



PHYSICS PART

Question (1) (15 degrees)

(A) Give short notes on:

i) Saturation current and stopping potential

Saturation Current: is the maximum value of photo-current after which the current can not increased by increasing the potential difference

Stopping Potential: is the value of negative potential at which the photo-current is zero

ii) Types of absorption lines.

Absorption lines are typically classified as:

Electronic lines: correspond to a change in the electronic state of an atom or molecule and are typically found in the visible and ultraviolet region.

Vibrational lines: correspond to changes in the vibrational state of the molecule and are typically found in the infrared region.

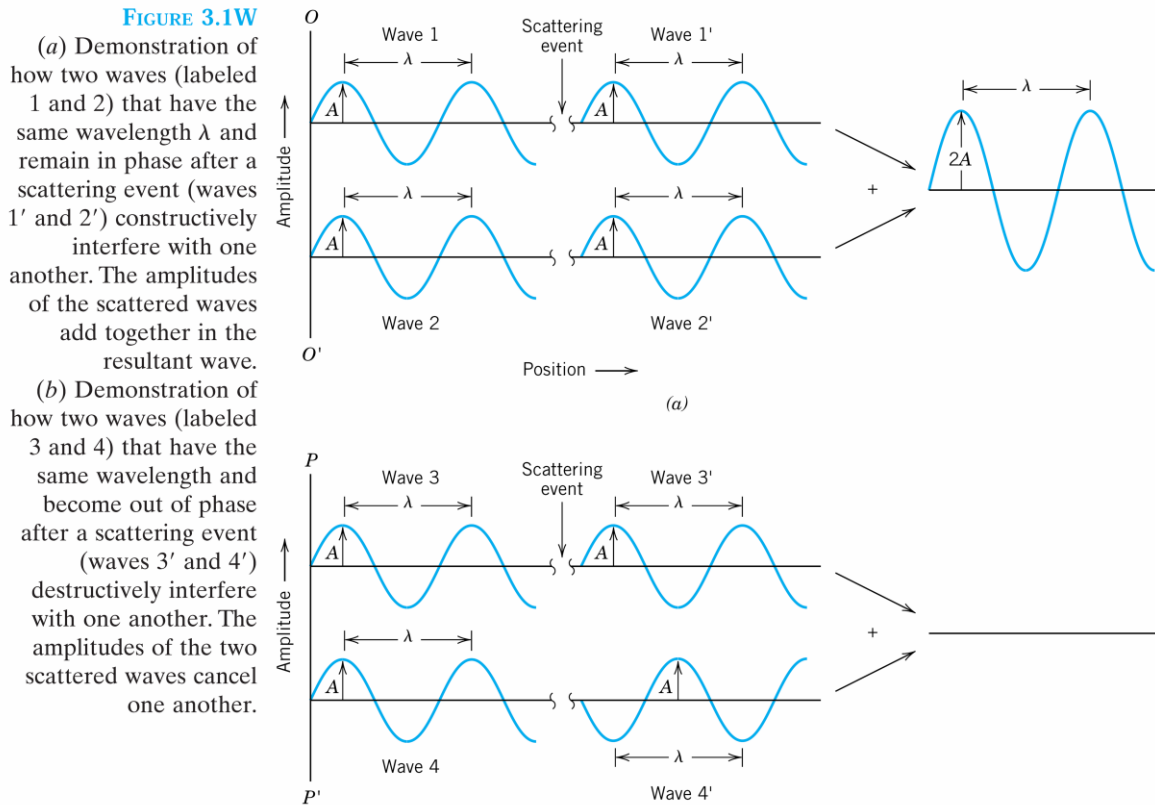
Rotational lines: correspond to changes in the rotational state of a molecule and are typically found in the microwave spectral region.

iii) Types of polymers

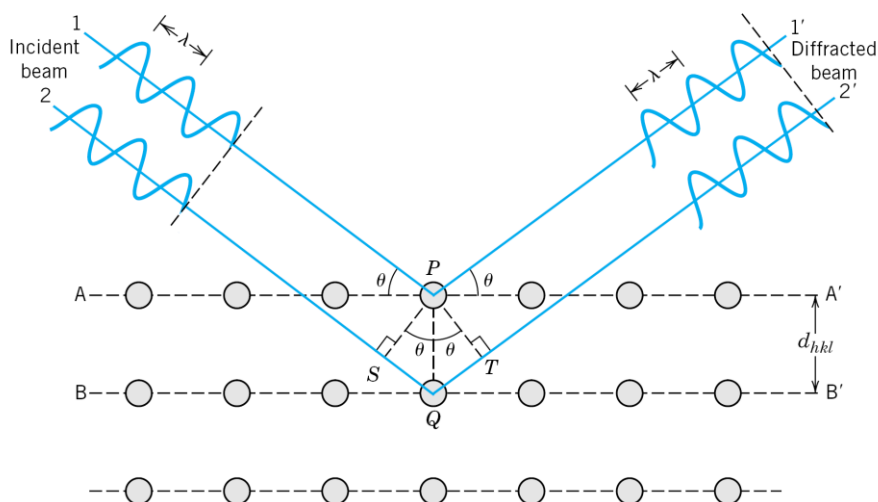
Polymers are often classified as being either a thermoplastic or a thermosetting material. Thermoplastic materials can be easily remelted for forming or recycling and thermosetting material cannot be easily remelted. In thermoplastic materials consist of long chainlike molecules. Heat can be used to break the van der Waal forces between the molecules and change the form of the material from a solid to a liquid. By contrast, thermosetting materials have a three-dimensional network of covalent bonds. These bonds cannot be easily broken by heating and, therefore, can not be remelted and formed as easily as thermoplastics.

