecules.

## 6. POTENTIAL ENERGY, INTERATOMIC FORCES AND INTERATOMIC SEPARATION

**From this general idea of bonding we will now proceed to understand the nature of different materials. We will have to consider the changes in energy involved in keeping the atoms together, why the atoms do not collapse or fuse together?; or why does a substance change its state, say from solid to liquid?.**

**Properties of material depends upon the nature of their bonding. Their response to external changes due to mechanical forces, heat etc. Choice of a material, for a specific purpose, can be made from the materials performance under different (relevant) conditions.**

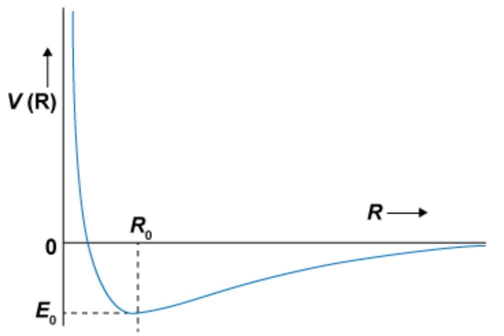
**The fact that atoms and molecules stay together means there must be attractive forces between them –or they must have a bond. Also atoms and molecules cannot come together beyond a point .This means there must be repulsion between them as well, because we cannot imagine a solid cooled enough such that its volume disappears. This is reason enough to believe that interatomic or intermolecular forces exist and they can be both attractive and repulsive.**

Detailed calculations, as well as deductions from experiments show that the interaction between any isolated pair of atoms or molecules may be represented by a curve (fig(1)) that shows how their potential energy varies with separation between them,

This curve describes the inter-atomic potential energy.

We call it potential energy as this energy is due to configuration of the atoms/molecules in the solid state of matter.

**fig 1**

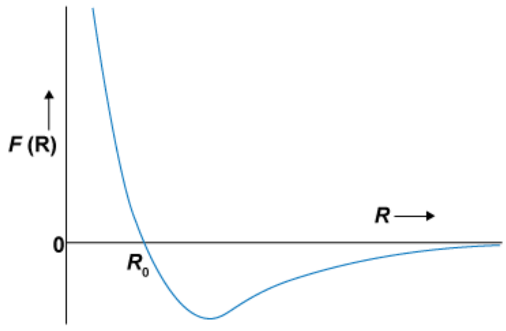



Interatomic potential energy V(R) between two identical atoms as a function of separation R between their nuclei.

The force between the atoms can be found from the potential energy by using the relation,

**F(R) = - dV/dR**

The resulting inter-atomic force curve is shown in figure (2).




Interatomic force $F$(R) between two identical atoms as a function of separation R between their nuclei.

**Fig (2)**

The force is along the line joining the two atoms or molecules, and is shown negative for attraction and positive for repulsion.

**We see that as the distance R decreases, the attractive force first increases and then decreases to zero at a separation $R_0$ where the potential energy is minimum**.

**For smaller distances the force is repulsive**, because at these distances, the negative charge distribution associated with one atom, begins to overlap with that associated with the neighboring atom.

## ORIGIN OF FORCES

These forces are of two types **attractive force ($F_A$)** and **repulsive force ($F_R$)** and the magnitude of each is a function of the interatomic distance.

The origin of the attractive part, **depends on the particular type of bonding**. Primary bonding (metallic, ionic or covalent) suggest the **interaction** between atoms and molecules gives rise to attractive forces.

This **attractive force depends upon**

- **Interatomic/ intermolecular separation**
- **Atoms / molecules making up the material**

**The repulsion** between atoms, when they are brought close to each other, is related to the principle known as **Pauli's exclusion principle. This suggests that each electron has exclusive quantum coordinates. This leads to slight energy variation of electrons.**

When the electronic clouds, surrounding the atoms, start to overlap, the energy of the system increases abruptly. The net force F, is the algebraic sum of both attractive and repulsive forces.

When $F_A$ and $F_R$ balance, or become equal, there is no net force i.e., $F_A + F_R = 0$.

Then a **state of equilibrium** exists. This corresponds to the equilibrium spacing $r_0$.

Sometimes it is more convenient to work with potential energies between two atoms instead of forces.

