ELECTRONIC DEVICES (ED)
(18EC33)

Module - 1: Semiconductors

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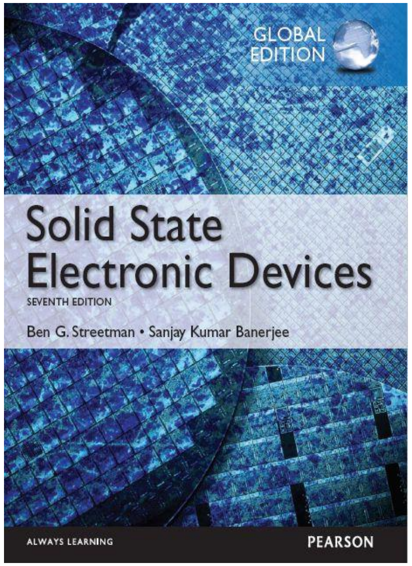

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(Text 1: 3.1.1, 3.1.2, 3.1.3, 3.1.4, 3.2.1, 3.2.3, 3.2.4, 3.4.1, 3.4.2, 3.4.3, 3.4.5).

OBJECTIVES

1. Understand conduction and valence energy bands, and how band gaps are formed
2. Appreciate the idea of doping in semiconductors
3. Use the density of states and Fermi Dirac statistics to calculate carrier concentrations
4. Calculate drift currents in an electric field in terms of carrier mobility, and how mobility is affected by scattering
5. Discuss the idea of “effective” masses

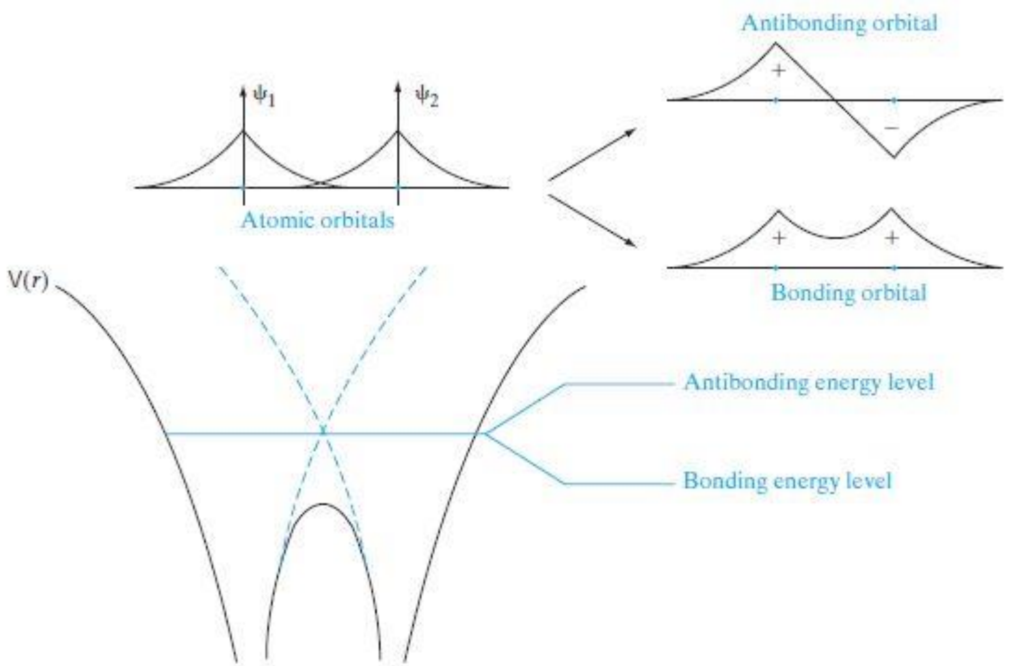
INTRODUCTION

We will briefly look at that last item as is concerns our study of solid materials. There are few things that we need to note.

1) Atoms have discrete energy levels caused by the potential wells around the nucleus.

2) Solids are made up a large number of atoms. These atoms have energy levels as well, but the potential wells are adjusted by the fields from the nearby atoms. Here the Pauli Exclusion principle comes into play.