(B) Discuss the x-ray diffraction by a crystal lattice then deduce Bragg's law when x-rays are incident at an angle θ on a set of crystallographic planes with interplaner spacing of d ?

Answer:



Let us now examine the necessary conditions for diffraction of X-rays by a periodic arrangement of atoms.



Consider the two parallel planes of atoms A–A' and B–B' in Figure (2), which have the same h, k, and l Miller indices and are separated by the interplanar spacing d_{hkl} . Constructive interference of the scattered rays 1' and 2' occurs also at an angle θ to the planes, if the path length difference between 1-P-1' and 2-Q-2' (i.e., SQ + QT) is equal to a whole number, n, of wavelengths. That is, the condition for diffraction is:

$$\begin{aligned} n \lambda &= SQ + QT \\ n \lambda &= d_{hkl} \sin \theta + d_{hkl} \sin \theta \\ &= 2 d_{hkl} \sin \theta \quad \dots(1) \end{aligned}$$

Equation (1) is known as **Bragg's law**; also, n is the order of reflection, which may be any integer (1, 2, 3, . . .) consistent with $\sin \theta$ not exceeding unity.

(C) If the photoelectric threshold in a certain metal is 600 nm. Find:

- i) The work function of the metal
- ii) The frequency of light which ejects electrons from the metal surface that are fully retarded by a reverse potential of 3 V?

$$[h = 6.6 \times 10^{-34} \text{ J.s, } c = 3 \times 10^8 \text{ m/s, } e = 1.6 \times 10^{-19} \text{ C, } m = 9.1 \times 10^{-31} \text{ Kg}]$$

Answer:

$$i) h = 6.6 \times 10^{-34} \text{ J.s,}$$

$$c = 3 \times 10^8 \text{ m/s,}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$w = h c / \lambda$$

$$= 6.6 \times 10^{-34} \times 3 \times 10^8 / 600 \times 10^{-9}$$

$$= 3.3 \times 10^{-19} \text{ J}$$

$$ii) h\nu = w + e V$$

$$6.6 \times 10^{-34} \nu = 3.3 \times 10^{-19} + 1.6 \times 10^{-19} \times 3$$

$$\nu = 1.23 \times 10^{15} \text{ Hz}$$

(D) X-rays of wavelength 15×10^{-2} nm are reflected from the (340) set of planes of a cubic crystal whose lattice parameter is 3 Å. Find:

- i) The interplaner spacing of (340) planes
- ii) The diffraction angle for the 1st order of reflection?

Answer:

$$i) d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

$$d_{hkl} = \frac{3}{\sqrt{3^2 + 4^2 + 0^2}} = 0.6A^\circ$$

$$ii) n \lambda = 2 d_{hkl} \sin \theta$$

$$1 \times 1.5 = 2 \times 0.6 \sin \theta$$

$$\sin \theta = 1.25$$

θ can not be calculated as $\sin \theta > 1$

this is results from that the wavelength of the x-rays used is more greater than the interplaner spacing so that no diffraction can be realized.

Question (2) **(15 degrees)**

(A) Define the concept of metal and non-metal materials then explain the main possible processes for bonding of these two types?

Answer:

If an atom has only a few electrons in its outer shell, it will tend to lose them to make this shell “empty”. These elements are metals.

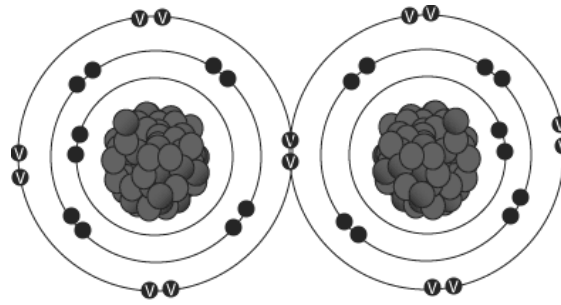
If an atom has a nearly full electron outer shell, it will try to find electrons from another atom so that it can fill its outer shell. These elements are described as nonmetals.