Energy stored = F dr

At equilibrium spacing, $r_0$, net force is zero and the net energy corresponds to **minimum energy Eo.**

When there are more than two atoms, force and energy interactions among many atoms have to be considered.

**The minimum energy, Eo, is the binding energy required to separate two atoms from their equilibrium spacing to an infinite distance apart.**

**Infinite here means far away, out of sphere of influence of each other.**

## POTENTIAL ENERGY CURVES:

**The energy Eo, and the shape and depth of the curve, defines various properties. The curves indicate the strength of the bond based on the depth of the potential well.**

**The general form of the potential energy curve can be represented by:**

$$U(R) = \frac{A}{R^n} - \frac{B}{R^m}$$

**The coefficients A and B and the exponents (n and m) depend on the nature of the atoms (or molecules) in question. The first term represents the repulsive part of potential and the second represents the attractive part. The exponents 'n' and 'm', for most substances, are close to, 12 and 6, respectively. Thus the repulsive part of the potential has a very short range and becomes effective only when atoms are brought very close to each other.**

**The above picture of inter-atomic or intermolecular forces is an over simplification of the actual situation. However, it provides a reasonable approximation.**

### THINK ABOUT THESE

- **Explanation for getting interatomic force –separation between molecules from potential energy –interatomic separation**

- **Would the graphs of forces and potential energy between molecules be similar, what would be the difference between the interatomic forces and interatomic separation as compared to intermolecular forces and intermolecular separation.**
- **An experiment to show interatomic force of repulsion, interatomic force of attraction**
- **We can obtain the equilibrium separation of molecules. Is it temperature dependant? Is the graph only for solid state? is it true for amorphous solids?**
- **Can we find the energy needed to completely separate two molecules initially at the equilibrium separation?**
- **Can we show expansion of a solid when it is heated?**
  Molecules remain stationary at absolute zero, since their thermal energy is zero .at higher temperature the vibrational energy gained by molecules makes them oscillate. Since the V- r curve is not symmetrical the mean position of oscillation shifts towards the right of $R_0$.so solid expands on heating
- **How can we explain change of solid to liquid state from the graphs?**

  Solid continues to expand at first till its energy equals a certain value (called latent heat) the energy enables the molecules to break completely the bonds of attraction which keep them in solid state. Further increase in temperature reduces the force of attraction between the molecules driving them into gas state

  - **In which state 10g of ice, 10 g of water or 10 g of water vapour, are the molecules in least energy, least inter molecular separation, maximum molecular volume?**
  - **Why interaction energy between the centres of positive and negative charges in an atom does not lead to repulsive force between two atoms?**
  - **Why the value of potential energy remains negative until the two atoms came very close to each-other?**
  - **In the force versus separation graph what is that distance R0 where force is zero and potential energy is minimum?**
    **Equilibrium separation**
  - **If the potential energy between two atoms is increasing then what will be the nature of force between them?**
    **attractive**
  - **Why potential energy first decrease and then increase with the gradual decrease in separation?**
    **The repulsive force causes potential energy to increase as work will need to be done on the material.**
  - **Why the repulsive force in the force versus separation diagram is shown at positive side?**
    **the potential energy associated indicates the energy required to separate the two atoms/molecules**
  - **Does attractive and repulsive force work simultaneously between two atoms?**
    **No , depends upon the separation between the two atoms/molecules**

- **What is the potential energy of the system when two atoms are at equilibrium spacing $r_0$?**
  **Minimum energy**
- **Does the system of two atoms, separated at intermolecular distance, only consists potential energy?**
  **Yes, the kinetic energy exists as vibrational energy which is the least in solid state. in liquid and gaseous state more and more kinetic energy is due to rotation translation**
- **Does the same curve satisfy the situation for solid, liquid and gas?**
  **No**
- **Does the amount and magnitude of attractive or repulsive force depend on the type of bonding between the atoms or molecule?**
  **yes**
- **If a metal has high melting point then its potential energy will be less positive or more positive as compared to the metal which has low melting point?**
  **On heating the equilibrium position moves towards the right, causing expansion of the material when the energy equals latent heat the energy enables the molecules to break completely the bonds of attraction which keep the material on solid state the solid converts to liquid state (except in the case of sublimation) so a lower melting point means lower potential energy it is easier to break these less strong bonds, and because the melting point is a measure of the point at which all the bonds holding a metallic structure together are broken, it will decrease because this point is reached a lot sooner as the bonds are not as strong.**

