IONIC BONDING

The bond formed from the complete transfer of electrons from the outermost orbit of one atom to that of another is called an ionic bond.

Example

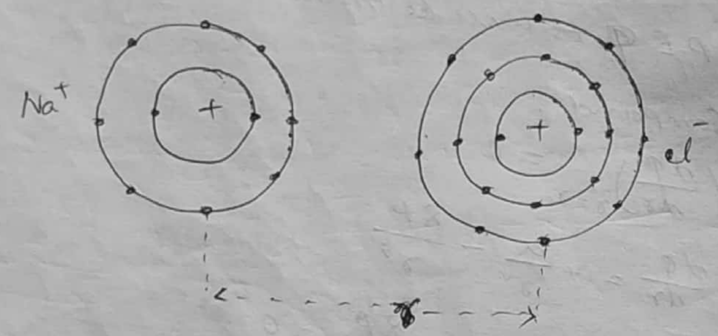
The formation of NaCl is given by

$$Na(11) + Cl(17) \longrightarrow Na^{+}Cl^{-}$$

2, 8, 1   2, 8, 7   (2,8) (2,8,8)

Complete transfer

$$Na^{\times} + \cdot\ddot{\underset{\cdot\cdot}{Cl}}: \longrightarrow Na^{+}[\overset{\times}{\ddot{Cl}}:] \text{ or } Na^{+}Cl^{-}$$



The Na-atom completely transfer its single valance electron to Cl-atom and Na-atom becomes Na^+ ion and its structure becomes (2,8) and each Cl-atom changes to Cl^- ion and its structure becomes (2,8,8). Thus each Na^+ ion and Cl^- ion are held together by electrostatic force of attraction. $CaCl_2$, KCl, CaO, Na_2O etc are the example of ionic bonding.

Characteristic properties of ionic crystal :-

The ionic crystals possess the following properties.

(i) The ionic crystals are strong, hard and brittle, because of the strong inter molecular force of attraction, their melting point and boiling point are very high.

(ii) The ionic crystals are generally insulator. Their electrical conductivity is very low at ordinary but increases with increase of Tempr.

(iii) Ionic crystals are generally transparent to visible light.

(iv) They are soluble in water because they ionise in water. The ions become hydrated and they disappear in the intermolecular space of water molecules and dissolve.

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

(vi) They are generally brittle in nature and can not be drawn into wire or sheet.

Explain

"Ionic crystals are hard but brittle"

The ionic crystals are strong, hard and brittle. The cohesive energy of ionic crystals is very high, so ionic bonds are very strong. Thus the ionic crystals have very high melting point 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 sharing 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.

"Ionic solids are poor conductor"

The ionic crystals are generally insulators. Their electrical conductivity is very low at ordinary tempr but increases with increase in tempr.

The ionic crystals consist of ion having closed shell structure, i.e they do not have free electrons. Hence they are electric insulators. The small conductivity present in the

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ionic crystals is due to the diffusive motion of ions and hence the conductivity of ionic crystals increases with increase in Tempr.

BINDING ENERGY OF IONIC CRYSTAL :-

To find the value of total binding energy of an ionic crystal we shall take up the typical case of sodium chloride. The force of attraction between the Na^+ and Cl^- ions is given by $F = \frac{Z_1 Z_2 e^2}{4\pi\epsilon_0 r^2}$ where $Z_1 e$ is the charge of positive ion (say) and $Z_2 e$ is the charge of negative ions, separated by a distance r. This force gives rise to an attractive potential energy term ϕ_a the value of which in S.I units is given by

$$\phi_a = -\frac{Z_1 Z_2 e^2}{4\pi\epsilon_0 r^2} = -\alpha \frac{e^2}{4\pi\epsilon_0 r}.$$

Where α is a constant known as Madelung constant. The force of attraction between the Na^+ and Cl^- ions increases as the distance r between the two ions decreases. When they come very close to each other, their electron shells interact, as their cores begin to overlape and Pauli's exclusion principle leads to a repulsive force which increases rapidly with decreasing inter nuclear distance r. The repulsive energy term arising due to this force of repulsion is given by $\phi_r = \frac{B_n}{r^n}$.

The sign of the repulsive energy term is +ve

∴ Resultant potential energy

$$\phi = \phi_a + \phi_r = -\frac{\alpha e^2}{4\pi\epsilon_0 r} + \frac{B_n}{r^n} \quad \text{------(1)}$$

At the equilibrium separation r_0, ϕ has a minimum value

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$$\therefore \left(\frac{d\phi}{dr}\right)_{r=r_0} = 0 \Rightarrow \frac{\alpha e^2}{4\pi\epsilon_0 r_0^2} - \frac{n B}{r_0^{n+1}} = 0$$ (putting the value of ϕ from (1) and differentiating.)

$$\text{or} \quad \frac{\alpha e^2}{4\pi\epsilon_0 r_0^2} = \frac{n B_n}{r_0^{n+1}}$$

$$\therefore B_n = \frac{\alpha e^2 r_0^{n-1}}{4\pi\epsilon_0 n}$$

putting the value of B_n in (1) and at $r = r_0$,

Hence $$\phi = -\frac{\alpha e^2}{4\pi\epsilon_0 r_0}\left(1 - \frac{1}{n}\right) \quad \text{--- (II)}$$

The total binding energy of a crystal having N positive and N negative ions is given by

$$\phi = \frac{N\alpha e^2}{4\pi\epsilon_0 r_0}\left[1 - \frac{1}{n}\right] \quad \text{--- (III)},$$