Ans. (*a*) **Ionic crystals.** The crystals, the molecules of which have ionic bonding are known as *ionic crystals*. Familiar examples are $NaCl$, KCl, ZnS etc.

Ionic bonding. The ionic bonding arises from the transfer of one or more electrons from the electropositive element to an electronegative element, thereby, creating a positive and a negative ion. The two types of atoms involved in ionic bonding are different from each other. The electropositive atoms have a *low ionising energy* (the energy required to remove an electron from the atom). The electro-negative elements are of high *electron affinity* and are ready to take up an additional electron to complete their outermost valence orbit and thus acquire stable configuration. The two ions thus formed, being oppositely charged, attract each other with an electrostatic coulomb force which gives rise to an attractive potential V_a the value of which in the S.I. units is given by

$$V_a = -\frac{Z_1 Z_2 e^2}{4\pi\varepsilon_0 r} = -\alpha \frac{e^2}{4\pi\varepsilon_0 r}$$

where $Z_1 e$ is the charge, say on the positive ion, $Z_2 e$ the charge on the negative ion separated by a distance r and α is a constant known as *Madelung constant*, which has the same value for all crystals of the same structure (The value of α for $NaCl$ crystal = 1.748, for $CsCl$ = 1.763 and ZnS = 1.638). This energy keeps the atoms bound inside the solids.

As an example for ionic bonding, let us consider the case of $NaCl$ crystal. The Na atom loses the only valence electron in its outermost valence orbit and becomes singly charged positive Na^+ ion. The Cl atom is short of one electron in its outermost valence orbit. It, therefore, takes up the electron from Na and becomes a singly charged negative Cl^- ion with its outermost electron orbit now completely filled. The Na^+ and Cl^- ions are bound strongly due to electrostatic force of attraction to form a stable $NaCl$ crystal as shown in Fig. 3.2.

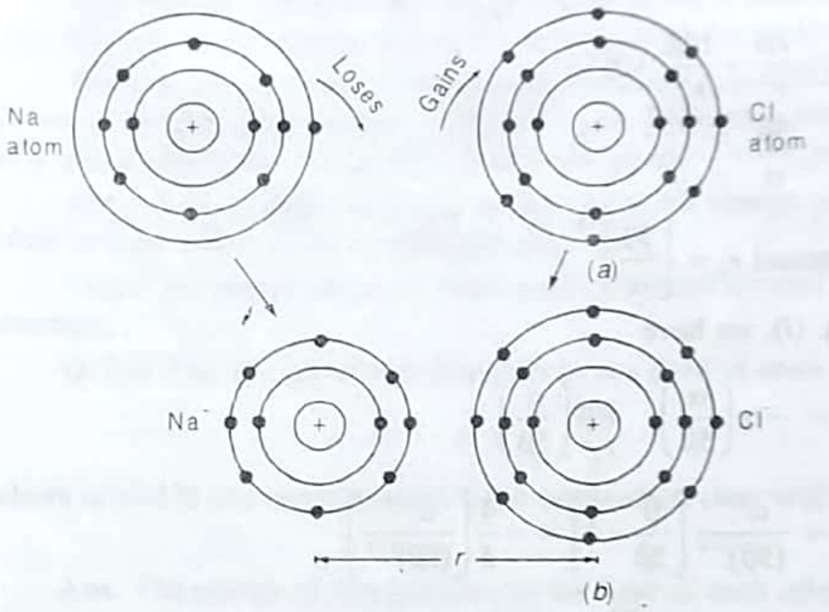

Fig. 3.2

Hence an ionic bond can exist between two atoms when one of them has as many valence electrons as are required by the other to complete its outermost valence orbit.

It is clear from the above discussion that after the transfer of electrons, the ions attain electronic configuration similar to inert gas atoms. The charge distribution in the two ions is, therefore, spherically symmetric and as a result *the bond is non-directional.*

As permitted by radius ratio rule, each Na^+ ion is surrounded by six Cl^- ions and in turn each Cl^- ion is surrounded by six Na^+ ions to maintain the charge neutrality.

Thus the binding together of atoms by virtue of the net electrostatic forces of attraction between ions formed by the shifting of electrons from one atom to the other is called *ionic bonding*. These are usually very strong. $NaCl$, KCl, LiF, $NaBr$ and ZnS are some examples of this types of bonding.

Properties of ionic crystals. Following are the properties of crystals formed by ionic bonds.

(*i*) The ionic crystals are *strong*, *hard* and *brittle*. The cohesive energy of ionic crystals is very high, *i.e.*, the ionic bonds are very strong. Thus the ionic crystals have very high melting point

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and possess high latent heat of fusion. For example, binding energy of $NaCl$ = 7.8 eV and of LiI = 10.4 eV.

Strong electrostatic forces between positive and negative ions make ionic crystals hard. However, when a shearing force is applied to an ionic crystal the ions tend to slip past one another with relatively more ease, as the ionic bonding is non-directional. A stage is reached when strong repulsive forces cause a fracture of the crystal, *i.e.*, the crystal is brittle.

(*ii*) The ionic crystals are generally insulators. Their electrical conductivity is very low at ordinary temperatures but increases with increase of temperature.

The ionic crystals consist of ions having closed shell structure, *i.e.*, they do not have free electrons. Hence they are electric insulators. The small conductivity present in the ionic crystals is due to the diffusive motion of ions and hence the conductivity of ionic crystals increases with increase in temperature.

(*iii*) Ionic crystals are normally transparent to visible light while they exhibit a single characteristic optical reflection peak in the infra-red region.

(*iv*) Their dielectric constant changes with the frequency of A.C. applied.

(*v*) They are generally brittle in nature and cannot be drawn into sheets or wires.

(*vi*) Polar liquids like water are able to dissolve many ionic crystals but they are not soluble in non-polar liquids like ether due to low value of di-electric constant.

(*b*) **Electron affinity.** *It is defined as the energy given up when a neutral atom gains an electron and becomes a negative ion.*

Ionisation energy. *It is the energy required to remove an electron from an atom and thereby creating a positive ion.*

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