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when we bring the atoms closer together, some force of attraction occurs between them and according to Quantum mechanics, their wave functions will start overlapping, Therefore *when two atoms are brought closer, it does not remain as two independent atoms, rather it forms a single two-atom system with two different energy levels to form energy band* as shown in fig. 4.3.

4.3 ORIGIN OF ENERGY BAND FORMATION IN SOLIDS

We know that when two atoms of equal energy levels are brought closer together, the original energy levels *viz* E_1 and E_2 splits each into two energy levels i.e., the $K-$ shell energy E_1 splits into E_1^1 and E_1^2, similarly the $L-$ shell energy E_2 splits into E_2^1 and E_2^2 (fig. 4.3 and fig. 4.4). Now, when three atoms are brought closer together, the original energy levels *viz* E_1 and E_2 splits each into three energy levels *viz* E_1^1, E_1^2, E_1^3 and E_2^1, E_2^2, E_2^3 respectively as shown in fig 4.5. *These type of transformations from the original energy levels into two (or) more energy levels is known as Energy Level Splitting.*

Energy Bands

Therefore, if 'N' number of atoms of equal energy levels are brought closer to form a solid, then it forms a closely spaced contineous energy levels, so called energy bands as shown in fig 4.6.

Hence an energy band can be defined as, the range of energies possessed by an electron in a solid. The magnified view of the energy band which consists of a large number of very closely spaced energy levels is shown in fig. 4.7.

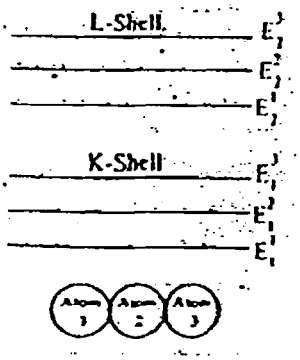

Fig. 4.5

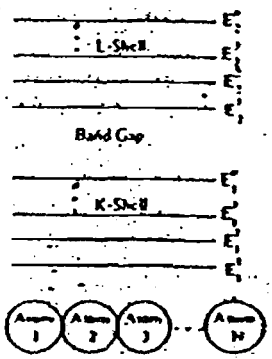

Fig. 4.6

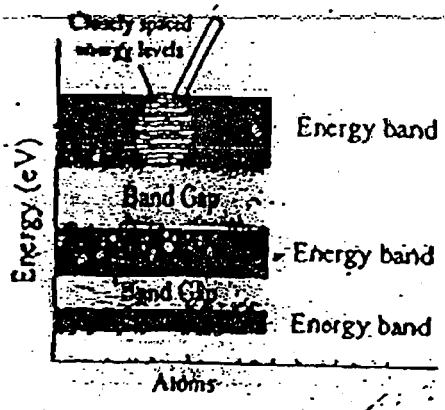

Fig. 4.7

Note: The overall range of energies from the lowest energy level to the highest energy level of a band is called the width of band. From fig. 4.7, we can also see that the width of band increases gradually due to the increase of electrons from the inner most orbit towards the outer most orbit.

Inner Filled Bands, Valence Band and Coduction Band

During the formation of energy bands, the inner filled energy levels forms a energy band, called *Inner filled bands.*

Similarly the electrons in the outermost shells of atoms forms a energy band, called valence band. The valence band will be of completely filled (or) partialy filled with electrons, based on the type of the materials.

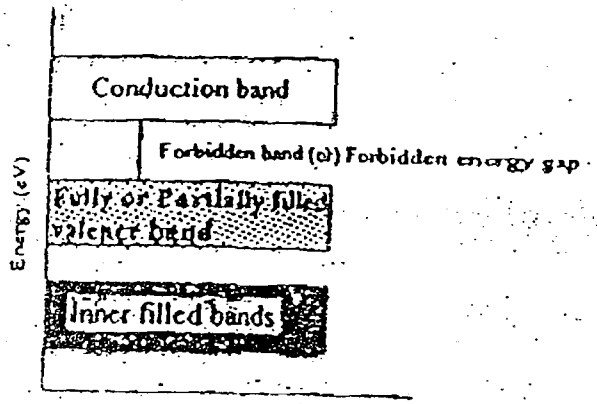

Fig. 4.8

If an electron comes out from valence band for conduction, then they form an energy level corresponding to the energy band called conduction band as shown in fig. 4.8.

Forbidden Band

While referring to energy bands, they are separated by small regions which does, not allow any energy levels. Such regions between the energy bands are called *forbidden bands* (or) *forbidden energy gap* E_g as shown in fig. 4.8.

Note: Though there are number of energy bands in solids, valence band (the range of energies possessed by valence electrons) and conduction band (the range of energies possessed by conduction electrons) are very important. Because only valence electrons (or) conduction electrons are capable of electrical conduction when it moves from valence band to conduction band.

4.4 ZONE THEORY OF SOLIDS

In quantum free electron theory of metals the electrons were assumed to be moving in a region of constant potential and hence it moves freely about the crystal. But it fails to explain why some solids behaves as conductors, some as insulators and some an semiconductors etc.

Therefore instead of considering an electron to move in a constant potential, *In Zone theory of solids the electrons are assumed to move in a field of periodic potential.*

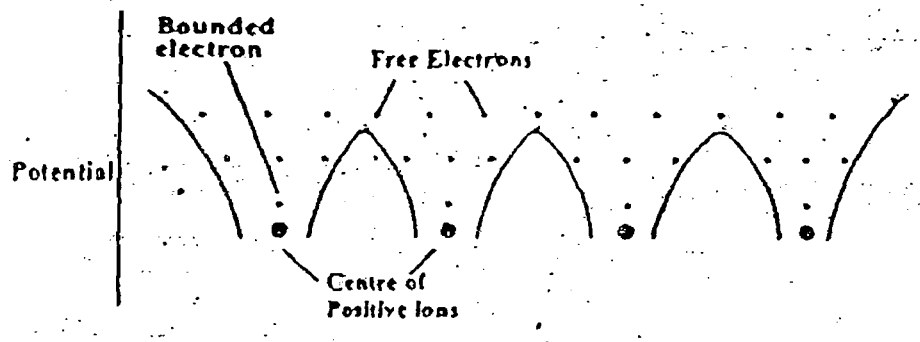

Fig. 4.9

In a metal piece, the positive ions are arranged in a regular and proper order, therefore a periodic potential (i.e) the potential field which varies periodically with the same period as the lattice, exists in the metal. Also the potential is minimum near the centre of positive ions and is maximum between the centres of ions as shown in fig. 4.9.

Therefore the potential energy of the electron near by the centre of positive ion is maximum and will not be able to move freely, but *the electrons which are above these potential peaks are free to move inside the metal and hence they are termed as free electrons.*

4.5 ENERGY SPECTRA IN ATOMS, MOLECULES AND SOLIDS

To picture the energy spectra in atoms, molecules and solids let us consider a metal say sodium, which consists of 11 electrons with electronic configuration of $1s^2\ 2s^2\ 2p^6\ 3s^1$. The energy spectrum of a single atom is as shown in fig. 4.10. When two sodium atoms and assembled to form a sodium molecule, the energy spectrum of the molecule is as shown in fig. 4.11. It is found that for a sodium molecule each atomic levels are splitted into two closely spaced levels.

Similarly if 'N' number of atoms are assembled to form a solid; then we have N number of very closely spaced sub levels so called as *energy band* as shown in fig. 4.12.