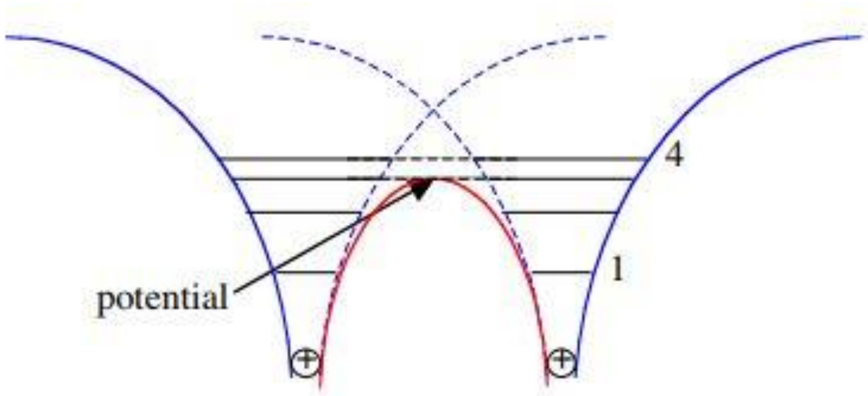
LINEAR COMBINATION OF ATOMIC ORBITALS (LCAO)



This leads us to a new issue. We are dealing with atoms that are in close proximity to each other. What happens in such cases?

Well let's put two atoms close together and draw the total potential well. This is effectively what happens when two atoms are bonded together.

LINEAR COMBINATION OF ATOMIC ORBITALS (LCAO)



Here we see that shells 3 and 4 above in each of the atoms 'mix' with the states in the other atoms. This would imply that if both atoms had state 3 filled, then we would have two identical electrons orbiting the two atoms.

ATOMIC BONDING

We bring this idea up because we are dealing with solid-state devices. Thus the interaction of multiple atoms and atomic species is important to our understanding of this topic. How these atoms bond together is critical to the characteristics of the devices.

We will now examine bonds between atoms. They fall into four main categories.

1) Ionic NaCl and all other salts
2) Metallic Al, Na, Ag, Au, Fe, etc
3) Covalent Si, Ge, C, etc
4) Mixed GaAs, AlP, etc.

