3. (a) In a diffraction experiment, the slit is illuminated by light of wavelength 600 nm. The first minimum of the pattern falls at $\theta = 30°$. Calculate the width of the slit.

(b) Show that the angular width of the first diffraction fringe is half of that of the central fringe.

(c) If a monochromatic source of light is replaced by white light, what change would you observe in the diffraction pattern?

4. (a) In Young's double slit experiment, derive the condition for (i) constructive interference and (ii) destructive interference at a point on the screen.

(b) A beam of light consisting of two wavelengths, 800 nm and 600 nm is used to obtain the interference fringes in a Young's double slit experiment on a screen placed 1.4 m away. If the two slits are separated by 0.28 mm, calculate the least distance from the central bright maximum where the bright fringes of the two wavelengths coincide.

5. Explain Huygen's principle. Name the types of wavefronts that corresponds to a beam of light

(a) coming from a convex lens when point source placed at focus.

(b) coming from very far off source.

(c) coming from a convex lens $\mu = 1.1$ when point source placed at its focus inside water $\mu = 1.33$.

(d) wave front from a distant source fall perpendicular to an equilateral hollow prism placed in side water.

SOLUTIONS/HINTS

1. Essential condition for diffraction: the size of the obstacle or aperture (slit) must be comparable to the wavelength of the light being used. For another part of the question refer the gist of the chapter

2. a) $\Delta x = \frac{yd}{D} = \frac{\lambda}{4}$; $\Phi = \frac{\pi}{2}$; $I = 4I_0 \cos^2\frac{\Phi}{2} = 2I_0$

b) No interference pattern observed, $I_{total} = 2I_0$

c) $d\sin\theta = 10\lambda$, find θ using this formula; Angular width, $\Delta\theta = \frac{\lambda}{d}$

d) distance $= |y_5 - y_5|$ Ans - $5\lambda D/2d$

3. a) Condition for minima; $a\sin\theta = n\lambda$ use this formula to find a = 1.2 nm

b) Condition for first minimum, $a\sin\theta = \lambda$; $\theta_1 = \frac{\lambda}{a}$ $\theta_2 = -\frac{\lambda}{a}$

Angular width $= 2\theta_1 = 2\lambda/a$

c) The central maximum will remain white, secondary maxima will become colored fringes and the overlapping of different colored secondary maxima will increase.

4. a) Refer to the gist of this chapter

b) Here $y_1 = y_2$ to find the order of the bright fringes. Then calculate the position of this coinciding fringe using both pair of values. Ans: 12 mm

5. Refer to the gist of this chapter for Huygen's principle

a) plane wavefronts b) plane wavefronts c) Using lens maker's formula, we will find that lens will behave diverging. So we get diverging wavefront d) Plane wavefront

CASE STUDY/PASSAGE-BASED QUESTIONS

1. Interference of light:- If double slit apparatus is immersed in a liquid of refractive index μ, the wavelength of light reduces to λ/μ and fringe width also reduces to $\beta' = \beta/\mu$. The given figure shows a double-slit experiment in which coherent monochromatic light of wavelength λ from a distant source is incident upon the two slits, each of width w ($w \gg \lambda$) and the interference pattern is viewed on a distant screen. A thin piece of glass of thickness t and refractive index n is placed between one of the slit and the screen, perpendicular to the light path.

(i) In Young's double slit interference pattern, the angular fringe width

(a) can be changed only by changing the wavelength of incident light

(b) can be changed only by changing the separation between the two slits
(c) can be changed either by changing the wavelength or by changing the separation between two sources
(d) is a universal constant and hence cannot be changed

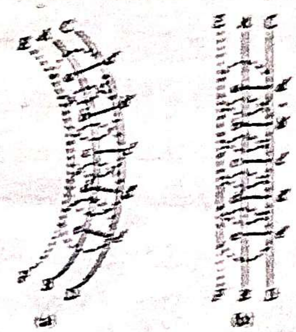
(ii) If the width w of one of the slits is increased to 2w, The amplitude due to slit become from a to:
a) 1.5a b)2a c)$\sqrt{2}$a d)no change

(iii) In YDSE, let A and B be two slits. Films of thicknesses t_A and t_B and refractive indices μ_A and μ_B are placed in front of A and B, respectively. If $\mu_A t_A = \mu_B t_B$ then the central maxima will
(a) not shift (b) shift towards A (c) shift towards B
(d) shift towards A if $t_B > t_A$ and shift towards B if $t_B < t_A$

(iv) In Young's double slit experiment, a third slit is made in between the double slits. Then
(a) fringes of unequal width are formed.
(b) contrast between bright and dark fringes is reduced
(c) intensity of fringes totally disappears
(d) only bright light is observed on the screen

(v) In Young's double slit experiment, if one of the slits is covered with a microscope cover slip, then
(a) fringe pattern disappears
(b) the screen just gets illuminated
(c) in the fringe pattern, the brightness of the bright fringes will decreases and the dark fringes will become more dark
(d) bright fringes will be more bright and dark fringes will become more dark

2. Read the following case/passage and answer the following questions:
Huygen's principle is the basis of wave theory of light. Each point on a wavefront acts as a fresh source of new disturbance, called secondary waves or wavelets. The secondary wavelets spread out in all directions with the speed light in the given medium. An initially parallel cylindrical beam travels in a medium of given refractive index, I is the intensity of the light beam.



(i) The initial shape of the wavefront of the beam from the sun is
(a)Planar (b)convex (c) concave (d)spherical

(ii) According to Huygens Principle, the surface of constant phase is
(a) called an optical ray (b) called a wave
(b) (c) called a wavefront (d) called a wavelet

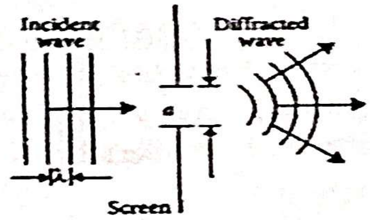
(iii) As the parallel beam enters the denser medium, it will
(a)becomes narrower (b) diverges (c) converges (d) becomes broader

(iv) Two plane wavefronts of light, one incident on a thin convex lens and another on the refracting face of a thin prism. After refraction at them, the emerging wavefronts respectively become
(a) plane wavefront and plane wavefront (b) plane wavefront and spherical wavefront
(c) spherical wavefront and plane wavefront (d) spherical wavefront and spherical wavefront

(v) Which of the following phenomena support the wave theory of light?
1. Scattering 2.Interference 3.Diffraction
4.Velocity of light in a denser medium is less than the velocity of light in the rarer medium
(a) 1,2,3 (b)1,2,4 (c)2,3,4 (d)1,3,4

3.Read the following case/passage and answer the following questions:

The phenomenon of bending of light around the sharp corners and the spreading of light within the geometrical shadow of the opaque obstacles is called diffraction of light. The light thus deviates from its linear path. The deviation becomes much more pronounced, when the dimensions of the aperture or the obstacle are comparable to the wavelength of light.



(i) Light seems to propagate in rectilinear path because

a) its spread is very large
b) its wavelength is very small
c) reflected from the upper surface of atmosphere
d) it is not absorbed by atmosphere

(ii) In diffraction from a single slit the angular width of the central maxima does not depends on

(a) λ of light used (b)width of slit
(c) distance of slits from the screen (d) ratio of λ and slit width

(iii) For a diffraction from a single slit, the intensity of the central point is

(a) infinite
(b) finite and same magnitude as the surrounding maxima
(c) finite but much larger than the surrounding maxima
(d) finite and substantially smaller than the surrounding maxima

(iv). Resolving power of telescope increases when

(a) wavelength of light decreases (b) wavelength of light increases
(c) focal length of eye-piece increases (d) focal length of eye-piece decreases

(v) In a single diffraction pattern observed on a screen placed at D metre distance from the slit of width d metre, the ratio of the width of the central maxima to the width of other secondary maxima is (approx.)

(a) 2: 1 (b) 1: 2 (c)1: 1 (d)3: 1

Answers: 1 i) c, Direct formula $\theta = \lambda/a$
ii) c, Intensity α Area of slit
iii) d, Solve using Shift = $(\mu-1)tD/d$
iv) b, Third slit also act like a coherent source and contribute in superposition
v) a, It is opaque, we will get lidht from one slit only

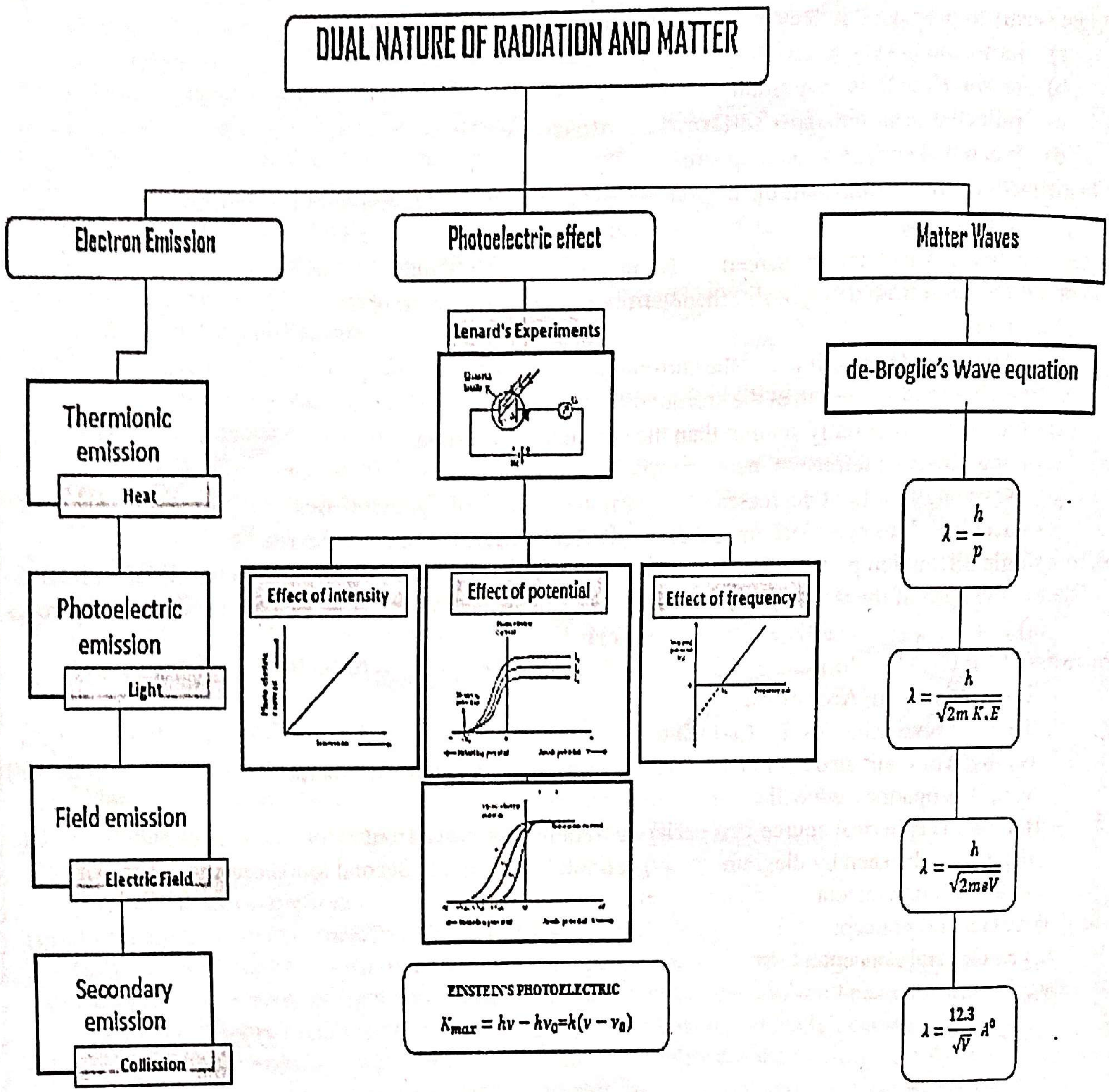
2. i) d, Sun is spherical source ii) c, Definition of wave front
iii) d, Can be seen by diagram iv) c, First is converged, Second remains as it is
v) a, General concept

3. i) a, General concept ii) c, Direct formula $2\theta = 2\lambda/a$
iii) c, General concept iv) a, Resolution α $1/\lambda$
v) a, General concept

CHAPTER-11: DUAL NATURE OF RADIATION AND MATTER

Dual nature of radiation, Photoelectric effect, Hertz and Lenard's observations; Einstein's photoelectric equation-particle nature of light. Experimental study of photoelectric effect Matter waves-wave nature of particles, de-Broglie relation.

MINDMAP



GIST OF THE CHAPTER

- **Electron Emission:** The phenomenon of emission of electron from a metal surface.

1. Thermionic emission (when metal is heated)
2. Field emission: (by applying very strong electric field to a metal)
3. Photo-electric emission (when light of suitable frequency illuminates a metal surface)

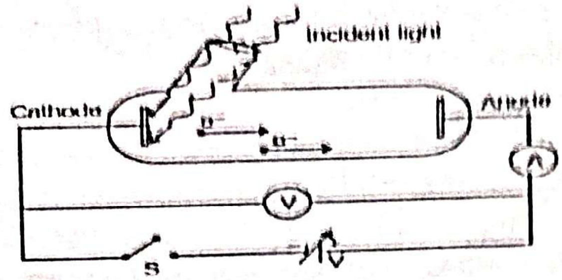
- **Work Function**: The minimum amount of energy required to be given to an electron to escape from the metal surface. It is generally denoted by ϕ_0 and unit is electron volt (eV).

$1\ eV = 1.602 \times 10^{-19}\ J$

Work function of platinum is 5.65 eV (metal having highest work function)

Work function of caesium is 2.14 eV (lowest work function)

- **Photoelectric Effect:** The phenomenon of emission of electrons from the metal surface, when light of suitable frequency illuminates it. (Discovered by Heinrich Hertz)
- **Lenard's Experimental setup:**



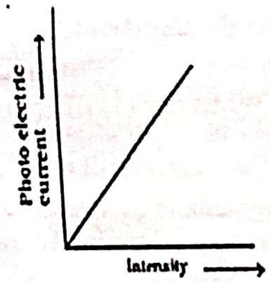
- **Effects on Photoelectric Current**

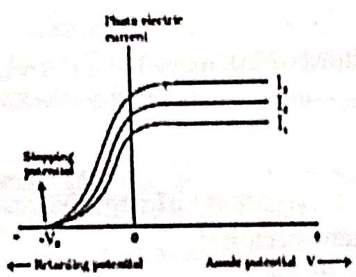
1. Effect of intensity: Photoelectric current increases linearly with intensity of incident light, keeping frequency and voltage constant.
2. Effect of potential.

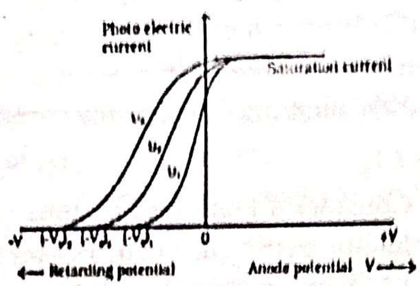
- Increasing positive potential increases current until saturation.
- Negative retarding potential decreases current. At a certain negative voltage (stopping potential), current becomes zero.
- Stopping Potential (V_0): Minimum negative potential to stop photoelectric current for a given frequency. - Independent of intensity, depends only on frequency. - Kinetic energy and stopping potential: $K_{max} = eV_0$

3. Effect of frequency:

- Greater frequency → greater stopping potential → greater K_{max}
- Saturation current remains same (constant intensity)







Laws of Photoelectric Effect

1. Photoelectric current ∝ intensity of radiation (fixed frequency)
2. Saturation current ∝ intensity; stopping potential is independent of intensity.
3. No emission occurs below threshold frequency (ν_0).
4. $K_{max} \propto$ frequency of incident radiation (ν); independent of intensity.
5. Photoelectric emission is instantaneous (delay $\approx 10^{-9}$ s)

- **Failure of Classical Theory:** Wave theory predicts electron absorbs energy continuously.

Contradictions: a. K_{max} should depend on intensity (observed: depends on frequency)

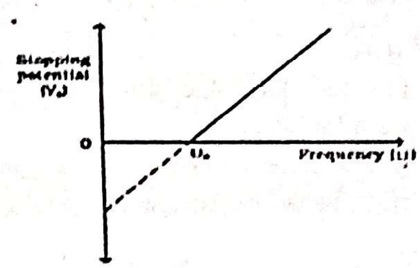
b. Any frequency should cause emission (observed: only above threshold frequency)

c. Should be delayed process (observed: instantaneous)

- **Einstein's Photoelectric Equation**: Photon energy $= h\nu = K_{max} + \phi_0 \Rightarrow K_{max} = h(\nu - \nu_0)$

- Explanation Laws of Photoelectric Effect:

- Intensity increases photon number → increases current. - $\nu < \nu_0$ →negative K which is impossible → no emission. - Photon-electron interaction is instantaneous → no time lag.



- Graph (freq vs Stopping potential) : $V_0 = (h/e)\nu - \phi_0/e$ → straight line. Slope $= h/e$, y-intercept $= -\phi_0/e$

Particle Nature of Light

- Light interacts with matter as photons.

- Photon energy: hν, momentum: hν/c
- Photon: no charge, not deflected by E or B fields
- Photon collisions conserve energy and momentum, but number of photons may change.
- Compton scattering confirmed particle nature of light.
- **Dual Nature of Radiation**
- Wave nature: Interference, diffraction, polarisation. - Particle nature: Photoelectric effect, Compton scattering. ⇒ Light shows wave-particle duality
- **Dual Nature of Matter:** Louis de Broglie (1924) proposed particles have wave nature.
- de-Broglie Equation: $\lambda = h/p = h/mv = h/\sqrt{2mK} = h/\sqrt{2meV}$
- Davisson-Germer experiment confirmed electron wave nature experimentally.