When metal atoms bind, the bond is called metallic

When nonmetal atoms bind, the bond is called covalent bond.

When metal and nonmetal atoms bind, the bond is called ionic bond.

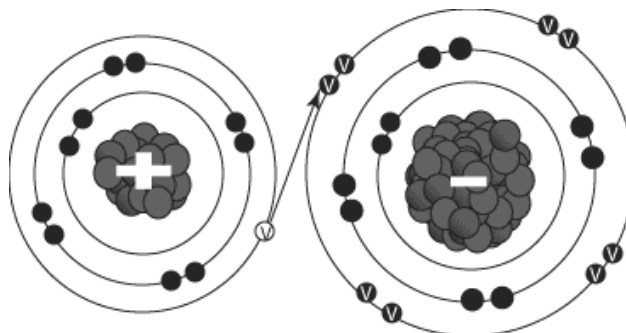
1. Covalent Bond



In *solid materials with covalent bonds*, the binding energies are of ~ 10 eV per molecule and hence covalent bonds are very strong. Generally, solid materials with covalent bonds:

- Are very hard because bond is strong and particles cannot easily slide past one another.
- Are good insulators because there are no free electrons or ions.
- Are transparent because their electrons are not moving from atom to atom and less likely to interact with light photons.
- Are brittle and tend to cleave rather than deform because bonds are strong.

1. Ionic Bond

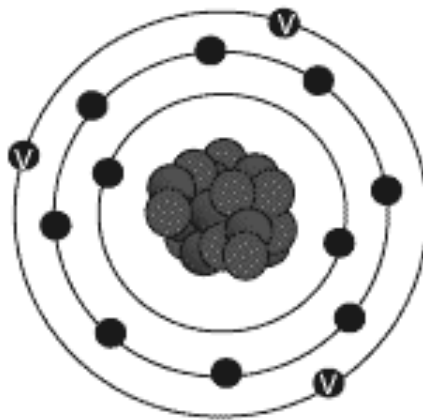


In *solid materials with ionic bonds*, the binding energies are of $\sim (5 - 10)$ eV per molecule and hence ionic bonds are relatively strong. Solids with ionic bonds:

- Are hard because bond is strong and particles cannot easily slide past one another.

- Are good insulators because there are no free electrons or ions (unless dissolved or melted).
- Are brittle and tend to cleave rather than deform because bonds are strong.
- Are transparent because their electrons are not moving from atom to atom and less likely to interact with light photons.
- Have high melting and boiling point because ionic bonds are relatively strong.

3. Metallic Bond



In *metallic solid*, the binding energies are of $\sim (1 - 5)$ eV per molecule and hence metallic bonds are little strong. Some common features of materials with metallic bonds:

- Considerably hard
- Good electrical and thermal conductors due to their free valence electrons
- Opaque because their electrons are free to move through the electron cloud and more likely to interact with light photons.
- Relatively ductile

(B) Compare the main characteristics of Amorphous and crystalline Solids?

Answer:

Solids with amorphous structure share the following common properties:

- These solids do not have long range of periodicity in arrangement of atoms.
- Amorphous solids do not have characteristic geometrical shape.
- When amorphous solids are rotated about an axis, their appearance will change.

This shows that they are *unsymmetrical*.

- Physical properties of amorphous solids are the same in different direction.

i.e. amorphous solids are known as *Isotropic*.

- They don't have particular melting point.

That they melt over a wide range of temperature.

- Amorphous solids don't break at fixed cleavage planes.

i.e. they break into two pieces with irregular surface

crystalline solids have the following fundamentals properties:

- Crystalline solids exist in a regular, orderly arrangement.
- Crystalline solids have characteristic geometrical shape.
- When crystalline solids are rotated about an axis, their appearance does not change.

This shows that they are *symmetrical*.

- Physical properties of crystalline solids are different in different directions.

i.e. crystalline solids are known as *Anisotropic*.

- They have sharp melting point.