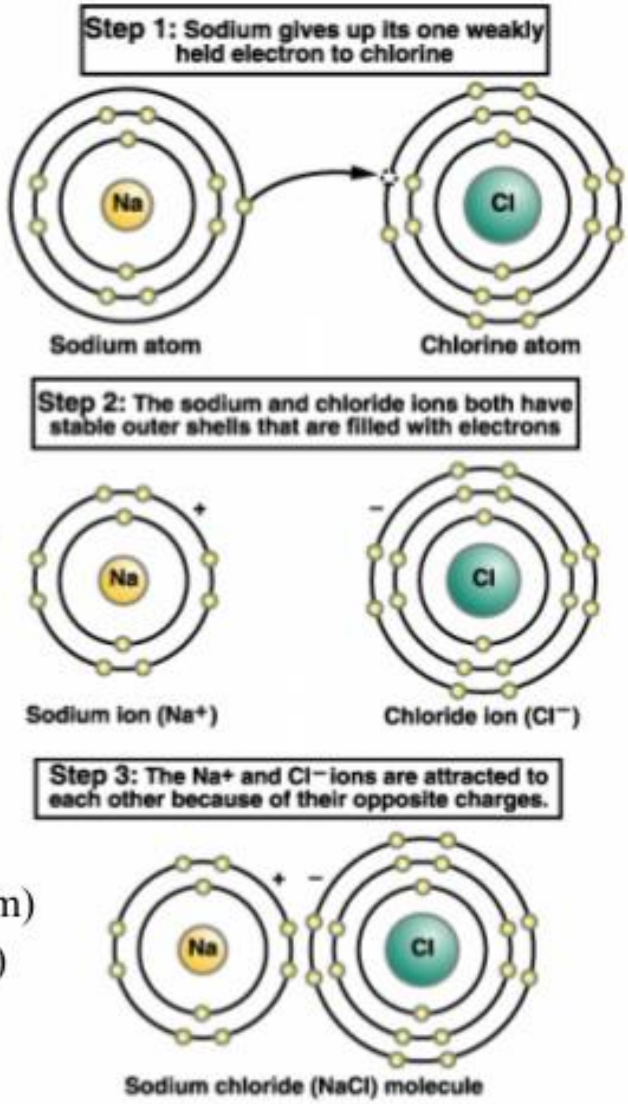
Ionic Bonding

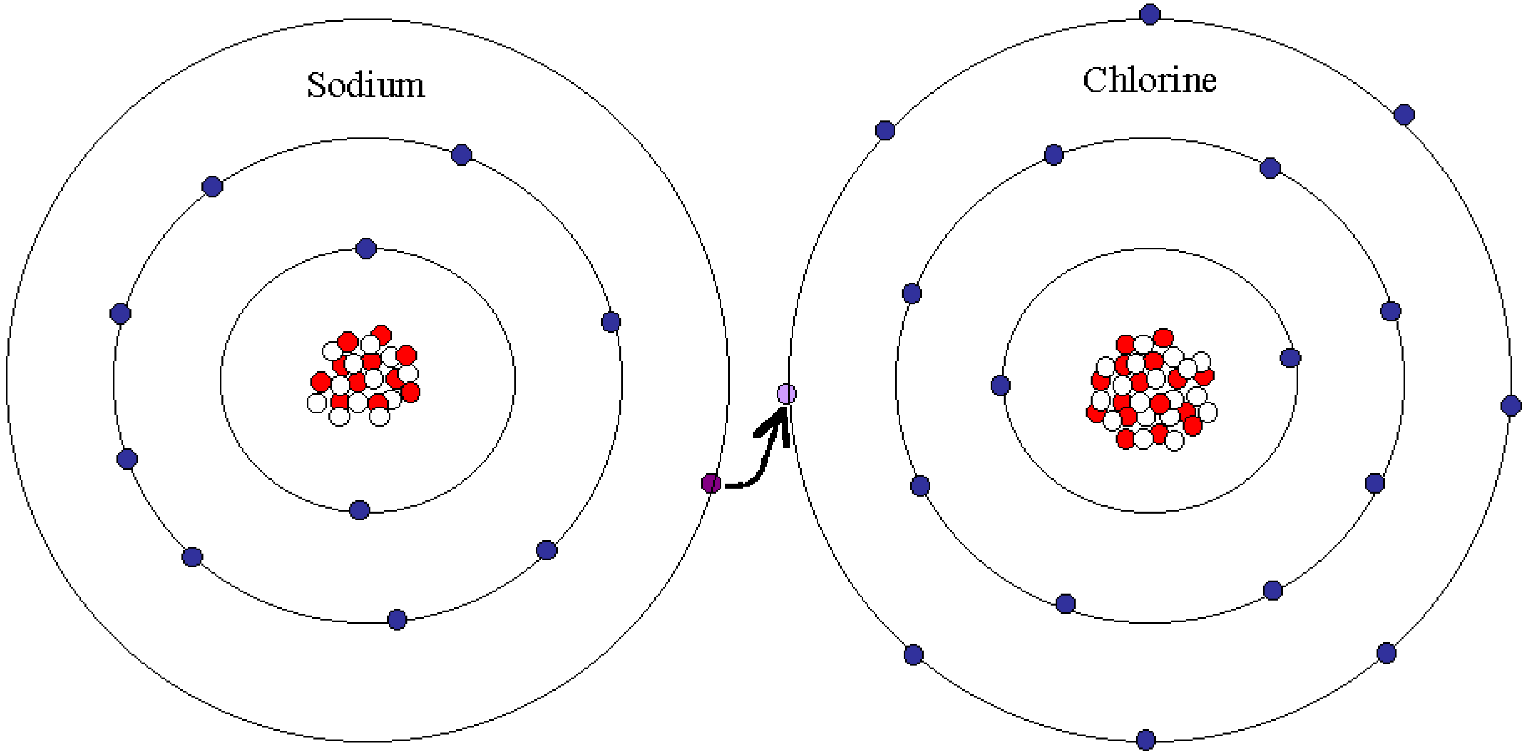
- **Ion**: an atom or molecule that *gains* or *loses* electrons (acquires an electrical charge). Atoms form **cations** (+charge), when they lose electrons, or **anions** (-charge), when they gain electrons.
- **Ionic bonds** are *strong bonds* formed when *oppositely charged ions are attrac to each other*.
- Ionic bonds are **non-directional** (ions may be attracted to one another in any direction)

Example:

Atomic Radius: Na (r = 0.192nm) Cl (r = 0.099nm)

Ionic Radius : Na (r = 0.095nm) Cl (r = 0.181nm)



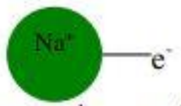

Sodium
Chlorine

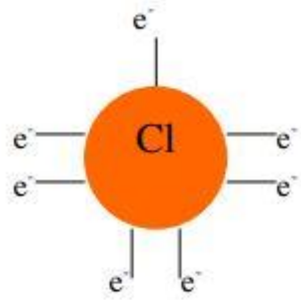
1.1 BONDING FORCES IN SOLIDS

BONDING FORCES IN SOLIDS

- The first of these types of material is related to the complete transfer of an electron from one atom to another.
- Cl for example would like to have a closed top shell and thus it takes an electron from the Na to produce a [Ar] electron cloud.
- Sodium on the other hand would like to give up an electron, so to also have a closed shell, in this case [Ne].
- Both of these acceptor/donor processes provide lower energy states. This means that the two particles Na+ and Cl- are electrostatically pulled together or bonded.