MULTIPLE CHOICE QUESTIONS

1. Which of the following cannot be observed by an increase in the intensity of light alone?
   (A) Increase in photocurrent (B) Increase in stopping potential
   (C) Increase in number of emitted electrons (D) Increase in rate of emission
2. In an experiment, intensity of light is increased but photoelectric current remains constant after sometime. This is due to:
   (A) saturation current has been reached
   (B) frequency of light is below threshold
   (C) work function is larger than incident photon energy
   (D) electrons are absorbed back
3. The photoelectric current becomes zero when:
   (A) The intensity of light is zero (B) Frequency is below the threshold
   (C) Work function is very high (D) Any of the above
4. In a photoelectric experiment with light of intensity I, the current is I_0. When light is filtered to allow only 50% photons through, the current becomes:
   (A) $2\,I_0$ (B) $I_0/2$ (C) $\sqrt{2}\,I_0$ (D) Remains same
5. Consider a photoelectric tube where magnitude of negative anode potential is gradually increased. The photoelectric current decreases to zero because:
   (A) Kinetic energy of electrons is reduced
   (B) All photons are absorbed
   (C) Potential suppresses even fastest electrons
   (D) Frequency becomes less than threshold
6. In an experiment, when frequency is increased, the stopping potential increases linearly. This verifies:
   (A) Planck's quantization (B) de Broglie relation
   (C) Einstein's photoelectric equation (D) Wave-particle duality
7. Which observation supports the quantum nature of light?
   (A) Instantaneous emission (B) KE ∝ frequency
   (C) Threshold frequency exists (D) All of the above
8. In photoelectric emission, a radiation whose frequency is 2 times threshold frequency of a certain metal is incident on the metal. Then the maximum possible velocity of the emitted electron will be:
   (A) $\sqrt{\frac{h\nu_0}{m}}$ (B) $\sqrt{\frac{2h\nu_0}{m}}$ (C) $2\sqrt{\frac{h\nu_0}{m}}$ (D) $\sqrt{\frac{6h\nu_0}{m}}$
9. For two particles with equal momenta, which of the following is true regarding their de Broglie wavelengths?
   (A) The heavier particle has smaller wavelength (B) Both have same wavelength
   (C) The faster particle has smaller wavelength (D) Depends on nature of the particles

ANSWERS

1. (B) The stopping potential is determined by the energy of the photons, which is related to their frequency, not their intensity.
2. (A) When intensity increases, more photons hit the metal, but once all available electrons are ejected, the current cannot increase further.
3. (D)
4. (B) The current in the photoelectric effect is proportional to the number of emitted electrons, which in turn depends on the number of photons hitting the metal. Reducing the number of photons to 50% will halve the number of emitted electrons, thus halving the current.
5. (C) As the stopping potential increases, it eventually becomes strong enough to prevent even the fastest emitted electrons from reaching the anode, causing the photoelectric current to drop to zero.
6. (C) Einstein's photoelectric equation shows that the kinetic energy (and hence stopping potential) of photoelectrons increases linearly with the frequency of incident light. This linear relationship confirms the equation $K_{max} = h(\nu - \nu_0)$.
7. (D)
8. (B) $KE = h\nu - h\nu_0 = 2h\nu_0 - h\nu_0 = h\nu_0$; $\frac{1}{2}mv_{max}^2 = h\nu_0$

$$Maximum\ velocity = \sqrt{\frac{2h\nu_0}{m}}$$

9. (B) $\lambda_1 = \frac{h}{p_1}$ and $\lambda_2 = \frac{h}{p_2}$ Given: $p_1 = p_1 \Rightarrow \lambda_1 = \lambda_2$

ASSERTION & REASON TYPE QUESTIONS

1. **Assertion:** In an experiment, two monochromatic light beams of the same frequency but different intensities are incident on identical photo-emissive surfaces. The beam with higher intensity results in greater photoelectric current.
   Reason: Higher intensity implies more photons per unit time, which increases the number of emitted photoelectrons even though their energy remains unchanged.
2. **Assertion:** At a fixed frequency above the threshold, doubling the intensity of light doubles the stopping potential.
   Reason: Stopping potential is proportional to the energy of the photoelectrons, which increases with intensity.
3. **Assertion:** In a photoelectric experiment, even when a very high positive potential is applied to the collector plate, the photoelectric current eventually saturates.
   Reason: The number of photoelectrons emitted depends only on the intensity of the incident light and not on the applied potential.
4. **Assertion:** Even when monochromatic light falls on a metal surface, the emitted photoelectrons have varying kinetic energies.
   Reason: Electrons originating from within the metal lose part of their energy due to collisions with other atoms before escaping the surface.
5. **Assertion:** If frequency is below threshold, increasing light intensity results in emission of photoelectrons.
   Reason: Higher intensity photons can collectively give enough energy to an electron to escape.
6. **Assertion:** A time delay is observed before photoelectrons are emitted from a metallic surface under light exposure.
   Reason: According to Einstein's theory, electrons take time to absorb sufficient energy from the incoming wavefront.
7. **Assertion:** A heavier particle moving slowly can have a longer de Broglie wavelength than a lighter

particle.

Reason: The de Broglie wavelength is independent of the particle's mass and velocity.

8. **Assertion:** An infinite time delay is observed when light of frequency less than the threshold is incident on a metal surface.

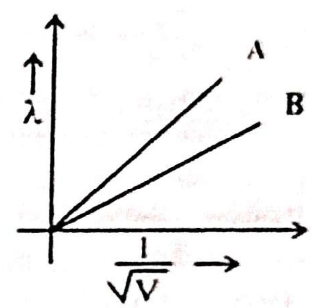
   Reason: According to Einstein's theory, electrons need to accumulate energy over time from multiple photons to be emitted.

ANSWERS

1. **(A)** – Higher intensity means more photons, hence more photoelectrons and current.
2. **(D)** – Stopping potential depends on photon energy, not intensity.
3. **(A)** – Current saturates due to limited photoelectrons; intensity controls emission.
4. **(A)** – When a light of single frequency falls on the electrons of inner layer of metal, then this electron comes out of the metal surface after a large number of collisions with atom of it's upper layer.
5. **(D)** – No emission below threshold frequency, regardless of intensity.
6. **(D)** – No time delay; photons transfer energy instantly.
7. **(C)** – $\lambda \propto 1/p$, depends on mass and velocity; reason is false.
8. **(C)** – Below-threshold frequency causes no emission, but energy can't be accumulated over time per Einstein's theory.

VERY SHORT ANSWER TYPE QUESTIONS (2 MARKS)

1. Find the change in energy of a photon of red light ($\lambda = 700\ A^0$) when the light enters glass medium of refractive index 1.5 from air.
2. Two lines, A and B, in the plot given below show the variation of de-Broglie wavelength, λ versus $\frac{1}{\sqrt{V}}$, where V is the accelerating potential difference, for two particles carrying the same charge. Which one of two represents a particle of smaller mass?



3. An electron, an alpha particle and a proton have the same kinetic energy, which one of these particles has (i) the shortest and (ii) the largest, de, Broglie wavelength?
4. An electron is accelerated through a potential difference of 100 volts. What is the de-Broglie wavelength associated with it? To which part of the electromagnetic spectrum does this value of wavelength correspond?
5. If an electron has a wavelength, does it also have a colour?
6. A parallel beam of monochromatic light of wavelength 663 nm is incident on a totally reflecting plane mirror. The angle of incidence is 60° and the number of photons striking the mirror per second is 1.0×10^{19}. Calculate the force exerted by the light beam on the mirror.
7. Ultraviolet radiations of different frequencies v_1 and v_2, are incident on two photosensitive materials having work functions W_1 and W_2 ($W_1 > W_2$) respectively. The kinetic energy of the emitted photoelectrons is same in both the cases. Which one of the two relations will be of the higher frequency?
8. Electrons are emitted from the surface when green light is incident on it, but no electrons are ejected when yellow light is incident on it. Do you expect electrons to be ejected when surface is exposed to (i) Red light and (ii) Blue light?
9. de-Broglie wavelength associated with an electron accelerated through a potential difference V is λ. What will be the de Broglie wavelength when the accelerating potential is increased to 4V?

ANSWERS

1. The energy of a photon is given by: $E = hc/\lambda$

When light enters a medium like glass, its speed and wavelength change, but frequency remains the same, and so does the energy of the photon. Therefor change in energy = 0

2. For a particle accelerated by a potential V, the de-Broglie wavelength is:

$\lambda = \frac{h}{\sqrt{2mqV}} \therefore \lambda \propto \frac{1}{\sqrt{m}}, \frac{1}{\sqrt{V}}$

So, when we plot λ versus $\frac{1}{\sqrt{V}}$, the slope is $\frac{1}{\sqrt{m}}$. Larger slope ⇒ smaller mass.

Line A has more slope than B ⇒ Particle A has smaller mass

3. $\lambda = \frac{h}{\sqrt{2mK}}$

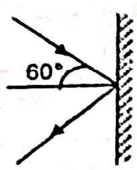
If the KE is same then: $\lambda \propto \frac{1}{\sqrt{m}}$ ⇒ Hence, α – particle has the shortest de Broglie wavelength and electron has the longest wavelength.

4. $\lambda = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{100}} = 1.227\ A°$. This wavelength corresponds to X-rays.

5. Colour is a characteristic of electromagnetic waves. Electrons behave as a de- Broglie wave because of their velocity. A de-Broglie wave is not an electromagnetic wave and is one dimensional. Hence, no colour is shown by an electron.

6. $\lambda = 663 \times 10^{-9}$ m, $\theta = 60°$ $n = 1 \times 10^{19}$,

$\lambda = \frac{h}{p} \Rightarrow p = \frac{h}{\lambda} = 10^{-27}$



Force exerted on the wall = $n(mv\cos\theta - (-mv\cos\theta)) = 2n\, mv\cos\theta = 2n\, p\cos\theta$

$= 2 \times 1 \times 10^{19} \times 10^{-27} \times ½ = 1 \times 10^{-8}$ N.

7. According to Einstein's photoelectric equation, kinetic energy of photoelectrons,

$$K = h\nu - W$$

As E_k is same, $h\nu_1 - W_1 = h\nu_2 - W_2 \Rightarrow h\nu_1 - h\nu_2 = W_1 - W_2$

$$\Rightarrow \nu_1 - \nu_2 = \frac{W_1 - W_2}{h}$$

As, $W_1 > W_2$, $\nu_1 > \nu_2$ That is, frequency of radiation ν_1 is higher.

8. The wavelength of red light is longer than threshold wavelength, hence no electron will be emitted with red light. The wavelength of blue light is smaller than threshold wavelength, hence electrons will be ejected.

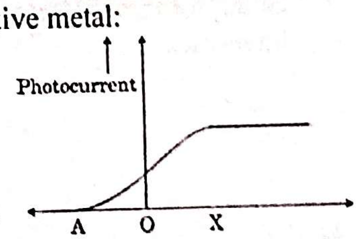
9. de Broglie wavelength associated with electron is,

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

$\therefore \lambda \propto \frac{1}{\sqrt{V}}$ ⇒ when accelerating potential becomes 4V, the de-Broglie wavelength reduces to half.

SHORT ANSWER TYPE QUESTIONS (3 MARKS)

1. The following graph shows the variation of photocurrent for a photosensitive metal:

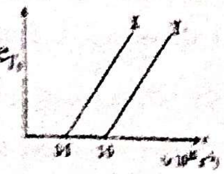


a) Identify the variable X on the horizontal axis.
b) What does the point A on the horizontal axis represent?
c) Draw this graph for three different values of frequencies of incident radiation ν_1, ν_2 and ν_3 ($\nu_1 > \nu_2 > \nu_3$) for same intensity.
d) Draw this graph for three different values of intensities of incident radiation I_1, I_2, and I_3 ($I_1 > I_2 > I_3$) having same frequency.

2. In a plot of photoelectric current versus anode potential, how does?
   a) The saturation current vary with anode potential for incident radiations of different frequencies but same intensity?
   b) The stopping potential vary for incident radiations of different intensities but same frequency?
   c) Photoelectric current vary for different intensities but same frequency of incident radiations?

Justify your answer in each case.

3. The following graph shows the variation of stopping potential V_0 with the frequency v of the incident radiation for two photosensitive metals X and Y:



   a) Which of the metals has larger threshold wavelength? Give reason.
   b) Explain, giving reason, which metal gives out electrons, having larger kinetic energy, for the same wavelength of the incident radiation.
   c) If the distance between the light source and metal X is halved, how will the kinetic energy of electrons emitted from it change? Give reason.
4. Two neutral particles are kept 1m apart. Suppose by some mechanism some charge is transferred from one particle to the other and the electric potential energy lost is completely converted into a photon. Calculate the longest and the next smaller wavelength of the photon possible.
5. Why do different metals emit electrons only when exposed to light of certain minimum frequencies? The threshold frequency of a metal is f_0. When the light of frequency $2f_0$ is incident on the metal plate, the maximum velocity of electrons emitted is v_1. When the frequency of the incident radiation is increased to $5f_0$ the maximum velocity of electrons emitted is v_2. Find the ratio of v_1 to v_2.
6. An electron and a photon each have a wavelength 1.00 nm. Find:
   a) Their momenta, b) The energy of the photon and,
   c) The kinetic energy of electron
7. Explain by giving reasons for the following:
   a) Photoelectric current in a photocell increases with the increase in the intensity of the incident radiation.
   b) The stopping potential (V_0) varies linearly with the frequency (v) of the incident radiation for a given photosensitive surface with the slope remaining the same for different surfaces.
   c) Maximum kinetic energy of the photoelectrons is independent of the intensity of incident radiation.

ANSWERS

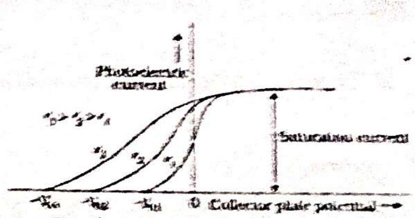
*(*Substitute the values for quantities before final answer in each numerical question*)

1.

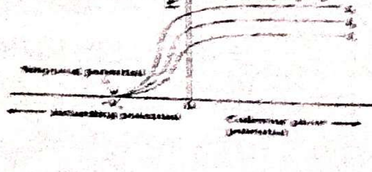
a. X is collector plate potential.

b. A is stopping potential.

c. Graph for different frequencies.

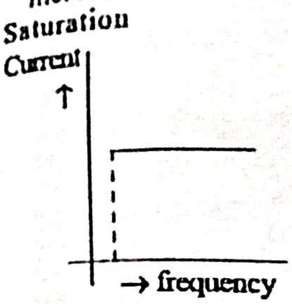


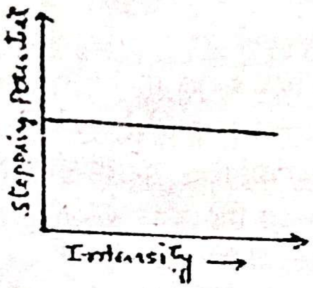
d. Graph for three different Intensities

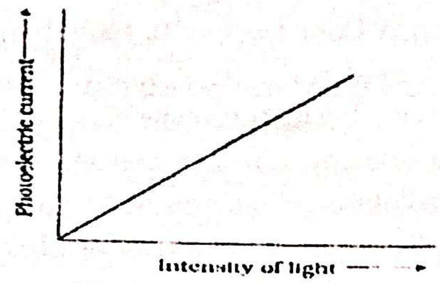


2.

i. Saturation current does not change. ii. Stopping potential does not change. iii. Photoelectric current increases with increase in intensity.







3.
   a) 'X' as it has smaller threshold frequency.
   b) $KE_{max} = h\nu - \phi_0$
   Since $\phi_y > \phi_x \Rightarrow K_y < K_x$ therefore 'X' gives out electrons with larger KE.
   c) No change as KE of photoelectron does not depend on the intensity of incident radiations.

4. r = 1m

   Potential Energy= $\frac{kq^2}{r} = \frac{kq^2}{1}$, Energy of photon= $\frac{hc}{\lambda} = \frac{kq^2}{1} \Rightarrow \lambda = \frac{hc}{kq^2}$

   For max λ, 'q' should be min, i.e $q = e = 1.6 \times 10^{-19}$ C
   Substituting we get, $\lambda_{max} = 863\ m$
   For next smaller wavelength, $q = 2e$ and $\lambda = {}^{863}/_{4} = 215.74\ m.$

5. There is minimum energy required to free an electron from its surface binding called work function.
   Einstein's photoelectric equation is $h\nu = h\nu_0 + \frac{1}{2}mv^2$
   In first case $\nu = 2f_0$, $\nu_0 = f_0$, $v = v_1$
   $h(2f_0) = hf_0 + \frac{1}{2}m v_1^2 \Rightarrow \frac{1}{2}m v_1^2 = hf_0$
   Similarly in second case we get, ${}^{1}/_{2}m\, v_2^2 = 4hf_0$

   Dividing both we get, $\frac{v_1}{v_2} = \sqrt{\frac{hf_0}{4hf_0}} = \frac{1}{2}$

6. $\lambda_e = \lambda$ photon $= 1.00\text{nm} = 10^{-9}\text{m}$.
   a) For electron or photon, momentum $p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{10^{-9}} = 6.63 \times 10^{-25}$ kg m/s
   b) Energy= $\frac{hc}{\lambda} = 19.89 \times 10^{-17}$ J ($\approx$ 124 eV)
   c) Kinetic energy of electron= $\frac{p^2}{2m} = 2.42 \times 10^{-19} J = 1.51\ eV$

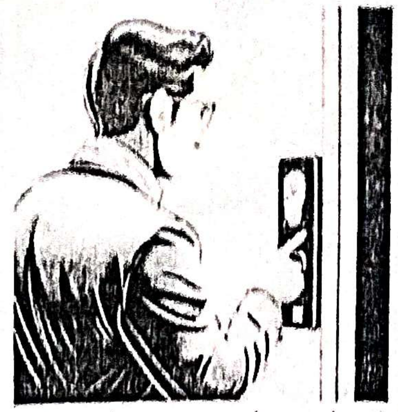
7. a) The collision of a photon can cause emission of a photoelectron (above the threshold frequency). As intensity increases, number of photons increases. Hence the current increases.
   b) We have, $eV_s = h(\nu - \nu_o)$

   $$V_s = \frac{h}{e}\nu + (-\frac{h}{e})\nu_o$$

   ∴ Graph of V_s with ν is a straight line and slope (h/e) is a constant.
   c) According to Einstein's photoelectric equation ($KE_{max} = h\nu - \phi_0$), KE is independent of intensity.