- They have a definite heat of fusion.
- Crystalline solids break along particular direction at fixed cleavage planes.

i.e. they break into two pieces with plane surfaces

(C) In what way do impurities can improve the electrical properties of semiconductors? Discuss the main methods of impurity doping? (your answer must be supported by the atomic and energy band diagrams)

Answer:

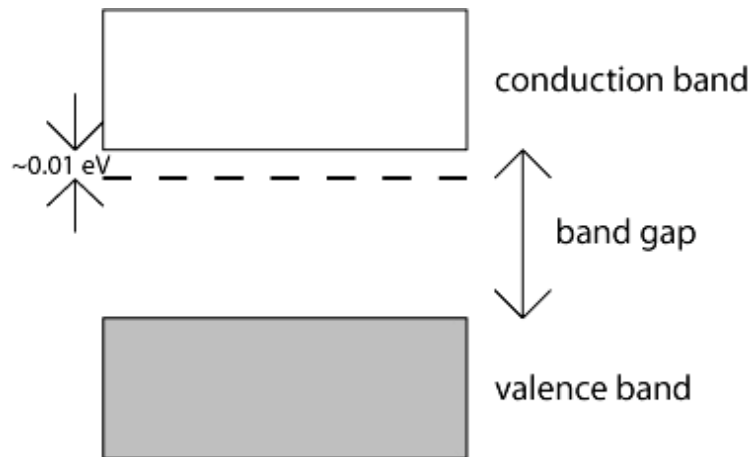
In most pure semiconductors, at room temperature, the concentration of charge carriers is much lower than for a metallic conductor. For example, The number of thermally excited electrons in silicon (Si), at 298 K, is 1.5×10^{10} electrons per cm^3 . In gallium arsenide (GaAs) the population is only 1.1×10^6 electrons per cm^3 . This may be compared with the number density of free electrons in a typical metal, which is of the order of 10^{28} electrons per cm^3 .

Given these numbers of charge carriers within semiconductors, it is no surprise that, when they are extremely pure, silicon and other semiconductors have high electrical resistivities, and therefore low electrical conductivities. This problem can be overcome by doping a semiconducting material with impurity atoms. Even very small controlled additions of impurity atoms at the 0.0001% level can make very large differences to the conductivity of a semiconductor. Electrical conductivity of semiconductors can be increased by two different types of doping which will be described as follows:

a. n-type semiconductors

In this case, a very small number of atoms of group V elements such as arsenic (As) are added to the silicon (Si) crystal as substitutional atoms in the lattice. Arsenic atoms have five valence electrons while silicon atoms has only four valence electrons so, the fifth electrons of arsenic are bound only weakly to their parent impurity atoms (the bonding energies are of the order of 0.01 eV), This is often represented

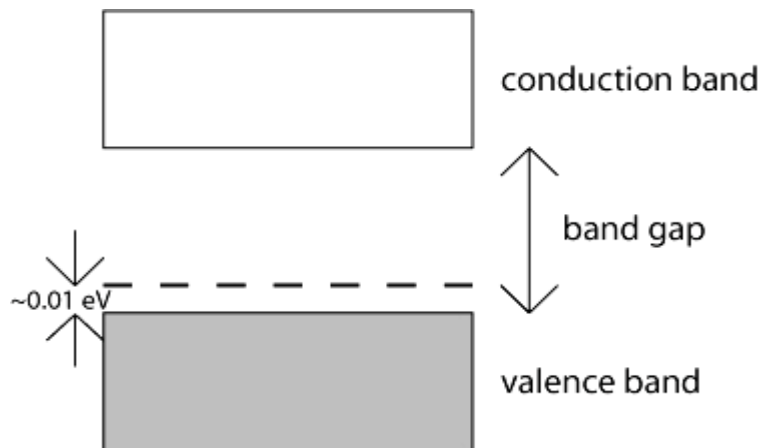
schematically in band diagrams by the addition of 'donor levels' just below the bottom of the conduction band.



b. p-type

semiconductors

In this case, a very small number of atoms of group III elements such as gallium (Ga) are added to the silicon (Si) crystal as substitutional atoms in the lattice. Gallium atoms have three valence electrons while silicon (Si) atoms has only four valence electrons so, this case results in presence of vacancies called holes in the electron structure of the crystal. This is often represented schematically in band diagrams by the addition of 'acceptor levels' just above the highest valence band



(D) Nickel has atomic mass of 58.69 g/mol and at room temperature; it has a density of 8.91 g/cm³. If Nickel crystallizes with a Face-centered cubic structure, Find:

- i)** The edge length of the unit cell of nickel.
- ii)** The radius of a nickel atom.

[Avogadro's number = 6×10^{23} atom/mole]

Answer:

i) $n = 4$

$$\rho = 8.91 \text{ g/cm}^3$$

$$A = 58.69 \text{ g/mol}$$

Avogadro's number = 6×10^{23} atom/mole

$$\rho = \frac{nA}{V_c N_A}$$

$$8.91 = \frac{4 \times 58.69}{6 \times 10^{23} (a^3)}$$

$$a = 3.5 \times 10^{-8} \text{ cm}$$

ii) $a = 2R\sqrt{2}$ (FCC)

$$3.5 \times 10^{-8} = 2R\sqrt{2}$$

$$R = 1.24 \times 10^{-8} \text{ cm}$$