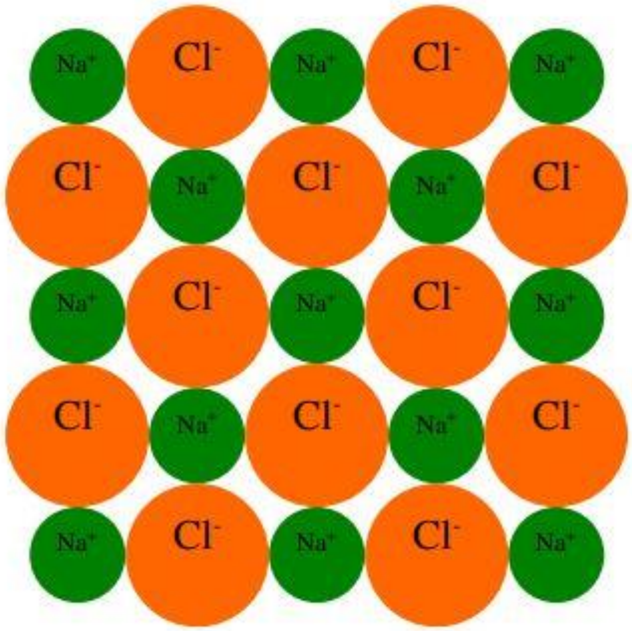
BONDING FORCES IN SOLIDS CONT..,



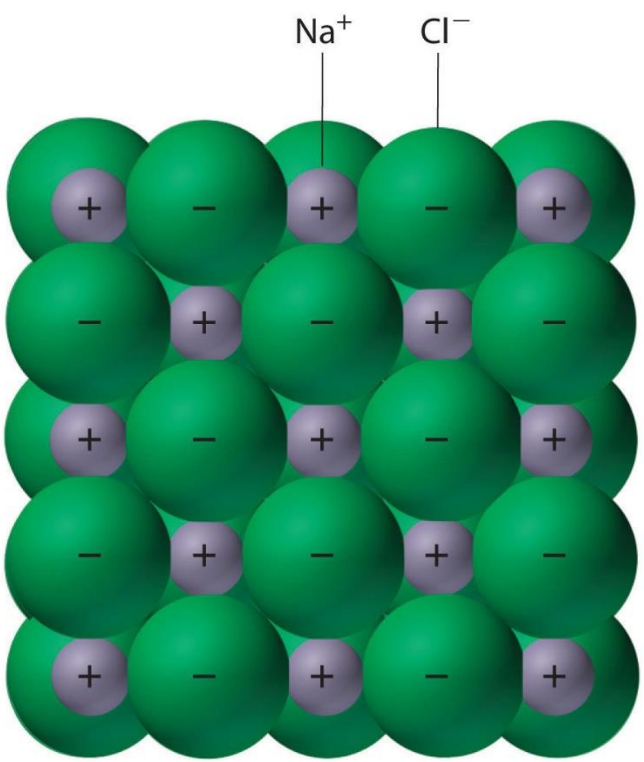


$Na = [Ne]\ 3s^1 \Rightarrow Na^+ = [Ne]$

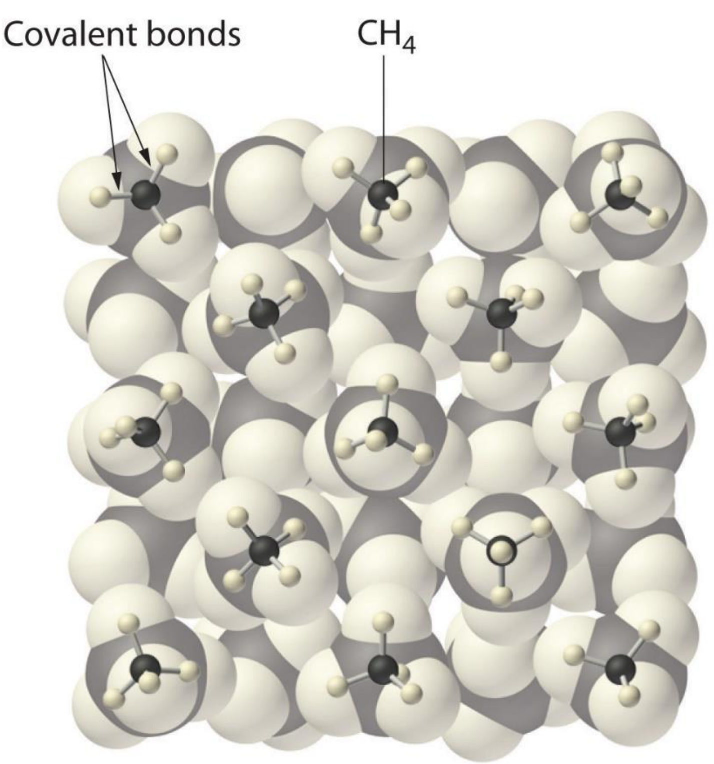