CASE STUDY BASED QUESTIONS (4 MARKS)

Case Study: Smart Door Lock with Fingerprint Scanner



1. In modern homes and offices, smart biometric door locks that use fingerprint scanning have become popular. These devices work based on the photoelectric effect, a concept that demonstrates the dual nature of radiation. When you place your finger on the scanner, a beam of light, usually from a laser or LED source, illuminates your fingerprint. The light consists of photons (particles of light) that strike the surface of the finger. The ridges and valleys of the fingerprint reflect this light differently. Some parts absorb the photons, while others reflect them back to a sensor.

Inside the sensor, semiconducting materials absorb the incident photons, causing electrons to be emitted from their surface—this is the photoelectric effect. These emitted electrons generate a current that the device reads as a specific digital signal, unique to your fingerprint. This process is not explainable by the wave theory of light alone, and instead demonstrates light's particle nature.

i. Why can't the wave theory of light alone explain the working of fingerprint scanners based on the photoelectric effect?

(A) The wave theory fails to explain reflection of light.
(B) The wave theory does not account for the threshold frequency required to emit electrons.
(C) The wave theory suggests light can't interact with electrons.
(D) The wave theory explains the continuous emission of light, not its speed.

ii. What would happen if the intensity of light increased but its frequency remains below the threshold frequency in a fingerprint scanner?

(A) More electrons would be emitted with higher energy.
(B) The fingerprint image would become clearer.
(C) Electrons would emit with the same energy as before.
(D) The emission of electrons would not occur.

iii. How does the concept of de Broglie wavelength support the miniaturization and efficiency of the fingerprint scanner's electronic components?

(A) By allowing light to be diffracted and focused more accurately.
(B) By explaining how heat is dissipated in semiconductors.
(C) By enabling high-resolution imaging using wave properties of electrons.
(D) By reducing the speed of electron movement in circuits.

iv. Which technological limitation would most directly challenge the use of wave nature of electrons in fingerprint sensor development?

(A) Requirement for extremely small de Broglie wavelengths for high resolution
(B) Slow scanning speed
(C) Difficulty in focusing particle beams
(D) Interference from ambient light

OR

Suppose a new fingerprint scanner is designed using blue light instead of red light. What would be the most likely outcome regarding the photoelectric effect?

(A) The emitted electrons would have lower kinetic energy.
(B) The emission of electrons would decrease due to lower intensity.
(C) The emitted electrons would have higher kinetic energy due to higher photon frequency.
(D) The resolution of the scanner would decrease.

ANSWERS:

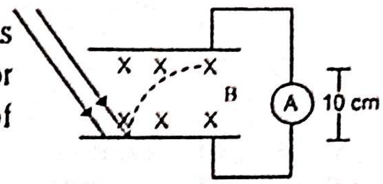
1. Ans: i) B ii) D iii) C iv) A or C

LONG ANSWER TYPE QUESTIONS (5 Marks)

1. a) Light of a particular wavelength does not eject electrons from the surface of a given metal. Should the wavelength of the light be increased or decreased in order make ejection of electrons possible? Justify.

b) In an experiment on photoelectric effect, the emitter and the collector plates are placed at a separation of 10 cm and are connected through an ammeter without any cell. A magnetic field B exists parallel to the plates.

The work function of the emitter is 2.39 eV and the light incident on it has wavelengths between 400 nm and 600 nm. Find the minimum value of B for which the current registered by the ammeter is zero. Neglect any effect of space charge.



2. a) A particle of mass M at rest decays into two particles of masses m_1 and m_2 having non-zero velocities. What is the ratio of de Broglie wavelengths of the two particles?

b) Determine the value of the de Broglie wavelength associated with the electron orbiting in the ground state of hydrogen atom. How will the de Broglie wavelength change when it is in the first excited state?

ANSWERS

1. a) The wavelength should be decreased because photon energy is inversely proportional to wavelength ($E=hc/\lambda$). Decreasing the wavelength increases the energy of incident photons, making it possible to overcome the metal's work function and eject electrons.

b) $\phi_0 = 2.39ev$ $\lambda_1 = 400$ nm, $\lambda_2 = 600$ nm

for B to be minimum, energy should be maximum $\therefore \lambda$ should be minimum (i.e. λ_1)

$$K = \frac{hc}{\lambda} - \phi_0 = 3.105 - 2.39 = 0.715\ eV = 1.144 \times 10^{-19} J$$

The presence of magnetic field will bend the beam and there will be no current if the electron does not reach the other plate.

$$r = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB} \Rightarrow B = \frac{\sqrt{2mK}}{qr} = \frac{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.144 \times 10^{-19}}}{1.6 \times 10^{-19} \times 0.1} = 2.85 \times 10^{-5}\ \text{T}$$

2. a) According to the law of conservation of momentum, the momentum of a system remains conserved.

$$Mv = m_1v_1 + m_2v_2 \Rightarrow 0 = m_1v_1 + m_2v_2 \Rightarrow m_1v_1 = -m_2v_2$$

So, we can write, $p_1 = p_2 \Rightarrow \frac{hc}{\lambda_1} = \frac{hc}{\lambda_2} \Rightarrow \frac{\lambda_1}{\lambda_2} = 1$

b) In ground state, the kinetic energy of the electron is, $K = 13.6\ eV = 2.18 \times 10^{-18} J$

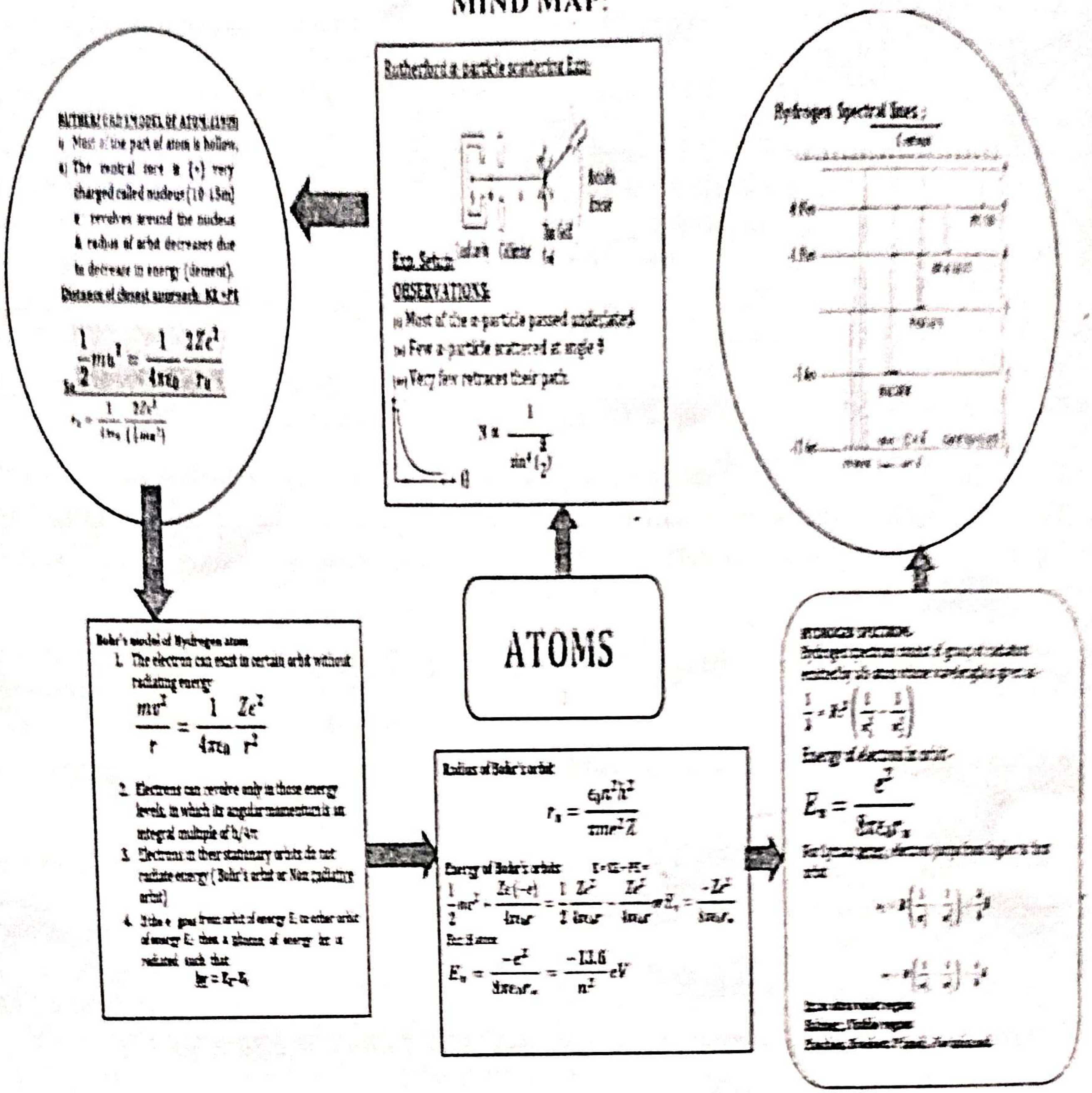
$$\lambda_0 = \frac{h}{\sqrt{2mK}} = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 2.18 \times 10^{-18}}} = 3.32 \times 10^{-10}\ m$$

In the first excited state, $K = \frac{13.6}{2^2} = \frac{13.6}{4}$ so we get $\lambda_1 = 2 \times \lambda_0 = 6.64 \times 10^{-10}\ m$

CHAPTER–12: ATOMS

Content: Alpha-particle scattering experiment; Rutherford's model of atom; Bohr model of hydrogen atom, Expression for radius of nth possible orbit, velocity and energy of electron in nth orbit, hydrogen line spectra (qualitative treatment only).

MIND MAP:



GIST OF CHAPTER: ATOMS

Rutherford's Atomic Model

On the basis of this experiment, Rutherford made following observations

(i)The entire positive charge and almost entire mass of the atom is concentrated at its centre in a very tiny region of the order of 10-15 m, called nucleus.

(ii)The negatively charged electrons revolve around the nucleus in different orbits.

(iii)The total positive charge 011 nucleus is equal to the total negative charge on electron. Therefore atom as a overall is neutral.

(iv)The centripetal force required by electron for revolution is provided by the electrostatic force of attraction between the electrons and the nucleus.

Distance of Closest Approach

$r_0 = 1/4\pi\varepsilon_0 \cdot 2Ze^2/E_k$ where, E_k = kinetic energy of the cc-particle.

Impact Parameter

The perpendicular distance of the velocity vector of a-particle from the central line of the nucleus, when the particle is far away from the nucleus is called impact parameter.

Impact parameter

where, Z = atomic number of the nucleus, E_k = kinetic energy of the c- particle and θ = angle of scattering.

Rutherford's Scattering Formula

where, N(θ) =number of c-particles, Ni = total number of α-particles reach the screen. n = number of atoms per unit volume in the foil, Z = atoms number, E = kinetic energy of the alpha particles and t = foil thickness

Limitations of Rutherford Atomic Model

(i)About the Stability of Atom According to Maxwell's electromagnetic wave theory electron should emit energy in the form of electromagnetic wave during its orbital motion. Therefore. radius of orbit of electron will decrease gradually and ultimately it will fall in the nucleus. (ii) About the Line Spectrum Rutherford atomic model cannot explain atomic line spectrum.

Bohr's Atomic Model

Electron can revolve in certain non-radiating orbits called stationary or bits for which the angular momentum of electron is an integer multiple of $(h/2\pi)$

$$mvr = nh/2\pi$$

where n = 1, 2, 3,... called principle quantum number.The radiation of energy occurs only when any electron jumps from one permitted orbit to another permitted orbit. Energy of emitted photon

$$h\nu = E_2 - E_1$$ where E1 and E2are energies of electron in orbits.

Radius of orbit of electron is given by $r = n^2h^2/4\pi^2 mK\,Ze2 \Rightarrow r \propto n^2/Z$

where, n = principle quantum number, h = Planck's constant, m = mass of an electron, $K = 1/4\pi\varepsilon$, Z = atomic number and e = electronic charge.

Velocity of electron in any orbit is given by $v = 2\pi KZe^2/nh \Rightarrow v \propto Z/n$

Frequency of electron in any orbit is given by $\nu = KZe^2/nhr = 4\pi^2Z^2e^4mK^2/n3\,h^3$

$\Rightarrow \nu$ prop; $Z3/n^3$

Kinetic energy of electron in any orbit is given by $E_k = 2\pi^2me^4Z^2K2/n^2\,h2 = 13.6\,Z^2/n^2$ eV

Potential energy of electron in any orbit is given by

$$E_p = -4\pi^2me^4Z^2K^2/n^2\,h^2 = 27.2\,Z^2/n^2 \quad \Rightarrow Ep = \propto Z^2/n^2$$

Total energy of electron in any orbit is given by $E = -2\pi^2me^4Z2K^2/n^2\,h^2 = -13.6\,Z2/n^2$ eV

$\Rightarrow Ep = \propto Z^2/n^2$ In quantum mechanics, the energies of a system are discrete or quantized. The energy of a particle of mass m is confined to a box of length L can have discrete values of energy given by the relation $En = n^2\,h2/8mL2$; n < 1, 2, 3,...

Hydrogen Spectrum Series

Each element emits a spectrum of radiation, which is characteristic of the element itself. The spectrum consists of a set of isolated parallel lines and is called the line spectrum.

Hydrogen spectrum contains five series **(i) Lyman Series** When electron jumps from n = 2, 3,4, ...orbit to n = 1 orbit, then a line of Lyman series is obtained. This series lies in ultra violet region.

(ii)Balmer Series When electron jumps from n = 3, 4, 5,... orbit to n = 2 orbit, then a line of Balmer series is obtained. This series lies in visual region.

(iii)Paschen Series When electron jumps from n = 4, 5, 6,... orbit to n = 3 orbit, then a line of Paschen series is obtained. This series lies in infrared region

(iv)Brackett Series When electron jumps from n = 5,6, 7.... orbit to n = 4 orbit, then a line of Brackett series is obtained. This series lies in infrared region.

(v)Pfund Series When electron jumps from n = 6,7,8, ... orbit to n = 5 orbit, then a line of Pfund series is obtained. This series lies in infrared region.

MCQ WITH SOLUTION - ATOMS

1. When alpha particles are sent through a thin gold foil, most of them go straight through the foil, because
   (a) Alpha particles are positively charged
   (b) Mass of alpha particle is more than mass of electron
   (c) Most of the part of an atom is empty space
   (d) Alpha particles moves with high velocity
2. In an experiment of scattering of alpha particle showed for the first time that the atom has,
   (a) Electron (b) Proton (c) Neutron (d) Nucleus
3. In Geiger Marsden experiment, the expression of distance of closest approach to the nucleus of a alpha particle before it comes to momentarily at rest and reverse its direction is,
   (a) $\frac{Ze^2}{4\pi\epsilon_0 k}$ (b) $\frac{Ze^2}{2\pi\epsilon_0 k}$ (c) $\frac{Ze^2}{2\epsilon_0 k}$ (d) $\frac{Ze^2}{4\epsilon_0 k}$
4. The angular momentum of the electron in the nth allowed orbit is;
   (a) $\frac{Ph}{2\pi}$ (b) $\frac{h}{2\pi}$ (c) $\frac{2h}{\pi}$ (d) $\frac{nh}{2\pi}$
5. In equation, what does this $E_n = \frac{-13.6}{n^2} eV$ 'negative sign indicates.
   a) Electrons are free to move
   b) Electron is bound with nucleus.
   c) Kinetic energy is equal to potential energy
   d) Atom is radiating energy
6. Kinetic energy of electron in hydrogen atom is
   a.) $\frac{e^2}{4\pi\epsilon_0 r}$ b. $\frac{e^2}{8\pi\epsilon_0 r}$ c. $\frac{e^3}{8\pi\epsilon_0 r}$ d. $\frac{e^2}{3\pi\epsilon_0 r}$
7. Energy required to excite an electron in hydrogen atom to its ground state to its first excited state is.
   (a). 6.2eV (b). 3.40eV (c). 10.2eV (d). -13.6eV
8. What is the angular momentum of an electron revolving in the 3rd orbit of an atom?
   a. 31.5×10^{-34} J.sec b. 3.15×10^{-34} J.sec c. 315×10^{-34} J.sec d. 0.315×10^{-34} J.sec
9. If the electron in hydrogen atoms is excited to n = 5 state, the number of different frequencies of radiation which may be emitted is:
   (a) 4 b) 10 c) 8 d) 5

ANSWERS:-

1 : (c) Explanation : When alpha particles are sent through a thin gold foil, most of them go straight through the foil, because of lots of empty space present in the atom.