**USE YOUR CHEMISTRY LESSONS TO ANSWER THE FOLLOWING**

- **What decides the number of atoms in a molecule?**
- **Can all the properties of an element be represented by its single atom?**
- **Does the nature of interaction energy that combines atoms of same element is same when the combination of different elements like in $CO_2$ takes place?**
- **Why most of the elements with stable electronic configuration are in gaseous state?**
- **What is the basic nature of electron, to fly away from the nucleus of to stick to it?**
- **Can a single element form ionic bond when taken with certain kind of elements while covalent bond with other kind of element?**
- **Can an ionic bond form between the atoms of same element?**
- **If we heat a substance, what will be the effect on ionic bond between atoms?**
- **What is that force which comes into play when different molecules combine with each-other?**

- **Can we assume that the bond between the atoms and molecule is merely a force of attraction not a chemical formation?**
- **Since ionic materials are predominantly insulator of electricity then why NaCl solution conducts electricity?**
- **In NaCl there is also sharing of one electron then how the bonding in NaCl is different from covalent bond?**
- **For the electrical conductivity of material free electrons are necessary but when a covalent bond forms between the molecule of different elements then it absorbs free electrons. Will it still conduct electricity?**
- **Can a there be a formation of covalent bond between the molecules of same element?**

## 7. BULK PHYSICAL PROPERTIES AND INTERNAL STRUCTURE

Physical properties are predicted on the basis of interatomic forces that bind the atoms/molecules together.

Consider the interaction of two isolated atoms as they are getting closer from an infinite separation. These forces as discussed above, are of two types: attractive force ($F_A$) and repulsive force ($F_R$) and the magnitude of each is a function of interatomic distance.

The attractive force is neither the same for all separations, nor for different types of atoms/molecules making up the material.

**We can make a few guesses from the graph**

- **The deeper the well, the more stable is the molecule, and a shallower potential well indicates the molecule has low dissociation energy.**
- **Increase in depth of the potential well, increases the melting temperature.**
- **Molecules with large bonding energies should have high melting temperatures.**
- **Generally, as the depth of the potential well decreases, the molecules move from solid state to gaseous state.**

We can now consider many of the properties of materials and use the above idea to explain the associated property.

**In this unit, in subsequent modules, we will briefly study some selected properties of solids liquids and gases.**

**We will use the interatomic potential energy graphs to suitably explain the bulk behavior of materials.**

**THINK ABOUT THESE:**

- **Why do vehicles have rubber tyres?**
- **What decides that a certain quantity of water will convert to solid state or turn into steam?**
- **Why are wires made of metals and chalk for the board with calcium carbonate?**
- **Elastic of socks that we wear becomes loose with time, why?**
- **Why do deep sea divers wear special suits?**
- **How does a pain relieving medicine comfort a patient in pain?**
- **Soap bubbles are spherical, why?**
- **Why materials expand on heating?**
- **Oil is sprinkled on sea waves to calm them. Why?**
- **Blood pressure is higher near the feet, as compared to the head, for a man standing upright. Why?**
- **What makes atoms or molecules to undergo a fluctuating distortion in its shape?**

**Answers to the above questions will be taken up in this unit**

## 8. SUMMARY

You have learnt

- **Forces between atoms and molecules make up the bulk matter**
- **Bonding in materials existing in solid, liquid or gaseous state.**
- **Reasons to believe that intermolecular and interatomic forces exist**
- **The forces are both attractive and repulsive**
- **The nature of force and its strength depends upon interatomic separation, state of matter, nature of material and external conditions of heat, pressure etc**
- **Potential energy interatomic separation graph and its link to interatomic force and interatomic separation graph. explanation of dependence of state on the above two considerations**
- **Overview of unit based on interatomic /intermolecular force /energy graphs, vis Study of few selected properties of different states of matter**

**Solid-Elasticity**

**Liquid and fluid – pressure up thrust, buoyancy Archimedes principle, Pascal's law, Bernoulli's principle, viscosity.**

**Liquid surface property of surface tension, capillarity**

**Solid liquid and gaseous state Thermal properties for, expansion, change in temperature, change of state and heat transfer**