$Cl = [Ne]\ 3s^2 3p^5 \Rightarrow Cl^- = [Ne]\ 3s^2 3p^6 = [Ar]$



3D EXAMPLE



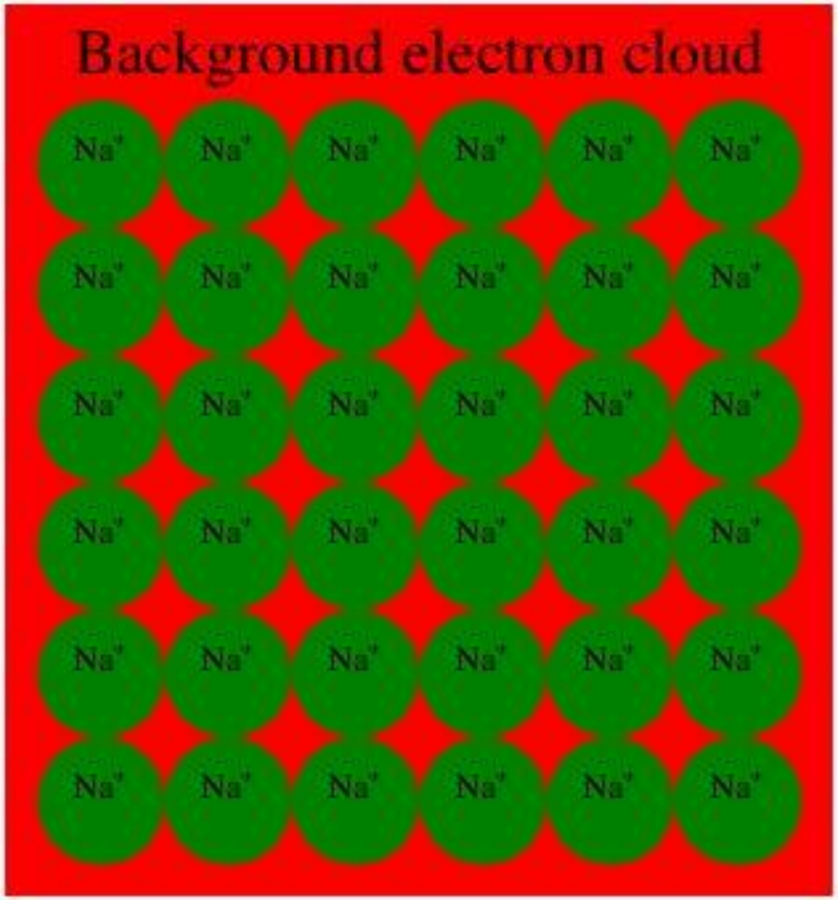
(a) Ionic solid: strong electrostatic interactions