2: (d) Nucleus Explanation : few alpha particles were bouncing back which concluded that a part of the atom consists of a positively charged which was called as nucleus.

3 :(b) Explanation : Let *d* be the distance of closest approach then by the conservation of energy. Initial kinetic energy of incoming α-particle K
= Final electric potential energy U of the system
as $K = 1/4\pi\varepsilon 0 \times (2e)(Ze)/d/d$
$\therefore d = Ze^2/2\pi\varepsilon_0 1k$

4 : (d) explanation : Bohr's third postulate states that the angular momentum of an electron revolving around the nucleus of an atom is quantized. The angular momentum is an integral multiple of $h/2\pi$ where h is the Planck's constant.
That is, $mvr = nh/2\pi$ Here, n has integer values and is the principal quantum number. It denotes the orbit in which the electron resides.

(b) Explanation the negative sign in the energy of an electron in the nth shell represents the energy decrease resulting from the electron's binding to the atom and its position relative to the nucleus. It signifies that the electron is in a lower energy state than it would be if it were free from the atom's influence.

: (b) $\frac{e^2}{8\pi\epsilon_0 r}$

(C) 10.2eV soln- E_2-E_1=-3.40-(-13.6)= 10.2eV

(b) explanation : Here n = 3; h = 6.6 x 10-34 Js

Angular momentum L = $nh/2\pi$ = (3 × 6.6 × 10^{-34})/2 × 3.14 = 3.15 x 10^{-34} Js

(b) Explanation : Orbital Frequency of electron -

- wherein $f \propto \frac{Z^2}{n^3}$
- $f = \frac{mz^2e^4}{4\epsilon_0^2 n^3 h^3}$

Number of frequency emitted from n^{th} orbital is $\frac{n(n-1)}{2}$

$\because n = 5$ => number of frequency emitted = $\frac{5 \times 4}{2}$ = 10

ASSERTION AND REASONING : ATOMS

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

1. **Assertion (A):** According to Bohr's theory in the hydrogen atom, the electron revolves in circular orbits.
   Reason (R): The centripetal force is provided by the electrostatic attraction between the proton and the neutron.
2. **Assertion (A):** The frequency of radiation emitted or absorbed by an atom is related to the difference in energy between two energy levels.
   Reason (R): The energy of the photon emitted or absorbed is equal to the difference in energy between the two levels.
3. **Assertion (A):** The ground state of an atom is its highest energy state.
   Reason (R): In the ground state, the electron occupies the farthest possible orbit to the nucleus.
4. **Assertion (A):** The Bohr model of the atom explains the line spectra of hydrogen atom.
   Reason (R): The energy levels of the electron in the hydrogen atom are quantized, leading to discrete spectral lines.
5. **Assertion (A):** The angular momentum of an electron in a Bohr orbit is quantized.
   Reason (R): The angular momentum of the electron is an integral multiple of $h/4\pi$.
6. **Assertion (A):** The emission spectrum of an element is characteristic of the element.
   Reason (R): The energy levels of electrons in an atom are unique to each element.
7. **Assertion (A):** The ionization energy of an atom is the energy required to remove an electron from the atom in its ground state.
   Reason (R): Ionization energy is a measure of the binding energy of the protons in the ground state.
8. **Assertion (A):** The wavelength of light emitted in an electronic transition is inversely proportional to the energy difference between the initial and final states.
   Reason (R): The energy of a photon is inversely proportional to its wavelength.
9. **Assertion (A):** The energy levels in an atom are quantized due to the wave nature of electrons.
   Reason (R): Electrons exhibit both particle and wave properties

ANSWERS (ASSERTION AND REASONING)

1: (c) Explanation : The centripetal force is provided by the electrostatic attraction between the proton and the electron.

2: (A) Explanation : Both A and R are true and R is the correct explanation of A.

3: (D) both the Assertion and Reason are incorrect.
Explanation : The ground state of an atom is its lowest energy state.
In the ground state, the electron occupies the closest possible orbit to the nucleus.

4: (A) Explanation : Both A and R are true and R is the correct explanation of A.

5: (c) Explanation : The angular momentum of the electron is an integral multiple of $h/2\pi$.

6: (a) Explanation : Both A and R are true and R is the correct explanation of A.

7: (c) Explanation : Ionization energy is a measure of the binding energy of the electron in the ground state.

8: (a) Explanation : Both A and R are true and R is the correct explanation of A.

9: (b) both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

SHORT ANSWER QUESTIONS: (02 MARKS)

1. What is the shortest wavelength present in the Paschen series and Balmer series of hydrogen spectrum?
2. In the Rutherford's scattering experiment the distance of closest approach for an α –particle is d_0. If α –particle is replaced by a proton, how much kinetic energy in comparison to α particle will it require to have the same distance of closest approach d_0?
3. Find the ratio of Bohr's radius in ground state and 1[st] excited state of H-atom?
4. The value of ground state energy of hydrogen atom is $-13.6\ eV$.
(i) what does the negative sign signify?
(ii) How much energy is required to take an electron in this atom from the ground state to the first excited state?
5. Use Rydberg formula to determine the wavelength of H_α & H_β line.
(Given: Rydberg's constant $R = 1.03 \times 10^7\ m^{-1}$)
6. Calculate the shortest wavelength of the spectral lines emitted in Balmer series. [Given Rydberg constant, $R = 10^7\ m^{-1}$].
7. When an electron in hydrogen atom jumps from the third excited state to the ground state, how would the de Broglie wavelength associated with the electron change? Justify your answer.

SOLUTIONS FOR SHORT ANSWER QUESTIONS: (02 MARKS)

1. solution

$\lambda = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$

$n=3,\ n_2=\text{infinity}$

$\lambda = 9/R$

$= 8204\ Å$

2. $$E_{K_\alpha} = \frac{1}{4\pi\epsilon_0}\frac{(2e)(2e)}{d_0} \ \&\ E_{K_p} = \frac{1}{4\pi\epsilon_0}\frac{(2e)(e)}{d_0} \Rightarrow E_{K_p} = \frac{1}{2}E_{K_\alpha}$$

3. Solution : $R_2 : R_1 = 4\ [illegible]$ $= 4:1$

4. Solution : (i) Negative sign shows that electron is bound with the nucleus by electrostatic Force
(ii) $E_n = -\frac{13.6}{n^2}$ eV. For ground state n=1 and for first excited state n=2

5. Solution

For H_α line $n_1=2$ and $n_2=3$

$$[illegible]$$

6. (Hint: for shortest wavelength of Balmer series $n_i = \infty$, $n_f = 2$)
Answer: Wavelength $= 4\times10^{-7}\ m$

7. Answer: 970×10^{-10} m. It lies in the ultra-violet region.

QUESTIONS : (03 MARKS)

Q.1:- Write two important limitations of Rutherford model which could not explain the observed features of atomic spectra. How were these explained in Bohr's model of hydrogen atom? Use the Rydberg formula to calculate the wavelength of the Hα line.

(Take $R = 1.1 \times 10^7\ m^{-1}$).

Q2 :- Calculate the shortest wavelength in the Balmer series of hydrogen atom. In which region (infra-red, visible, ultraviolet) of hydrogen spectrum does this wavelength lie?

Q.3:- Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom.

Q.4:-An α-particle moving with initial kinetic energy K towards a nucleus of atomic number z approaches a distance 'd' at which it reverses its direction. Obtain the expression for the distance of closest approach 'd' in terms of the kinetic energy of α-particle K.

Q.5:- Using Rutherford model of the atom, derive the expression for the total energy of the electron in hydrogen atom. What is the significance of total negative energy possessed by the electron?

Q.6 . A hydrogen atom initially in the ground state absorbs a photon which excites it to the n- 4 level. Determine the wavelength of the photon.

(i) The radius of innermost electron orbit of a hydrogen atom is 5.3×10^{-11}m. Determine its radius in n = 4 orbit.

Q7. (i) In hydrogen atom, an electron undergoes transition from 2nd excited state to the first excited state and then to the ground state. Identify the spectral series to which these transitions belong.
(ii) Find out the ratio of the wavelengths of the emitted radiations in the two cases.

SOLUTIONS FOR 3MARKS QUESTIONS

1. Limitations of Rutherford Model : (i) Electrons moving in a circular orbit around the nucleus would get, accelerated, therefore it would spiral into the nucleus, as it looses its energy. (ii) It must emit a continuous spectrum.

Explanation according to Bohr's model of hydrogen atom :

(ii)Electron in an atom can revolve in certain stable orbits without the emission of radiant energy. (ii) Energy is released/absorbed only, when an electron jumps from one stable orbit to another stable orbit. This results in a discrete spectrum. Wavelength of Hα line :

Hα line is formed when an electron jumps from $n_f = 3$ to $n_i = 2$ orbit. It is the Balmer series

After calculations $\lambda = 65.3$ nm

2. In Balmer series, an electron jumps from higher orbits to the second stationary orbit ($nf = 2$). Thus for this series : $\lambda = 4/R = 3646$ Å

3. Answer: When an electron moves around hydrogen nucleus, the electrostatic force between electron and hydrogen nucleus provides necessary centripetal force.

Also we know from Bohr's postulate, $mv^2/r = (1/4\pi\varepsilon_0)\, e^2/r^2$

$mvr = nh/2\pi$ or $m^2v^2r^2 = n^2h^2/4\pi^2$

from both equations $r = (n^2h^2/4\pi^2 m e^2) \times 4\pi\varepsilon_0$ therefore $r \propto n^2$

4. At the distance d, the KE (K) gets converted into PE (P) of the system.

Therefore PE at distance (d) = $(1/4\pi\varepsilon_0)(2e \times Ze)/d = (1/4\pi\varepsilon_0) 2Ze^2/d = K$

Therefore $d = (1/4\pi\varepsilon_0) 2Ze^2/K$

5. Expression for total energy of electron in H-atom using Rutherford model : As per Rutherford model of atom, centripetal force (Fc) required to keep electron revolving in orbit is provided by the electrostatic force (Fe) of attraction between the revolving electron and nucleus.

The negative sign indicates that the revolving electron is bound to the positive nucleus.

$F_c = F_e$

$mv^2/r = ee/4\pi\varepsilon_0 r^2$ so, $r = e^2/4\pi\varepsilon_0 mv^2$

$KE = \frac{1}{2} mv^2 = e^2/ 8 \pi \varepsilon_0 r$

$PE = e(-e)/ 4 \pi \varepsilon_0 r = \; e^2/ 4 \pi \varepsilon_0 r$

$TE = KE + PE = -e^2/ 8 \pi \varepsilon_0 r$

6. Energy of the ground state = -13.6 eV

Energy of (n= 4) state = -13.6/16 eV

Therefore energy of photon absorbed $E = hc/ \lambda = 12.75 \times 1.6 \times 10^{-19}$ J

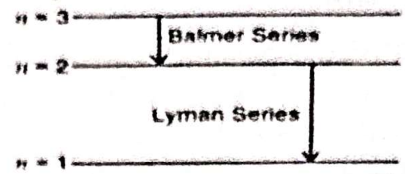
$\lambda = hc/(12.75 \times 1.6 \times 10^{-19}) = 97$ nm

Radius of (n=4) orbit = $(4)^2 \times (5.3 \times 10^{-11})$m = 8.48 A°

7

(i) $n_f = 2, \quad n_i = 3$ *Balmer series*

$n_i = 2, \quad n_f = 1$ *Lyman series*



(ii) $\frac{1}{\lambda_H} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5}{36} R$

...where [λ_B is the wavelength for Balmer series. λ_L is the wavelength for Lyman series.

CASE BASED QUESTIONS

1. *The spectral series of hydrogen atom were accounted for by Bohr using the relation*

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

where, R=Rydberg constant = 1.097×10^7 m^{-1}

Lyman series is obtained when an electron jumps to first orbit from any subsequent orbit. Similarly,

Balmer series is obtained when an electron jumps to 2nd orbit from any subsequent orbit. Paschen series is obtained when an electron jumps to 3rd orbit from any subsequent orbit. Whereas Lyman series in U.V. region, Balmer series is in visible region and Paschen series lies in infrared region. Series limit is obtained when n2=∞.

Q.1:- What is the ratio of minimum to maximum wavelength in Balmer series?

(a) 5:2 (b) 5:9 (c) 5:8 (d) 9:5

Q.2:- Which series of hydrogen spectrum can we see through naked eye?

(a) Laymen (b) Balmer Series (c) paschan (d) none

Q.3:-What is the wavelength of first spectral line of Lyman series?

(a) 1215.4 (b) 5121.4 (c) 2115.4 (d) 4211.5

Q.4 :-What is the frequency of first spectral line of Balmer series?

(a) 4.57×10^{14} Hz (b) 5.57×10^{14} Hz (c) 7.57×10^{14} Hz (d) 0.57×10^{14} Hz

2. Lyman series is obtained when an electron jumps to first orbit from any subsequent orbit. Similarly, Balmer series is obtained when an electron jumps to 2nd orbit from any subsequent orbit. Paschen series is obtained when an electron jumps to 3rd orbit from any subsequent orbit. Whereas Lyman series in U.V. region, Balmer series is in visible region and Paschen series lies in infrared region. Series limit is obtained when n2=∞.

(i) The wavelength of first spectral line of Lyman series is

(a) 1215.4 A° (b)1215.4 cm (c) 1215.4 m (d)1215. 4 mm

(ii) The wavelength limit of Lyman series is

(a) 951.6 A° (b) 511.9 A° (c)1215.4 A° (d) 911.6 A°

(iii) The frequency of first spectral line of Balmer series is

(a) 1.097×10^7 Hz (b) 4.57×10^{14} Hz (c) 4.57×10^{15} Hz (d) 4.57×10^{16} Hz

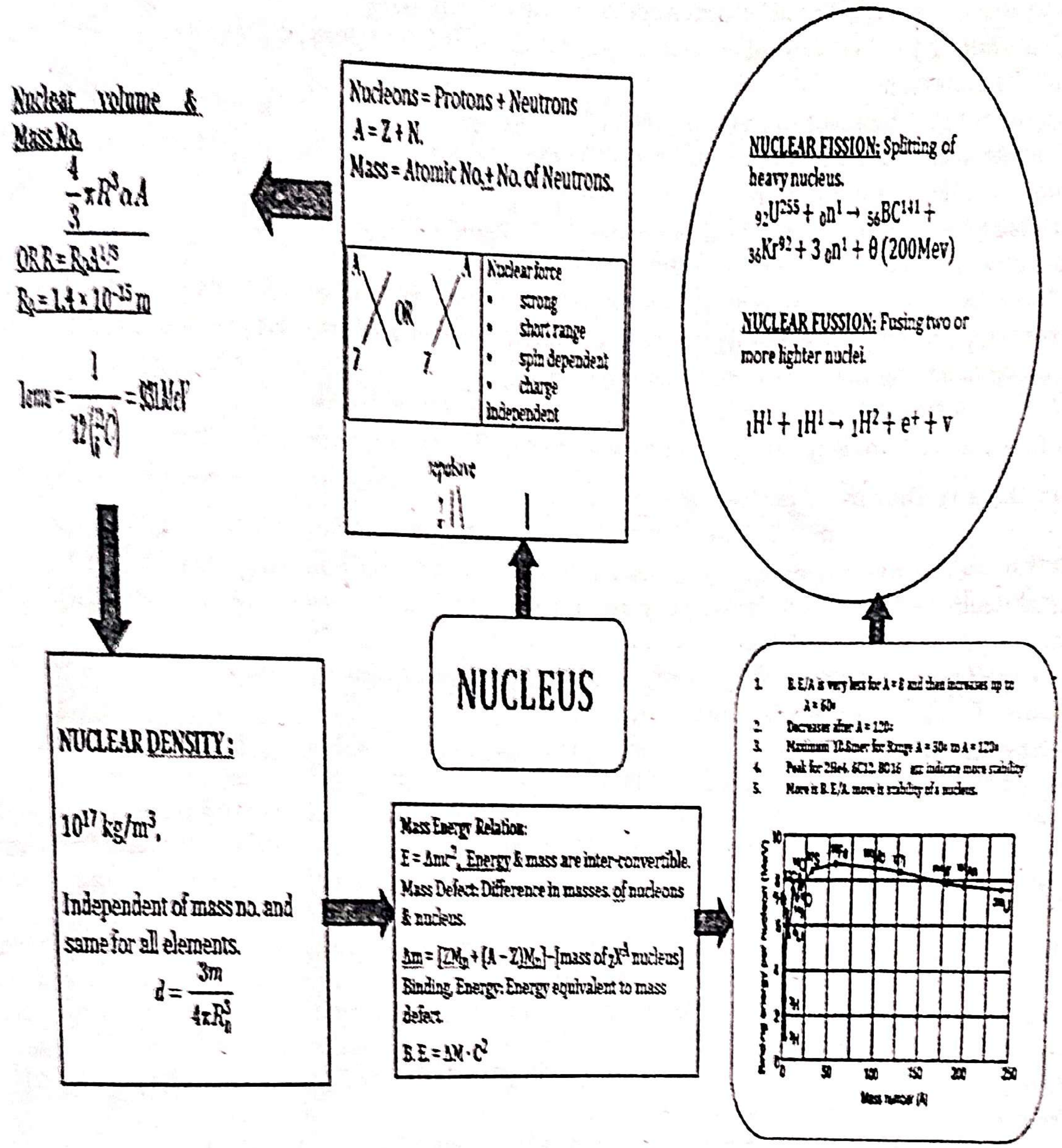
(iv) Which of the following transitions in hydrogen atom emit photon of highest frequency?

(a) n=1 to n=2 (b) n=2 to n=6 (c) n=6 to n=2 (d) n=2 to n=1

CHAPTER–13: NUCLEI

Syllabus:-Composition and size of nucleus, nuclear force Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission, nuclear fusion.

MIND MAP :



GIST – NUCLEUS

Nucleus: The small, dense region consisting of protons and neutrons at the center of an atom is the atomic nucleus. In every atom, the positive charge and mass are densely concentrated at the central core of the atom, which forms its nucleus. More than 99.9% mass of the atom is concentrated in the nucleus.

Nucleons: The nucleus of an atom consists of protons and neutrons. They are collectively called nucleons.

Atomic Mass Unit (amu) :The unit of mass used to express mass of an atom is called atomic mass unit.

Atomic mass unit is defined as 1/12th of the mass of carbon (126C) atom.
1 amu or 1 u=1.660539 x10-27 kg (1) Mass of proton (mp)=1.00727 u
(2) Mass of neutron (mn)=1.00866 u (3) Mass of electron (me) =0.000549 u Relation between amu and MeV 1 amu=931 Mev

Composition of Nucleus

The composition of a nucleus can be described by using the following.

Atomic Number (Z) :Atomic number of an element is the number of protons present inside the nucleus of an atom of the element.

Atomic number (Z) = Number of protons = Number of electrons (in a neutral atom)

Mass Number (A): Mass number of an element is the total number of protons and neutrons inside the atomic nucleus of the element.

Mass number (A)= Number of protons(Z) +Number of neutrons(N)
= Number of electrons +Number of neutrons A=Z+N

Size of Nucleus: According to the scattering experiments, nuclear sizes of different elements are assumed to be spherical, so the volume of a nucleus is directly proportional to its mass number. If R is the radius of the nucleus having mass number A, then

$R \propto A^{1/3}$ $R=R0\ A^{1/3}$

Where, R_0= $1.2x10^{-15}$ m is the range of nuclear size. It is also known as nuclear radius.

Nuclear Density Density of nuclear matter is the ratio of mass of nucleus and its volume. $\rho=m/(4/3\pi R_0^3)$ => ρ = $2.38x10^{17}kg/m^3$ where, m = average mass of one nucleon and R_0=1.2 fm = $1.2x10^{-15}m$ **=>The nuclear density (ρ) does not depend on A (mass number). Mass Defect** The sum of the masses of neutrons and protons forming a nucleus is more than the actual mass of the nucleus. This difference of masses is known as mass defect.

Δm=Zmp+(A-Z)mn – M where, Z= atomic number, A= mass number, mp = mass of one proton, mn= mass of one neutron and M= mass of nucleus.

Mass-Energy Relation Einstein's mass-energy equivalence equation is given by $E = mc^2$, (where E is the energy and c is the speed of light =$3x10^8$ m/s and m = mass of nucleus)

Nuclear Forces Short ranged (2-3 fm) strong attractive forces which hold protons and neutrons together in against of Colombian repulsive forces between positively charged particle is called nuclear force. The nuclear force between neutron-neutron, proton-neutron and proton-proton is approximately the same. The nuclear force does not depend on the electric charge.

Nuclear Energy When nucleons form a nucleus, the mass of nucleus is slightly less than the sum of individual masses of nucleons. This mass is stored as nuclear energy in the form of mass defect. Also, transmutation of less stable nuclei into more tightly bound nuclei provides an excellent possibility of releasing nuclear energy. Two distinct ways of obtaining energy from nucleus are Number of nucleons given below

The phenomenon of splitting of heavy nuclei (usually A>230) into lighter nuclei of nearly equal masses is known as nuclear fission, e.g.

$$92U^{235} + 0n^1 \text{ -------->} \quad 56Ba^{141} + 36Kr^{92} + 3\ 0\ n^1 + Q$$

Nuclear Fusion

The phenomenon of fusing or combining of two lighter nuclei into a single heavy nucleus is called nuclear fusion, e.g.

$$1\ H^1 + 1\ H^1 \text{ ---------->} \quad 1\ H^2 + e^1 + v + 0.42 \text{ MeV}$$

[The energy released during nuclear fusion is known as thermonuclear energy.]

Binding Energy

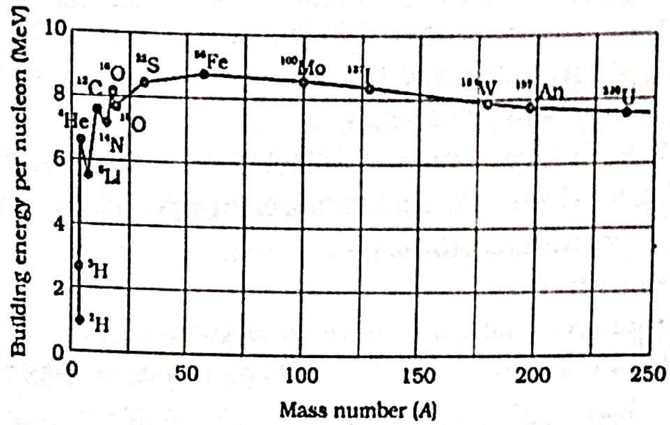
The binding energy of a nucleus is defined as the minimum energy required to separate its nucleons and place them at rest at infinite distance apart. Using Einstein's mass-energy relation, ΔE= (Δmc^2), the binding energy of the nucleus isΔE =[Zmp + (A-Z)mn – M]c^2

Average Binding Energy Per Nucleon of a Nucleus

It is the average energy required to extract a nucleon from the nucleus to infinite distance. It is given by total binding energy divided by the mass number of the nucleus.

Binding energy curve:

It is a plot of the binding energy per nucleon versus the mass number A for a large number of nuclei as shown below:



The binding energy per nucleon as a function of mass number.

Binding energy per nucleon as a function of mass number :It is used to explain phenomena of nuclear fission and fusion.

Nuclear Stability

The stability of a nucleus is determined by the value of its binding energy per nucleon. The constancy of the binding energy in the range 30< A<170 is a consequence of the fact that the nuclear force is short-ranged.

MCQ - QUESTIONS : NUCLEI)

1.The binding energy per nucleon of a nucleus is a measure of its:

a) Stability b) Instability c) Radioactivity d) Mass defect

2. The binding energy per nucleon is maximum for nuclei with a mass number around:

a) 50 b) 100 c) 150 d) 200

3. The binding energies per nucleon for a deutron and an α- particle are x_1 and x_2 respectively. The energy Q released in reaction $_1H^2 + {_1H^2} \rightarrow {^4_2He} + Q$ is

(a) $4(x_1 + x_2)$ (b) $4(x_1 - x_2)$ (c) $2(x_1 + x_2)$ (d) $2(X_1 - x_2)$.

4. Let m_n and m_p be the masses of a neutron and a proton respectively. M_1 and M_2 are the masses of a $^{20}_{10}Ne$ nucleus and a $^{40}_{20}Ca$ nucleus respectively. Then

(a) $M_2 < 2M_1$ (b) $M_2 > 2M_1$ (c) $M_2 = 2M_1$ (d) $M_1 < 10(m_n + m_p)$.

5. One requires an energy E_n to remove a nucleon from a nucleus and an energy E_e to remove an electron from an atom. Then

(a) $E_n = E_e$ (b) $E_n > E_e$ (c) $E_n < E_e$ (d) $E_n > E_e$.

3. When the number of nucleons in nuclei increases, the binding energy per nucleon numerically

(a) increases continuously with mass number.

(b) decreases continuously with mass number. (c) First increases and then decreases with increase of mass number.

(d) Remains constant with mass number.

7. Consider the fission reaction : $^{236}_{92}U \rightarrow x^{117} + Y^{117} + {_0n^1} + {_0n^1}$ i.e., two nuclei of same mass numbers 117 are formed plus two neutrons. The binding energy per nuclear of X and Y is 8.5 MeV whereas U^{236} is 7.6 MeV. The total energy liberated will be about:

(a) 2 MeV (b) 20 MeV (c) 2,000 MeV (d) 200 MeV

8. Fusion takes place at high temperature because:

(a) Atom are ionised at high temperature

(b) Molecules break up at high temperature

(c) Nuclei break up at high temp.

(d) Kinetic energy is high enough to overcome repulsion between nuclei

9. The binding energy per nucleon for the parent nucleus is E1 and that for the daughter nuclei is E2. Then

(a) E1 > E2 (b) E2 > E1 (c) E1 = 2E2 (d) E2 = 2E1

ANSWERS MCQ

1. Ans : a Explanation : Binding energy per nucleon refers to the average energy that holds a nucleus together, calculated by dividing the total binding energy of the nucleus by the number of nucleons (protons and neutrons) it contains.
2. Ans : b Explanation : Excluding the lighter nuclei, the average binding energy per nucleon is about 8 MeV. The maximum binding energy per nucleon occurs at around mass number $A = 50$, and corresponds to the most stable nuclei.
3. Answer: (b) $4(x_1 - x_2)$

Explanation : Number of nucleon on reactant side = 4 Binding energy for one nucleon = x1 Binding energy for 4 nucleons = 4x1 Similarly on product side binding energy = 4x2 Now, Q = change in binding energy $= 4(x_1 - x_2)$.

4. Answer: (a) Explanation : It is found that the mass defect increases with increase in mass number So, $20(m_n + m_p) - M_2 > 10(m_p + m_n) - M_1$

Or $10(m_n + m_p) > (M_2 - M_1)$

Or $M_1 + 10(m_n + m_p) > M_2$

i.e. $M_2 < M_1 + 10(m_n + m_p)$ but $M_1 < 10(m_n + m_p)$ $\therefore M_2 < 2M_1$

5. Answer: (b) $E_n > E_e$ Explanation : the work function for nuleon is much greater than the electron.
6. Answer: (c) First increases and then decreases with increase of mass number.
7. Answer: (d) 200 MeV Explanation : The total energy liberated will be the difference between the binding energy of two sides. Binding energy of nucleus $= 236 \times 7.6 MeV$

Binding energy of product $= 117 \times 8. + 117 \times 8.5 = 2 \times 117 \times 8.5$

Hence, net binding energy = Binding energy of product - Binding energy of nucleus

$= 234 \times 8.5 - 234 \times 7.6 = 1989 - 1793.6 = 195.4 MeV \approx 200 MeV$

Thus, in per fission of uranium nearly $200 MeV$ energy is released

8. Answer (d) Kinetic energy is high enough to overcome repulsion between nuclei

Explanation: This happens because at high temperature, there is enough kinetic energy to overcome the repulsion and the strong interaction pulling the protons together is stronger than repulsion pushing the protons apart, the atoms will fuse together forming a new atom containing protons of both atoms we pushed together.

9. Answer : (b) E2 > E1

Explanation: When a heavy nucleus of higher mass number (less stable) splits into two lighter nuclei the daughter nucleus is of less mass number and becomes more stable, having more binding energy per nucleon. Therefore, E2 > E1

ASSERTION AND REASONING : NUCLEI

Directions: These questions consist of two statements; each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

1. **Assertion (A):** The mass of a nucleus is less than the sum of the masses of its constituent protons and neutrons.
   Reason (R): The mass defect is converted into binding energy, which holds the nucleus together.
2. **Assertion (A):** The binding energy per nucleon is a measure of the unstability of a nucleus.
   Reason (R): A higher binding energy per nucleon means the nucleons are not tightly bound and the nucleus is more stable.
3. **Assertion (A):** Heavy nuclei tend to be unstable and undergo radioactive decay.

Reason (R): In heavy nuclei, the repulsive electrostatic forces between protons are sufficiently balanced by the attractive nuclear forces.

4. Assertion (A): Nuclear fission is accompanied by the release of a large amount of energy. Reason (R): The binding energy per nucleon of the fission fragments is greater than that of the original nucleus.
5. Assertion(A): Nuclear fusion requires extremely high temperatures. Reason (R): High temperatures provide the necessary kinetic energy to overcome the electrostatic repulsion between nuclei.
6. Assertion (A): The mass number of a nucleus is the sum of the number of protons and neutrons. Reason (R): Protons and neutrons are the nucleons that make up the nucleus.
7. Assertion(A): Distance of closest approach of α-particle to the nucleus is always greater than the size of the nucleus.

   Reason(R): Strong nuclear repulsion does not allow α-particle to reach the surface of nucleus

ANSWERS FOR ASSERTION AND REASONING.

1. Answer: (a) Explanation : Both A and R are true and R is the correct explanation of A
2. Answer: (d) Both A and R are false, Explanation : The binding energy per nucleon is a measure of the stability of a nucleus. A higher binding energy per nucleon means the nucleons are more tightly bound and the nucleus is more stable.
3. Answer: (c). Explanation : In heavy nuclei, the repulsive electrostatic forces between protons are not sufficiently balanced by the attractive nuclear forces.
4. Answer: (a), Explanation : Both A and R are true and R is the correct explanation of A.
5. Answer: (a), Explanation : Both A and R are true and R is the correct explanation of A.
6. Answer: (a), Explanation : Both A and R are true and R is the correct explanation of A.
7. Answer : (a) Explanation : Both A and R are true and R is the correct explanation of A.

CASE BASED QUESTIONS (NUCLEI)

1. Einstein was the first to establish the equivalence between mass and energy. According to him, whenever a certain mass (Δm) disappears in some process the amount of energy released is $E = \Delta m c^2$, where c is the velocity of light in vacuum $= 3 \times 10^8$ m/s. The reverse is also true i.e. whenever energy E disappears an equivalent mass $\Delta m = E/c^2$ appears.

i) What is the energy released when 1a.m.u mass disappears in a nuclear reaction?

a) 1.49×10^{-10} J   b) 1.49×10^{-7} J   c) 1.49×10^{10} J   d) 1.49×10^{-10} MJ

ii) Which of the following process releases energy?

a) Nuclear Fission   b) Nuclear Fusion   c) Both (a) and (b)   d) None

iii) Which process is used in today's nuclear power plant to harness nuclear energy?

a) Nuclear Fission   b) Nuclear Fusion   c) Both (a) and (b)   d) None

iv) Which process releases energy in Atom Bomb?

a) Nuclear Fission   b) Nuclear Fusion   c) Both (a) and (b)   d) None

OR

Which of the following is used as Moderator in a Nuclear Reactor?

(a) Deuterium Water   b) Normal Water   c) Mineral Water   d) Soft water

ANS: 1(a)   2(c)   3(a)   4(a) or 4(a)

2. Neutrons and protons are identical particle in the sense that their masses are nearly the same and they are bounded with the force, called nuclear force. Nuclear force is the strongest force. Stability of nucleus is determined by binding energy per nucleon or the neutron proton ratio or packing fraction. Density of nucleus independent on the mass number. Whole mass of the atom (nearly 99%) is present at the nucleus

(i) The force between a neutron and a proton inside the nucleus is

(a) Only nuclear attractive (b) Only Coulomb force

(c) Both of the above (d) None of these

(ii) Outside a nucleus

(a) Neutron is stable (b) Proton and neutron both are stable

(c) Neutron is unstable (d) Neither neutron nor proton is stable

(iii) Nuclear force is

(a) Short range and charge dependent (b) Short range and charge independent

(c) Long range and charge independent (d) Long range like electrostatic type

(iv) If F_{pp} , F_{pm} and F_{nn} are the magnitudes of net force between proton-proton, proton-neutron and neutron-neutron respectively, then

(a.) Fpp = Fpn = Fnn (b) Fpp < Fpn < Fnn (c) Fpp > Fpn >Fnn (d) Fpp = Fpn < Fnn

ANSWER : (i) (a) (ii) (d) (iii) (b) (iv) (a)

SHORT ANSWER (02 MARKS)

1. What is mass defect of a nucleus? Express it mathematically. What light does it throw on the binding energy of nucleus?
2. Calculate the energy release in MeV in the deuterium fusion reaction
$_1H^2 + {}_1H^3$ ---------------- $_2He^4$ +n , Using the following data
m($_1H^2$)= 2.014102 u, m($_1H^3$)= 3.016049 u, m($_2He^4$)= 4.002603 u, mn= 1.008665 . u 1u =931.5MeV
3. A nucleus with mass number, A = 240 and BE /A = 7. 6 MeV breaks into two fragments each of A = 120 with BE /A = 8. 5 MeV Calculate the released energy.
4. What do you mean by binding energy of nucleus? Obtain an expression for binding energy. How binding energy per nucleon explains the stability of nucleus?
5. Obtain the binding energy (in MeV) of a nitrogen nucleus ($_7N^{14}$) given m ($_7N^{14}$) =14.00307u
6. Draw the graph showing the variation of binding energy per nucleon with mass number. What inference you get from this graph. Also explain the importance of binding energy curve.
7. (i) How is the size of a nucleus found experimentally? Write the relation between the radius and mass number of a nucleus.
(ii) Prove that the density of a nucleus independent of its mass number.