(b) Molecular solid: weak intermolecular forces

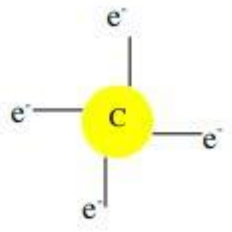
COVALENT BOND

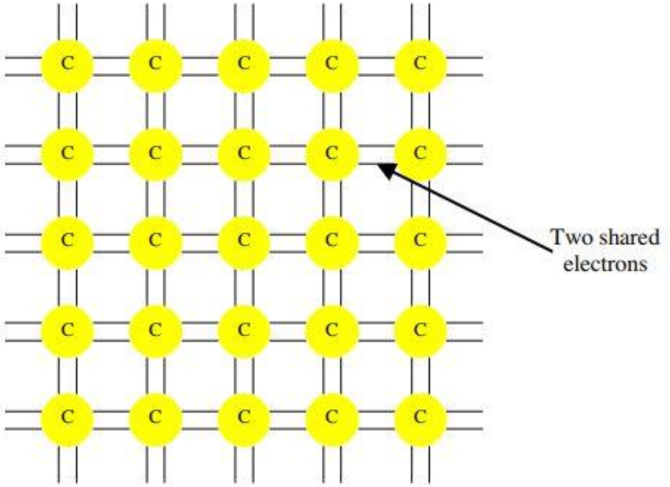
- The second of these comes in two forms. The first form has only a few valance electrons in the outer orbital.
- These outer valance electrons thus tend to be weakly bound to the atoms and are ‘free’ to move around.
- An example of this type would be Sodium, Na = [Ne]3s1



COVALENT BOND

- In the covalent bond, two atoms share one or more valance electrons.
- In this way, each atom thinks that it has a closed outer shell. Because the outer shell is closed, these materials are typically insulators – although some might also be semiconductors.
- This in part depends on the size of the atoms. The smaller it is, the more likely it is to be an insulator. An example of this is Carbon, C=[He]2s^2 2p^2

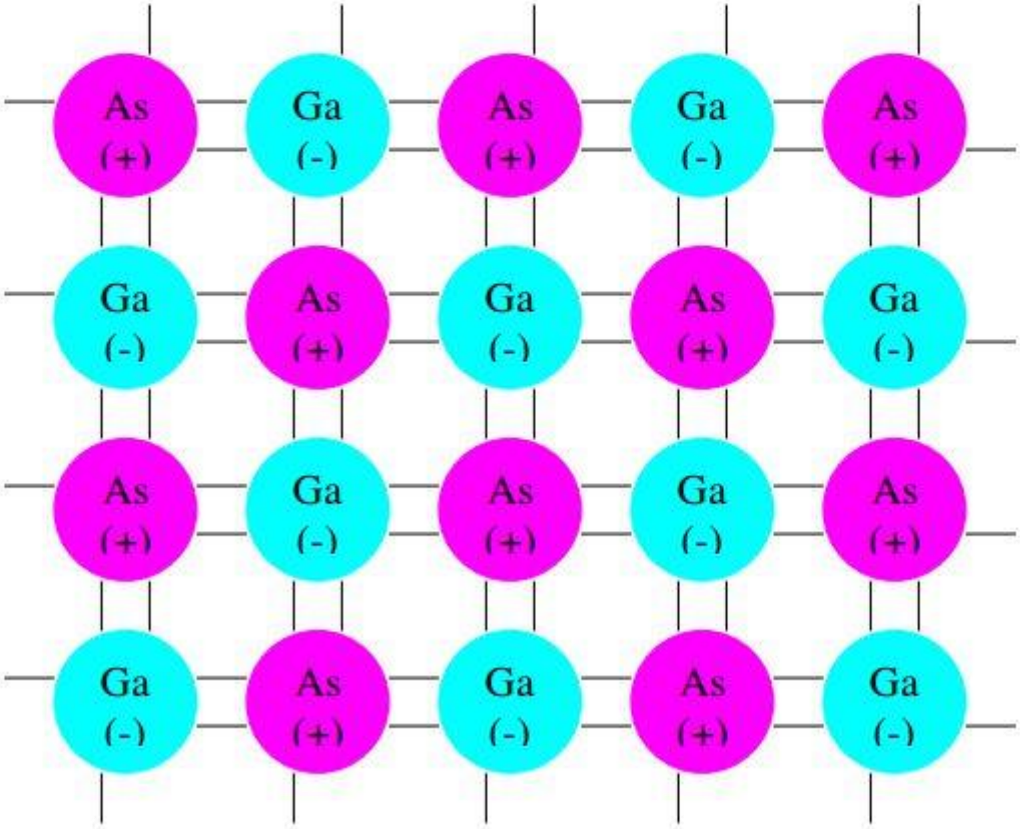




MIXED STATE

- Mixed states are a combination of Covalent and ionic. An example is GaAs.
- We see that Ga, which is column III, has three electrons in the outer shell while As, which is column V, has 5.
- As such the pair has 8 outer shell electrons, just enough to create a closed outer shell.
- Ga, it turns out wants to attract an additional electron more than As wants an additional electron.
- Thus one of the electrons spends more time near the Ga atom, making it partially negatively charged and the As partially positively charged. (A full electron is not transferred.)
- Thus, GaAs has some properties of covalent bonding and some properties of ionic bonding.

MIXED STATE CONT…,



THANK YOU