ANSWERS :

1. This missing mass is known as the 'mass defect' and it accounts for the energy released. The mass defect (ΔM) can be calculated by subtracting the original atomic mass (MA) from the sum of the mass of protons (mp= 1.00728 amu) and neutrons (mn= 1.00867 amu) present in the nucleus.
2. In this reaction total mass of reactant is=5.030151 amu and total mass of product is 5.011268 ,so mass defect is 0.018883 amu so total energy released will be 0.018883x931.5=17.5895245 Mev
3. Since the nucleus as a mass number A = 240 and binding energy for nucleon is 7.6 MeV. Its total binding energy is E1 = 240 X 7.6 = 1824 MeV. As both fragments of mass number A = 120 as a binding energy for nucleon of 8.5 MeV, so total energy of fragments is E2 = 2 X 120 X 8.5 = 2040 MeV. Therefore energy released is = 2040 – 1824 =216 MeV.
4. The energy evolve during formation of nucleus due to mass defect is called binding energy. Mass defect=(Zmp+(Z-A)mn-mN($_zX^A$)) ,Binding energy =mass defectx931.5MeV
Larger the binding energy per nucleon, the greater the work that must be done to remove the nucleon from the nucleus, the more stable the nucleus.
5. Nitrogen has 7 proton and 7 neutron so total mass of proton and neutron
=7X1.00728+7X1.0087 =14.11183520 mass defect will be=14.11183520-14.00307 = 0.10876520 so

binding energy will be 0.010876529x931.5=101.314867635 MeV.

6. Correct graph and importance of curve
7. Description of closest approach, relation and proof.

LONG ANSWER QUESTIONS 3 MARKS

1. (i) Why is the binding energy per nucleon found to be constant for nuclei in the range of mass number (A) lying between 30 and 170? (ii) When a heavy nucleus with mass number A = 240 breaks into two nuclei, A = 120, energy is released in' the process. (iii) In β-decay, the experimental detection of neutrinos (or antineutrinos) is found to be extremely difficult.
2. (a) In a typical nuclear reaction, e.g.

   $$^2_1H + ^2_1H \longrightarrow ^3_2He + n + 3.27\ MeV$$

   although number of nucleons is conserved, energy is released. How? Explain.
   (b) Show that nuclear density in a given nucleus is independent of mass number A.
3. Draw a plot of potential energy of a pair of nucleons as a function of their separations. Mark the regions where the nuclear force is (i) attractive and (ii) repulsive. Write any two characteristic features of nuclear forces.
4. (i) What characteristic property of nuclear force explains the constancy of binding energy per nucleon (BE/A) in the range of mass number 'A' lying $30 < A < 170$?
   (ii) Show that the density of nucleus over a wide range of nuclei is constant- independent of mass number A.
5.. Using the curve for the binding energy per nucleon as a function of mass number A, state clearly how the release of energy in the processes of nuclear fission and nuclear fusion can be explained.

1. Answer: (i) Nuclear forces are short ranged. For a particular nucleon inside a sufficiently large nucleus will be under the influence of some of its neighbours which come within the range of the nuclear force. The property that a given nucleon influences only nucleons close to it is also referred to as saturation property of the nuclear force.

(ii) The binding energy per nucleon of the parent nucleus is less than those of the two daughter nuclei. It is this increased binding energy that gets released in this process.

(iii) Neutrinos are chargeless and massless particles, whose interaction with other particles is almost negligible. Hence, they can pass through very large quantity of matter without getting detected.

2. Answer: (a) In all types of nuclear reactions, the law of conservation of nucleons is followed. But during the reaction, the mass of the final product is found to be slightly less than the sum of the masses of the reactant components. This difference in mass of a nucleus and its constituents is called mass defect. So, as per mass energy relation $E = (\Delta M)c^2$, energy is released. In the given reaction the sum of the masses of two deutrons is more than the mass of helium and neutron. Energy equivalent of mass defect is released.

(b) Nuclear density $= \dfrac{\text{Mass of nucleus}}{\text{Volum}} = \dfrac{mA}{\frac{4}{3}\pi R^3}$

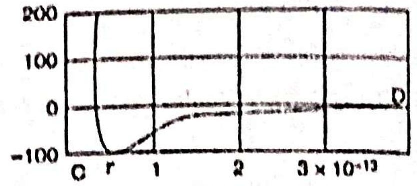
(m = mass of each nucleon)

As $R = R_0 A^{1/3}$ where $R_0 = 1.2 \times 10^{-15}$ m.

$\therefore$ Nuclear density $= \dfrac{3mA}{4\pi R_0^3 A} = \dfrac{3m}{4\pi R_0^3}$

i.e. independent of Mass Number A

3. Answer: The graph indicates that the attractive force between the two nucleons is strongest at a separation $r_0 = 1$ fm. For a separation greater than the force is attractive and for separation less than r_0, the force is strongly repulsive.



Two characteristic features of nuclear forces :1. Strongest interaction 2. Short-range force 3. Charge independent character (any two)

4. Answer:(i) Saturation is the Short range nature of nuclear forces

(ii) Let A be the mass number and R be the radius of a nucleus If m is the average mass of a nucleon, then

Mass of nucleus = mA

Volume of nucleus = $4/3\ \pi\ R^3$

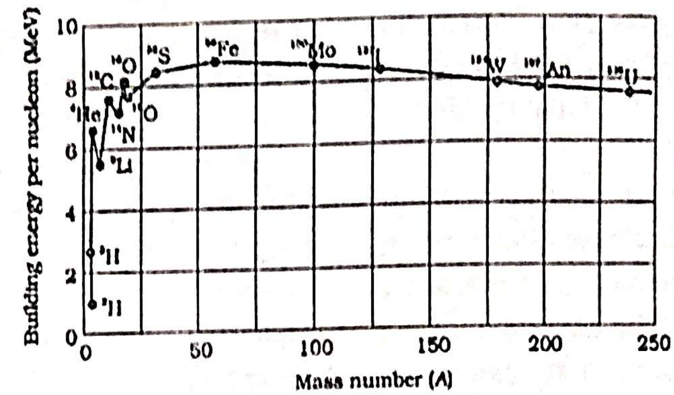
$= 4/3\ \pi\ (R_0 A^{1/3})^3 = 4/3\ \pi\ R_0^3 A$

Therefore nuclear density = mass of nucleus / volume of nucleus

$mA/(4/3\ \pi\ R_0^3 A) = 3m/(4\pi\ R_0^3)$

clearly , nuclear density is independent of mass number A of the size of nucleus.

5. Answer: 1. Nuclear fission : Binding energy per nucleon is smaller for heavier nuclei than the middle ones i.e. heavier nuclei are less stable. When a heavier nucleus splits into the lighter nuclei, the B.E./nucleon changes (increases) from about 7.6 MeV to 8.4 MeV. Greater binding energy of the product nuclei results in the liberation of energy. This is what happens in nuclear fission which is the basis of the atom bomb.

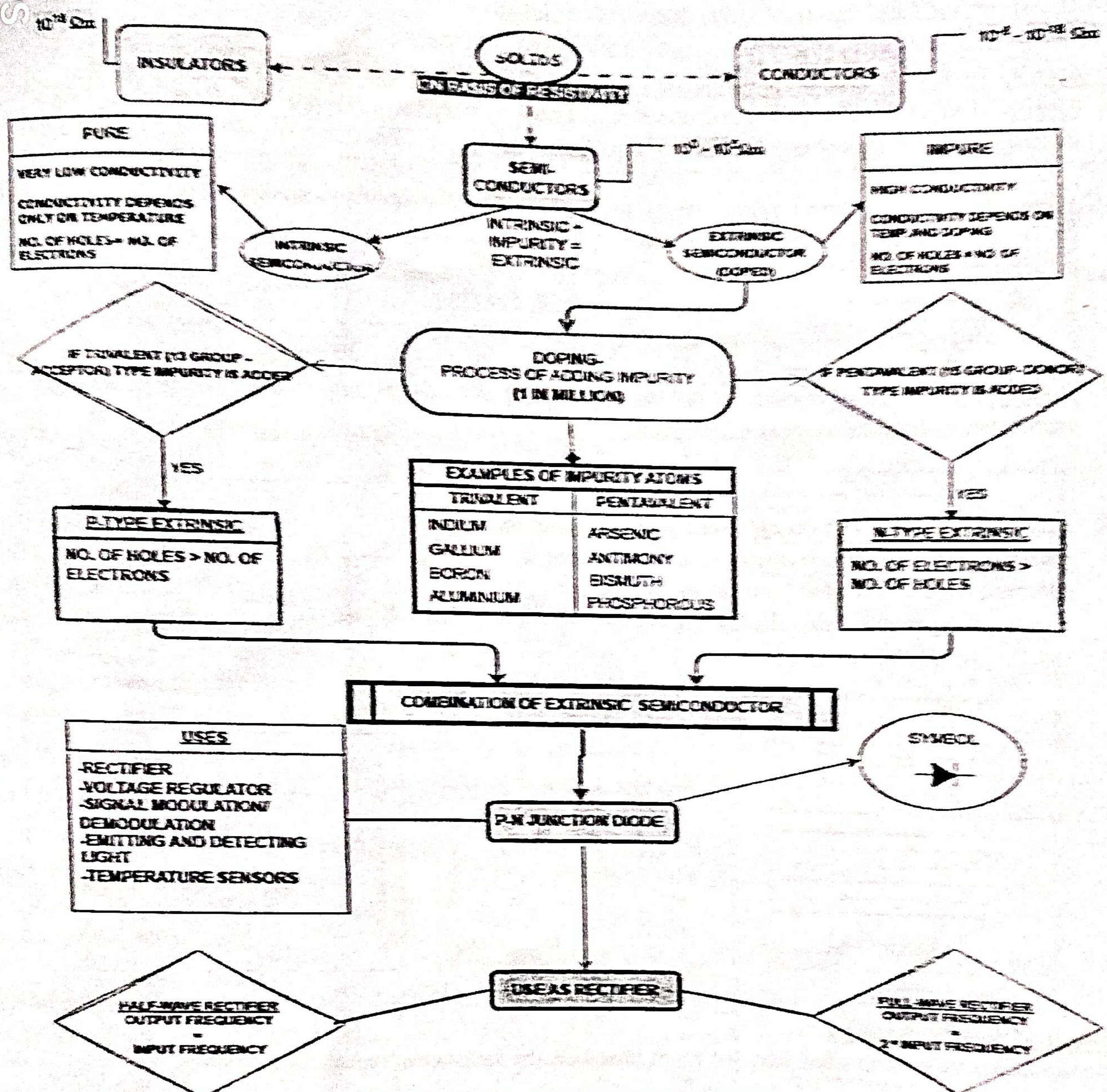


2. Nuclear fusion : The binding energy per nucleon is small for light nuclei, i.e., they are less stable. So when two light nuclei combine to form a heavier nucleus, the higher binding energy per nucleon of the latter results in the release of energy.

CHAPTER–14: SEMICONDUCTOR ELECTRONICS

Syllabus:- Materials, Devices and Simple Circuits Energy bands in conductors, semiconductors and insulators (qualitative ideas only) Intrinsic and extrinsic semiconductors- p and n type, p-n junction Semiconductor diode - I-V characteristics in forward and reverse bias, application of junction diode -diode as a rectifier.

Mindmap



GIST OF CHAPTER

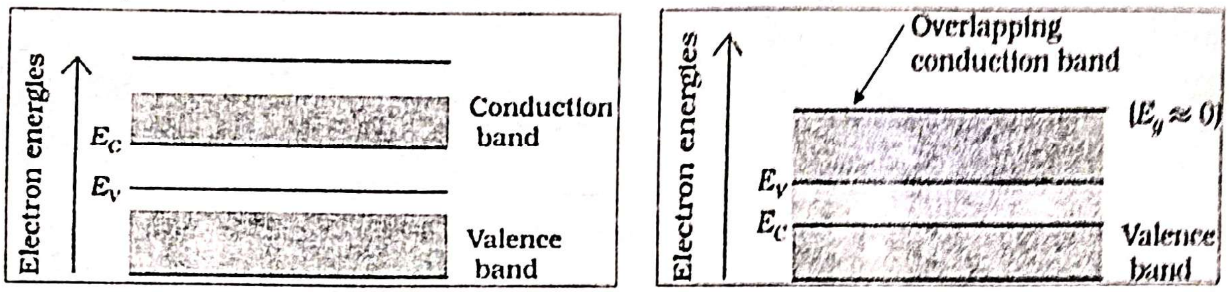
Semiconductor Electronics were discovered as a part of experiments in the 1930s. This led to the realization that certain solid-state semiconductors and their junctions had **the capacity to control the number and direction of flow of charge carriers** through them.

A semiconductor is a type of material whose resistivity is between a conductor (silver, copper, etc.) and insulator (glass, diamond) which is

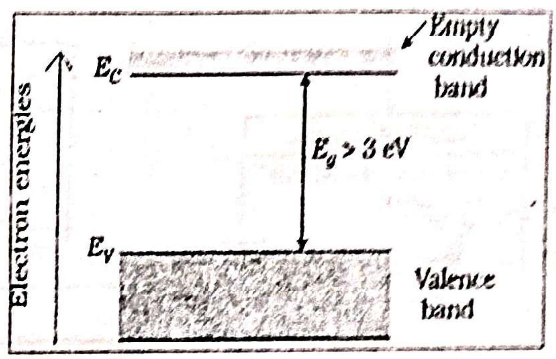
$$\rho = 10^0 - 10^5 \ \ \Omega - m$$

Insulators, conductors and semiconductors can be differentiated based on their energy bands.

- **Metals:-** In metals, the valence and conduction band lie very close to each other and sometimes even **overlap** which allows free movement of electrons.

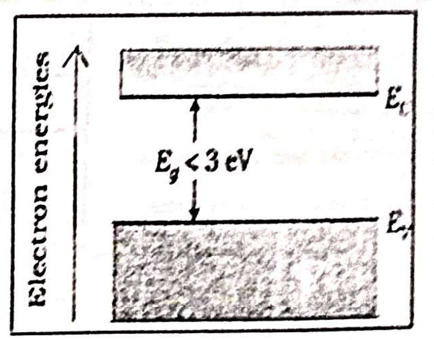


- **Insulators:-** In case of insulators, the conduction band and valence band is separated by a large gap which discourages movement of electrons.



- **Semiconductors:- The energy band gap is smaller in semiconductors** which encourages some electrons to enter the conduction band by crossing the gap.

  E_g-Si = 1.1 eV E_g-Ge = 0.74 eV



Types of Semiconductors

Semiconductors are classified into two types **based on the number of electrons and holes.**

- **Intrinsic**
- **Extrinsic**

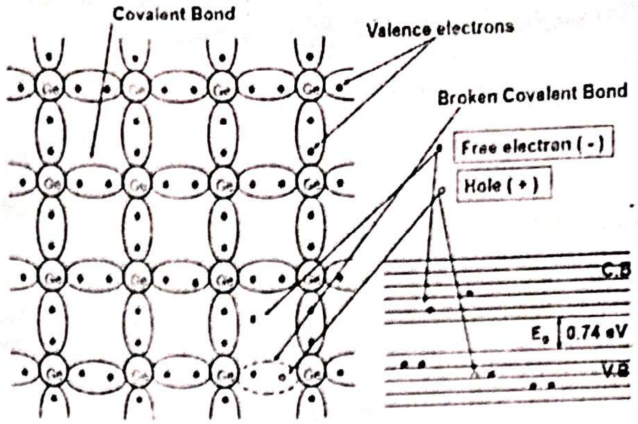
Intrinsic or Pure Semiconductor:

Intrinsic semiconductors are free from impurities. Examples: Germanium and silicon

- for Pure Si (Z=14) and for Pure Ge (Z=32). Both have 4 valence electrons.
- All 4 valence electrons are involved in covalent bond formation in Si or Ge crystal.
- It has an equal number of holes and free electrons.

  Thus, $n_e = n_h = n_i$

Here, n_i = intrinsic carrier concentration, n_e = number of electrons, n_h = number of holes



Extrinsic or impure Semiconductor:

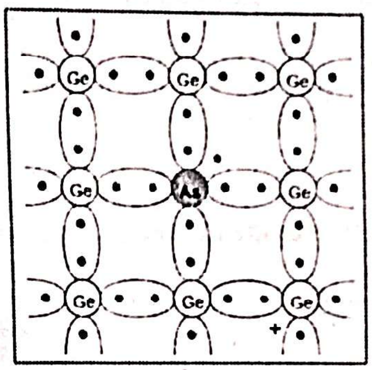
The electrical conductivity of intrinsic (pure) semiconductor is dependent on its temperature. However, at room temperature, its conductivity is very poor.

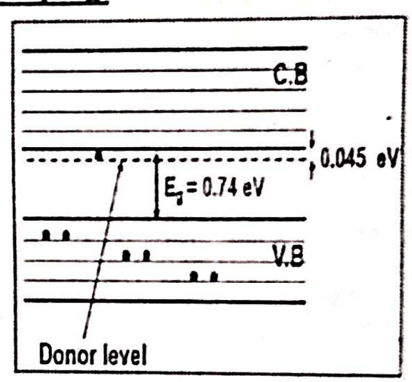
- The addition of certain impurities (very small amount-in part per million ppm) can increase the conductivity of the intrinsic (natural) semiconductors.
- The process of addition of impurity is called doping and the impurity atoms are called dopants.
- The impure semiconductor thus formed is called a "doped" semiconductor or Extrinsic Semiconductor.

An Extrinsic Semiconductor can be of two types based on the type of doping.

- ➢ n-type semiconductor doped with Pentavalent impurity atom. Examples include Phosphorus (P), Antimony (Sb), Arsenic (As).

  Here $n_e >> n_h$, that is the number of electrons is greater than the number of holes.

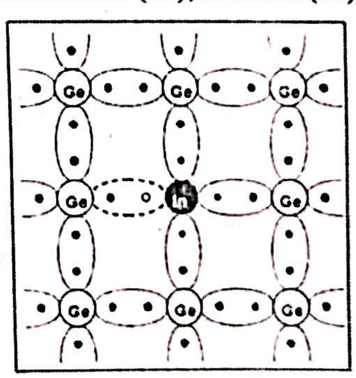


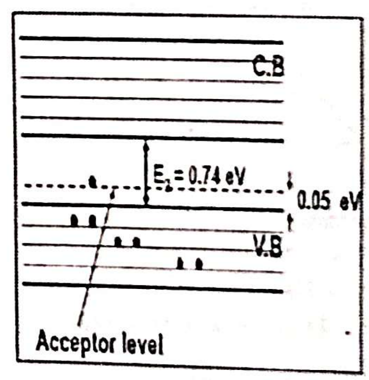


- ➢ p-type semiconductor doped with Trivalent impurities atom. Examples include Boron (B), Aluminium (Al), Indium (In).

  Here $n_h >> n_e$, that is the number of holes is greater than the number of electrons.

The electron and hole concentration in a semiconductor *in thermal equilibrium* is given by $n_e \cdot n_h = n_i^2$



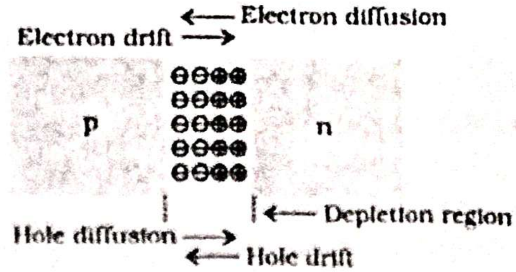


P-N Junction

By Considering a thin p-type silicon (p-Si) semiconductor wafer and adding precisely, a small quantity of pentavalent impurity, part of the p-Si wafer can be converted into n-Si. The wafer now contains p-region and n-region and a metallurgical junction between p-, and n-region.

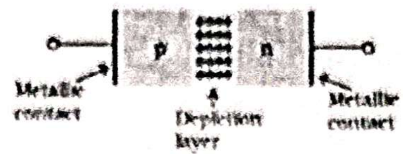
Two important processes occur during the formation of a p-n junction are **diffusion and drift.**

Initially, diffusion current is large and drift current is small. As the diffusion process continues, the space- charge regions on either side of the junction extend, thus increasing the electric field strength and hence drift current. This process continues until the diffusion current equals the drift current.



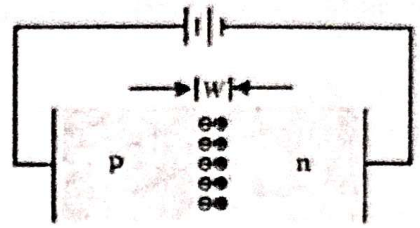
Semiconductor Diode

A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for the application of an external voltage. It is a two-terminal device.

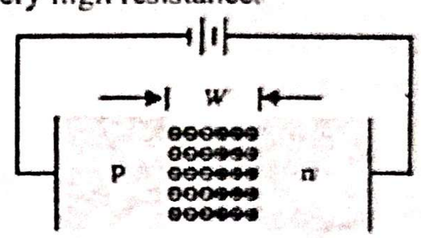


Symbol-

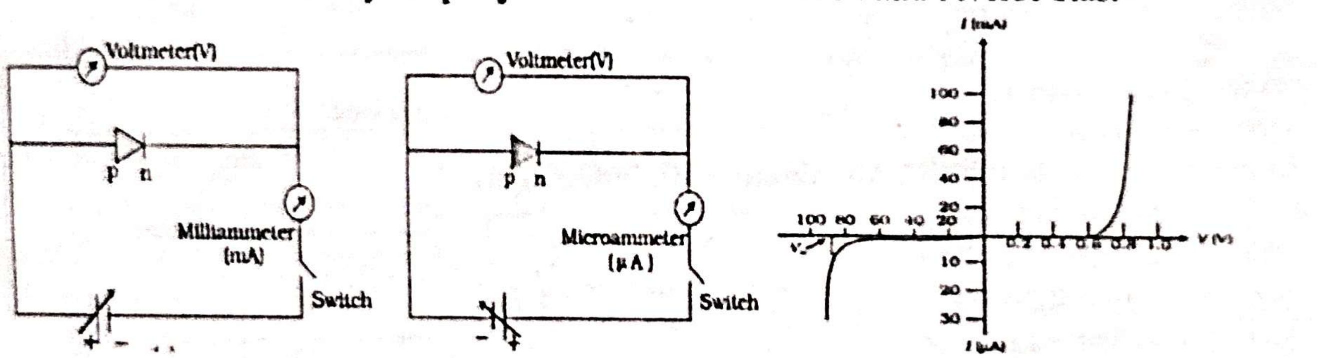
- When an external voltage V is applied across a semiconductor diode such that p-side is connected to the positive terminal of the battery and n-side to the negative terminal , it is said to be *forward biased.* In forward bias, it offers very low resistance.



- When an external voltage (V) is applied across the diode such that n-side is positive and p-side is negative, it is said to be *reverse biased.* In reverse bias, it offers very high resistance.
- The ratio of forward biased to reverse biased resistance for p-n junction diode is 10^{-4}:1.



Characteristic curve study for p-n junction diode in forward and reverse bias:-



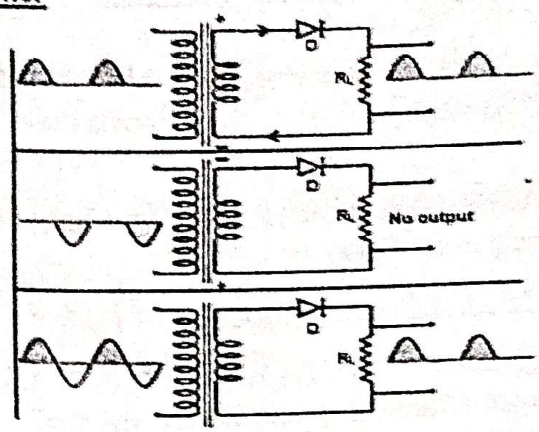
Application of Junction Diode as a Rectifier

An electrical device that converts alternating current into direct current with the help of a diode is called a Rectifier. There are two types of rectifiers:

1. **Half-Wave Rectifier**
2. **Full-Wave Rectifier**

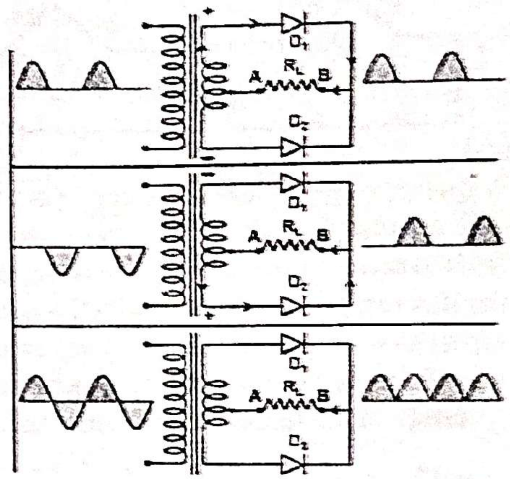
Half Wave Rectifier

A half-wave rectifier is defined as a type of rectifier that only allows the one-half cycle of an AC voltage and gives the pulsating DC voltage.
There is only one diode in the half-wave rectifier, which helps to rectify the AC voltage to DC voltage.
The average value of output direct current in a half wave rectifier is I_0/π.



Full Wave Rectifier

Full-wave rectifiers have two diodes where the first diode will conduct in the positive half cycle and other diode will conduct in the negative half cycle. It will give full pulsating DC.
The average value of output direct current in a full wave rectifier is $2I_0/\pi$
The sinusoidal wave is complete and with the help of the capacitor or inductor we can filter and convert pulsating DC into constant DC.



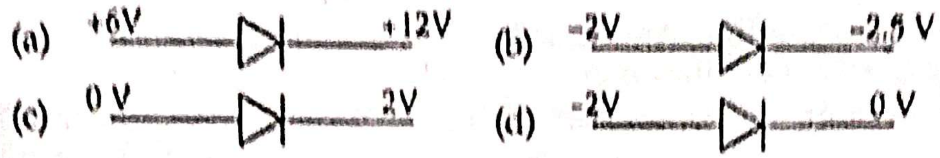
Application of Full Wave Rectifier and Half Wave Rectifier

The use of a half-wave rectifier can help us achieve the desired dc voltage by using step-
down or step-up transformers. Moreover, to power up the motor and LED that works on DC voltage, full wave rectifiers are used.

MULTIPLE CHOICE QUESTIONS

1. Carbon, silicon and Germanium have four valence electrons each. At room temperature which one of the following statements is most appropriate ?
   (a) The number of free electrons for conduction is significant only in Si and Ge but small in C.
   (b) The number of free conduction electrons is significant in C but small in Si and Ge.
   (c) The number of free conduction electrons is negligibly small in all the three.
   (d) The number of free electrons for conduction is significant in all the three.
2. In the energy band diagram of a semiconductor, if more charge carriers are seen near valence band. It would be
   (a) an intrinsic semiconductor (b) a metal may be n-type or p-type semiconductor
   (c) an n-type semiconductor (d) a p-type semiconductor
3. The peak voltage in the output of a half wave diode rectifier fed with a sinusoidal signal without filter is 10 V. The d.c. component of the output voltage is
   (a) $10/\sqrt{2}$ V (b) $10/\pi$ V (c) 10 V (d) $20/\pi$ V

4. In which case is the junction diode forward biased.

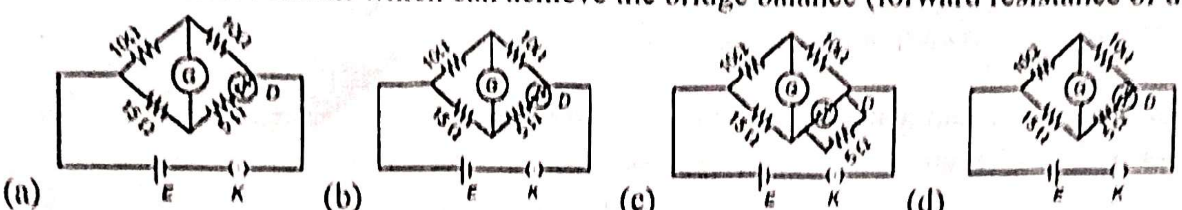


5. Assuming that the junction diode is ideal, and resistor has resistance of 200 Ω. The current in the arrangement shown here will be:

(a) 2 mA (b) 30 mA (c) 20 mA (d) 10 mA

6. Which of following statements is not true?
(a) Resistance of an intrinsic semiconductor decreases with increase in temperature.
(b) Doping pure Si with trivalent impurities gives p-type semiconductor.
(c) The majority carriers in n-type semiconductor are holes.
(d) A p-n junction can act as semiconductor diode.

7. Choose the correct circuit which can achieve the bridge balance (forward resistance of diode is 10 ohm)



8. A student wants to identify diode from a mixed collection of diodes, resistors, inductors, switch, thyristors, bulb etc using a multimeter, choose the correct statement out of the following about the diode :
(a) It is two terminal device which conducts current in both directions.
(b) It is two terminal device which conducts current in one direction only.
(c) It does not conduct current gives an initial deflection which decays to zero.
(d) It is three terminal device which conducts current in the direction only between central terminal and either of the remaining two terminals.

ANSWERS:

1. (a) Si and Ge are semiconductors, but C is an insulator. In Si and Ge at room temperature, the energy band gap is low due to which electrons in the covalent bonds gains kinetic energy and break the bond and move to conduction band. As a result, hole is created in valence band. So, the number of free electrons is significant in Si and Ge
2. (d)
3. (d) , $V_{dc} = V_{avg} = V_0 \times 2/\pi = 20/\pi$ V
4. (b) -2V > -2.5V
5. (d) 10 mA, ideal diode has zero resistance when forward biased.
6. (c) The majority carriers in n-type semiconductor are holes.
7. (a) In balanced bridge, Galvanometer will show zero result. Condition- P/Q = R/S
8. (b)

ASSERTION- REASON BASED QUESTIONS

For these Questions two statements are given one labelled Assertion (A) and other labelled Reason (R). Select the correct answer to these questions from the options as given below

A. If both Assertion and Reason are true and Reason is correct explanation of Assertion.
B. If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

C. If Assertion is true but Reason is false.
D. If both Assertion and Reason are false.

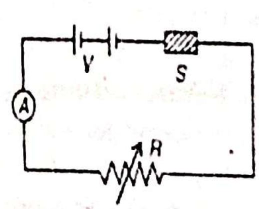
1. **Assertion (A):** As the temperature of a semiconductor increases, its resistance decreases.
Reason (R): The energy gap between conduction band and valence band is > 3eV in semiconductor.
2. **Assertion (A):** The resistivity of a semiconductor increases with temperature.
Reason (R): The atoms of a semiconductor vibrate with larger amplitude at higher temperature there by increasing it's resistivity.
3. **Assertion(A):** Semiconductors are used to build digital logic circuits.
Reason(R): They cannot easily switch between high and low voltage states.
4. **Assertion(A):** In digital electronics, we prefer Integrated circuits or diodes etc made up of Silicon over Germanium.
Reason(R): Silicon has better thermal stability.
5. **Assertion(A):** In an intrinsic semiconductor, the Fermi level lies midway between conduction and valence bands.
Reason(R): There are more electrons than holes in an intrinsic semiconductor.
6. **Assertion(A):** The band gap of Germanium is higher than that of silicon.
Reason(R): Germanium has higher resistivity than silicon.

ANSWERS

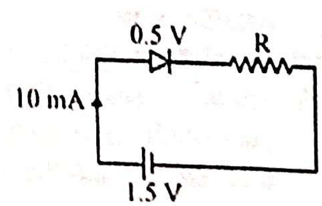
1. C, **Explanation:** As temperature rises, the electrons of valence band sufficient energy and jump to conduction band. Thus, the resistivity decreases. So assertion is true. In semiconductors the energy gap between conduction band and valence band is small.
2. D, **Explanation:** Resistivity of semiconductors decreases with temperature. So, assertion is false. Electrons from valence band jumps to conduction band with rise of temperature and hence the resistivity decreases. Hence, the reason is also false.
3. C, **Explanation:** Fast switching makes semiconductors ideal for logic.
4. A, **Explanation:** Silicon handles higher temperatures effectively.
5. C, **Explanation:** Reason is false; intrinsic semiconductors have equal electrons and holes.
6. D, **Explanation:** Both statements are false.

VERY-SHORT ANSWER QUESTIONS

1. In a p-n junction, width of depletion region is 300 nm and electric field of 7×10^5 V/m exists in it.
(i) Find the height of potential barrier.
(ii) What should be the minimum kinetic energy of a conduction electron which can diffuse from the n-side to the p-side?
Answer:- (i) $V=E.d=7\times10^5\times300\times10^{-9}=0.21V$
(ii) Kinetic energy $=eV=0.21$ eV
2. The diagram shows a piece of pure **semiconductor 'S'** in series with **variable resistor R** and a source of constant voltage V. Would you increase or decrease the value of R to keep the reading of ammeter (A) constant when semiconductor 'S' is cooled ? Give one reason.



{Answer- Decrease the value of R
Reason : on cooling, conductivity of the semiconductor decreases}
3. When a diode is forward biased, it has a voltage drop of $0.5V$. The safe limit of current through the diode is $10mA$. If a battery of emf $1.5V$ is used in the circuit, the value of minimum resistance to be connected in series with the diode so that the current does not exceed the safe limit will be?

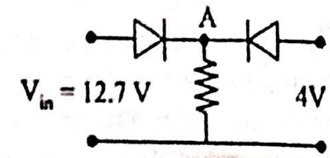


Answer- Applying Kirchhoff's voltage law

$1.5-0.5-R\times10\times10-3=0$

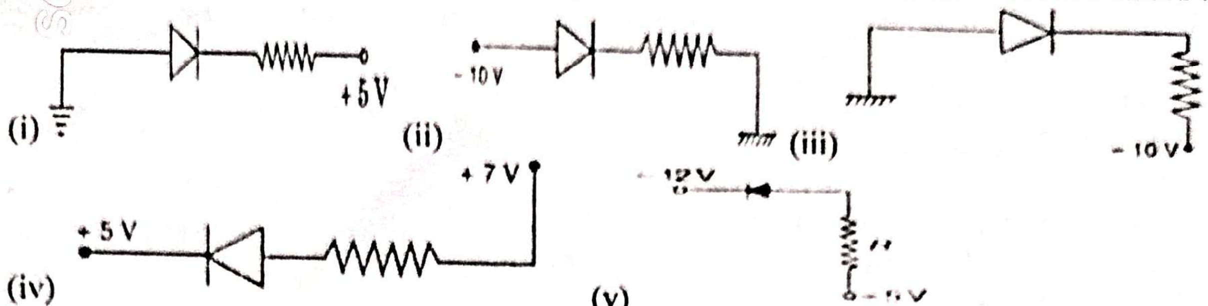
$\therefore R=100\Omega$

Both the diodes used in the circuit shown are assumed to be ideal and have negligible resistance when these are forward biased. Built in potential in each diode is 0.7 V. For the input voltages shown in the figure, the voltage (in Volts) at point A is _______.



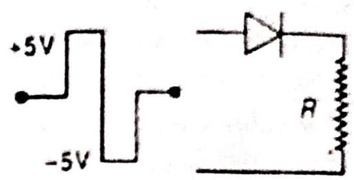
Answer- Right hand diode is reversed biased and left-hand diode is forward biased. Hence Voltage at 'A' $V_A = 12.7 - 0.7 = 12$ volt

5. In the following circuit diagram, is the junction diode forward biased or reverse biased ?



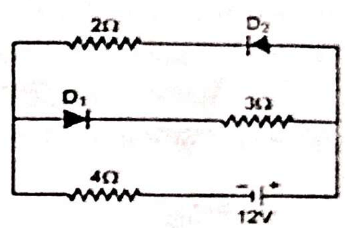
{Answer- (i) reverse bias (ii) reverse bias (iii) Forward bias (iv) forward bias (v) forward bias

6. Draw and explain the output wave forms across the load resistor R, if the input waveform is as shown in the figure.



{Answer:-since the diode will be forward biased during the first half only, so in 2[nd] half of input signal there will be no output.

7. The circuit shown in the figure has two oppositely connected ideal diodes connected in parallel. Find the current flowing through each diode in the circuit.



{Answer:- through D1, I=0, through D2, $I = \frac{12}{2+4} = 2A$ }

SHORT-ANSWER QUESTIONS

1. Three samples are given to you. One is Copper, 2[nd] is Germanium, 3rd is Glass. Identify them as a conductor, an insulator or a semiconductor. Distinguish them on the basis of energy band diagrams.

{Answer:- 1[st] is a Conductor, 2[nd] is a semiconductor, 3[rd] is an insulator

(a). Conductors (Metals) :

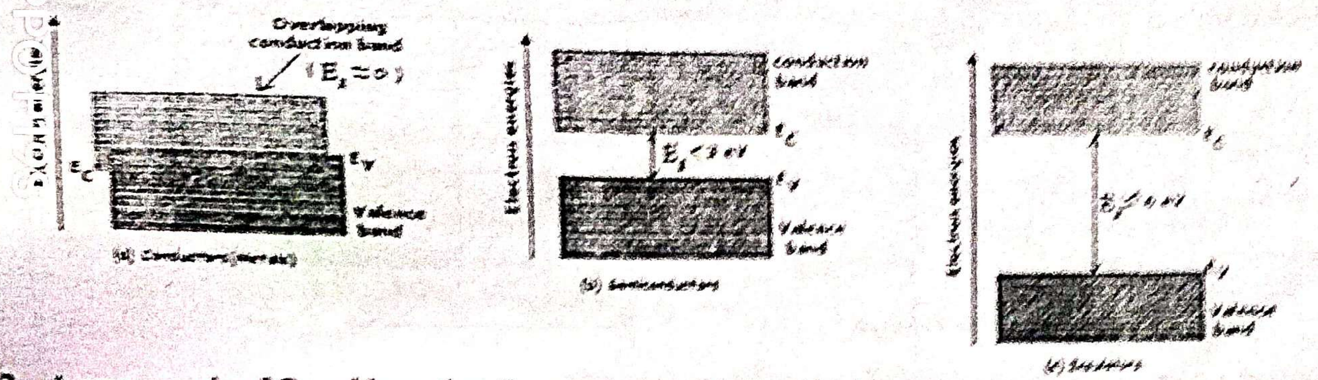
In conductors either conduction and valence band partly overlap each other or the conduction band is partially filled. Forbidden energy gap does not exist (This makes a large number of free electrons available for electrical conduction. So, the metals have high conductivity.

(b). Semiconductors :

In semiconductors, the conduction band is empty, and valance band is totally filled E_g is quite small (3 eV). At 0K, electrons are not able to cross this energy gap, and the semiconductor behaves as an insulator. But at room temperature, some electrons are able to jump to conduction band and semiconductor acquires small conductivity

(c). Insulators

In insulators, conduction band is empty and valance band is totally filled. E_g is very large (≈6 eV). It is not possible to give such large amount of energy to electrons by any means. Hence conduction band remains total empty, and the crystal remains as an insulator.



2. A pure sample of Ge with another Ge sample which is doped with an impurity of 13^{th} or 15^{th} group elements with impurity concentration 1 in million. Identify and compare the properties of both samples formed.

{**Answer-** One is intrinsic, 2^{nd} one is extrinsic.

Intrinsic Semiconductor	**Extrinsic Semiconductor**
1. It is a pure semiconductor.	1. It is a semiconductor with added impurity.
2. $n_e = n_h$	2. $n_e \neq n_h$
3. Low conductivity at room temperature	3. High conductivity at room temperature
4. Its electrical conductivity depends on the temperature only.	4. Its electrical conductivity depends on temperature and the amount of doping.

3. A sample of Si doped with trivalent impurity and another Si sample which is doped with pentavalent impurity (each with impurity concentration 1 in million).

{**Answer-** First is p-type extrinsic semiconductor, 2^{nd} one is n-type extrinsic semiconductor.

4. A student wants to produce **12 V** d.c. from **220 V, 50 Hz** a.c. signal. Firstly, he steps down the voltage from **220 V a.c. to 12 V a.c. using a transformer** and to convert **12 V a.c. to 12 V d.c.** he uses a **semiconductor device** which will produce an output frequency of 100Hz. Identify that semiconductor device. Explain its underlying working principle and working with help of a circuit diagram. Depict the input and output wave forms.

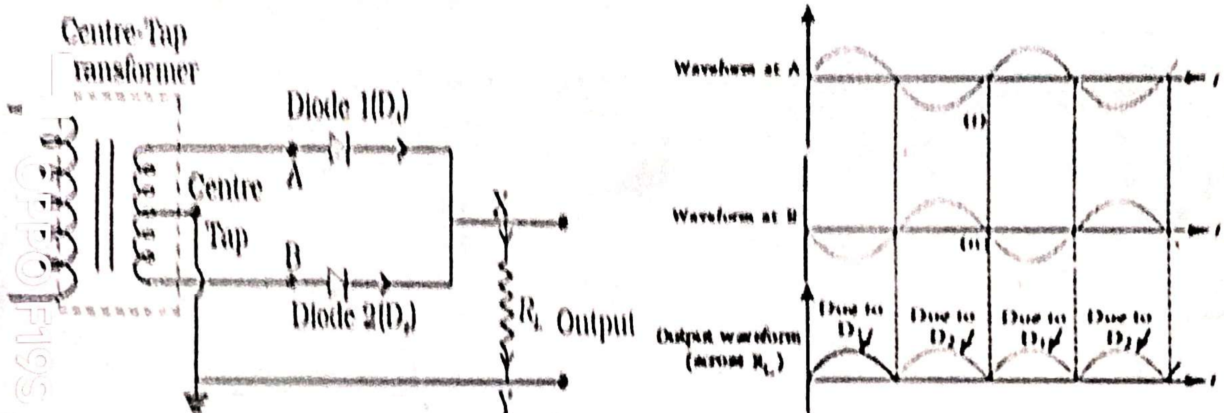
{**Answer:-** Device is Full wave rectifier.

Working Principle- a diode offers low resistance when forward biased and high resistance when reversed biased.

During the positive half cycle of a.c. input signal, diode D_1 gets forward biased and conducts while D_2 being reverse biased does not conducts. Hence, there is a current in R_L due to diode D_1 and we get an output voltage.

During the negative half cycle of ac input signal, diode D_1 gets reverse biased and does not conduct while D_2 being forward biased conducts. Hence, now there is a current in R_L due to diode D_2 and again we get an output voltage.

Thus, we get output voltage for complete cycle of a.c. input signal in the same direction.



5. Suppose a pure Si crystal has 5×10^{28} atoms m^{-3}. It is doped by 1ppm concentration of As. Calculate the number of electrons and holes. Given that $n_i = 1.5\times10^{16}\ m^{-3}$. Is the doped crystal n-type or p-type?

Answer:- Here $n_i = 1.5\times10^{16}\ m^{-3}$

Doping concentration of As atoms = 1 ppm= 1 part per million

∴ Number density of pentavalent As atoms,

$N_D = \frac{5\times10^{28}}{10^6} = 5\times10^{22}$ atoms m^{-3}

Now, the thermally generated electrons are negligibly small as compared to those produced by doping, so

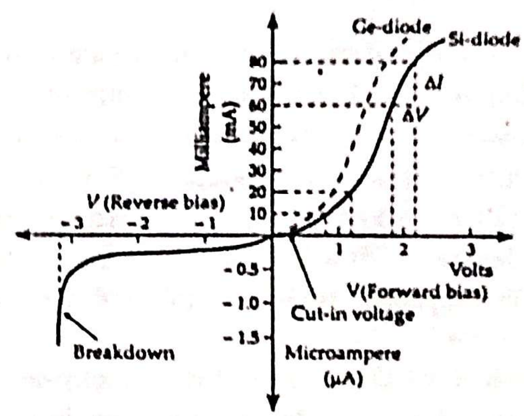
$n_e \approx N_D = 5\times10^{22}$ atoms m^{-3}

Also, $n_e n_h = n_i^2$

$\therefore n_h = \frac{n_i^2}{n_e} = \frac{1.5\times10^{16}\times1.5\times10^{16}}{5\times10^{22}} = 4.5\times10^9\ m^{-3}$

Since the impurity is pentavalent, the doped crystal is n-type.

6. The V-I characteristic of a silicon diode is given in fig. below. Calculate the diode resistance in : (a) forward bias at V=+2 V and V=+1 V, and (b) reverse bias V= -1 V and -2 V.



Answer:- (a) the forward bias diode resistance is given by

$r_f = \frac{\Delta V}{\Delta I}$, where ΔV and ΔI are the small changes in voltage and current near the desired voltages.

$$r_f(at+2V) = \frac{(2.2-1.8)V}{(80-60)mA} = \frac{0.4\ V}{20\times10^{-3}\ A} = 20\ \Omega$$

$$r_f(at+1V) = \frac{(1.2-0.8)V}{(20-10)mA} = \frac{0.4\ V}{10\times10^{-3}\ A} = 40\ \Omega$$

(b) in the reverse bias characteristic, the non-linearity in the V-I curve is small. The slopes of V-I curve at -1 V and -2 V are nearly equal.

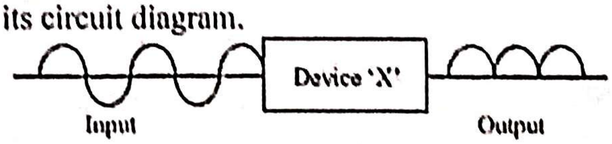
$$r_r(at-2V) = \frac{-2\ V}{-0.25\ \mu A} = 8\times10^6\ \Omega$$

Also, $r_r(at-1V) = 8\times10^6\ \Omega$

LONG ANSWER QUESTIONS

1. **(a) Explain the formation of depletion layer and potential barrier in a p–n junction.**

(b) In the figure given below the input waveform is converted into the output waveform by a device 'X'. Name the device and draw its circuit diagram.



Answer:- (a) p-n junction : When a semiconductor crystal is so prepared that, it's one half is p-type and other is n-type, then the contact surface dividing the two halves, is called p-n junction.

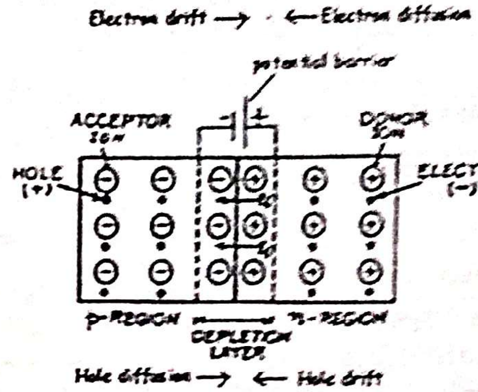
Formation of p-n junction : potential barrier & depletion region

Diffusion and drift are the two important processes involved during the formation of a p-n junction.

Due to different concentration gradient of the charge carriers on two sides of the junction, electrons from n-side starts moving towards p-side and holes start moving from p-side to n-side.

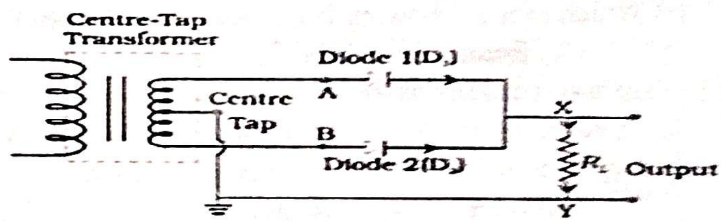
Due to diffusion, positive space charge region is created on the n-side of the junction and negative space charge region is created on the p-side of the junction. Hence an electric field called Junction field is set up from n-side to p-side which forces the minority charge carriers to cross the junction. This process is called Drift.

The potential difference developed across the p-n junction due to diffusion of majority charge carriers, which prevents the further movement of majority charge carriers through it, is called potential barrier. For Si, $V_B = 0.7$ V and for Ge, $V_B = 0.3$ V



The small space charge region on either side of the p-n junction, which becomes depleted from mobile charge carriers is known as depletion region (10^{-6} m)

(b) The device is a full-wave rectifier.
The circuit diagram of a full-wave rectifier is represented as-

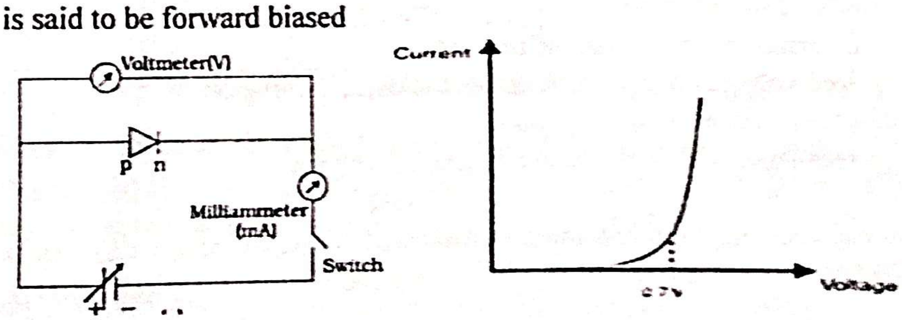


2. (a) A student connects p-side of a p-n junction diode with positive terminal of battery and n-side is connected with negative terminal of battery. Another student connects the diode in opposite way with battery. Identify the biasing in both the cases. Draw the circuit diagram of these biasings of a p-n junction.

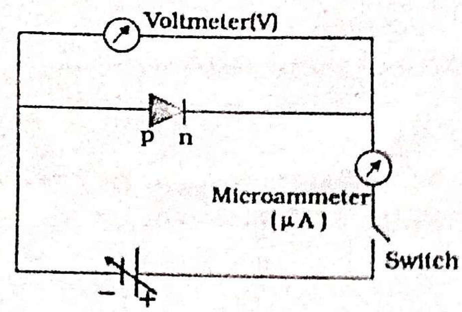
(b) If the ratio of the concentration of electrons to that of holes in a semiconductor is 5/7 and the ratio of currents is 4/7. Find the ratio of their drift velocities.

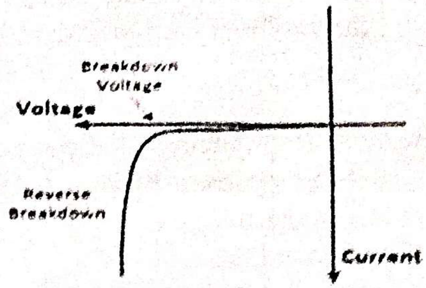
{Answer:- Case-1 Forward biasing :

When the positive terminal of external battery is connected to p-side and negative terminal to the n-side, then the p-n junction is said to be forward biased



Case-2 Reverse biasing : When the positive terminal of external battery is connected to n-side and negative terminal to the p-side, then the p-n junction is said to be reverse biased





(b) Relation between drift velocity and current is

$I = nAeV_d$, $\quad \frac{I_e}{I_h} = \frac{n_e AeV_e}{n_h AeV_h}$ or $\frac{7}{4} = \frac{7}{5} \times \frac{V_e}{V_h}$ or $\frac{V_e}{V_h} = \frac{5}{4}$

CASE STUDY-BASED QUESTIONS

1. Extrinsic semiconductors are made by doping pure or intrinsic semiconductors with suitable impurity. There are two type of dopants used in doping, Si or Ge, and using them p-type and n-type semiconductors can be obtained. A p-n junction is the basic building block of many semiconductor devices. Two important processes occur during the formation of a p-n junction: diffusion and drift. When such a junction is formed, a depletion layer is created consisting of immobile ion-cores.

This is responsible for a junction potential barrier. The width of a depletion layer and the height of potential barrier changes when a junction is forward-biased or reverse-biased. A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for application of an external voltage. Using diodes, alternating voltages can be rectified.

(i) Which of the following is a donor impurity atom for Ge ?

(A) Boron (B) Antimony (C) Aluminium (D) Indium

(ii) When a pentavalent atom occupies the position of an atom in the crystal lattice of Si, four of its electrons form covalent bonds with four silicon neighbors, while the fifth remains bound to the parent atom. The energy required to set this electron free is about :

(A) 0.5 eV (B) 0.1 eV (C) 0.05 eV (D) 0.01 eV

(iii) During formation of a p-n junction :

(A) a layer of negative charge on n-side and a layer of positive charge on p-side appear.
(B) a layer of positive charge on n-side and a layer of negative charge on p-side appear.
(C) the electrons on p-side of the junction move to n-side initially.
(D) initially diffusion current is small, and drift current is large.

(iv) (a) In reverse-biased p-n junction :

(A) the drift current is of the order of few mA.
(B) the applied voltage mostly drops across the depletion region.
(C) the depletion region width decreases.
(D) the current increases with increase in applied voltage.

OR

(b) The output frequency of a full-wave rectifier with 50 Hz as input frequency is :

(A) 25 Hz (B) 50 Hz (C) 100 Hz (D) 200 Hz

Answer:- i).B ii). C iii).B iv). (a) B OR (b) C