Modern Physics

1. Dual Nature of Radiation

(Electromagnetic Wave):

Electromagnetic radiation is an emission with a dual nature, i.e. it has both wave and particle aspects.

2. Photon Theory

According to quantum theory, light consists of photons as energy packets having following properties :

(i) Each photon is of energy $E = h\nu = hc/\lambda$

$$E = \frac{12400}{\lambda(\text{Å})} \text{ eV}$$

Where h is planck's constant. Where $h = 6.63\times10^{-34}$ J-sec = 4.14×10^{-15} eV–sec,

(ii) All photons travel in straight line with the speed of light in vacuum.

(iii) Photons are electrically neutral.

(iv) Photons have zero rest mass.

(v) Photons are not deflected by electric and magnetic fields.

(vi) The equivalent mass of a photon while moving is given by

$$m = \frac{E}{c^2} = \frac{h\nu}{c^2} = \frac{hc}{c^2\lambda} = \frac{h}{c\lambda}$$

(vii) Momentum of the photon

$$p = E/c = h\nu/c = h/\lambda$$

(viii) Number of photons per second of wavelength λ emitted from a lamp of power P is-

$$n = \frac{P\lambda}{hc}$$

(ix) Velocity of photon in vacuum is always c & it's independent from frame of reference.

(x) Equivalent mass

$$m = \frac{\text{energy of photon(E)}}{c^2} \Rightarrow m = \frac{hf}{c^2}$$

Example 1:

Find the number of photons in 6.63 joule of radiation energy of frequency 10^{12} Hz?

Solution:

No. of photons

$$n = \frac{\text{Total Energy}}{\text{Energy of one Photon}} = \frac{E}{h\nu} = \frac{6.63}{6.63\times10^{-34}\times10^{12}} = 10^{22}$$

Example 2:

Calculate the energy and momentum of a photon of wavelength 6600Å.

Solution:

Energy of photon

$$E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{6600 \times 10^{-10}} = 3 \times 10^{-19} \text{ J}$$

Momentum of photon

$$p = \frac{h}{\lambda} = \frac{6.6 \times 10^{-34}}{6600 \times 10^{-10}} = 10^{-27} \text{kg m/sec.}$$

3. Momentum, Force and Radiation Pressure

The electromagnetic wave transports not only energy but also momentum, and hence can exert a radiation pressure and force on a surface due to the absorption or reflection.

- The energy of photons is given as

  $$E = h\nu = \frac{hc}{\lambda} = mc^2$$

  where ν is frequency, λ is wavelength, h is Planck's constant.
- The photon is a charge less particle of zero rest mass.
- Photons are electrically neutral. They are not deflected by electric or magnetic fields.
- If E is the energy of source in joule then number of photons emitted is

  $$n = \frac{\text{total energy radiated}}{\text{energy of each photon}} = \frac{E}{h\nu} = \frac{E\lambda}{hc}$$

- Intensity of photons is defined as amount of energy carried per unit area per unit time. Or power carried per unit area

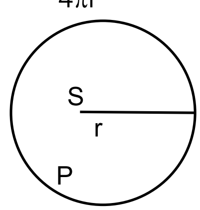
  $$\text{Intensity } (I_p) = \frac{\text{Energy}}{\text{area} \times \text{time}} = \frac{\text{Power}}{\text{area}}$$

  $$I_p = nh\nu = \frac{N}{4\pi r^2} P$$

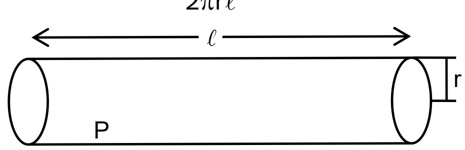
  where n = number of photons per unit area per unit time

  N = number of photons, P = power of source

e.g. (a) For a point source $I_p = nh\nu = \frac{N}{4\pi r^2} P$



(b) For a line source $I_p = nh\nu = \frac{N}{2\pi r\ell} P$



According to Newton's second law the force exerted by an electromagnetic wave on a surface may be related by the equation,

$F = \frac{\Delta p}{\Delta t}$

From Eq. (i), $\frac{\Delta p}{\Delta t} = \frac{1}{c}\left(\frac{\Delta E}{\Delta t}\right)$

$\therefore \quad F = \frac{1}{c}\left(\frac{\Delta E}{\Delta t}\right) \quad$ ...(ii).

Intensity (I) of a wave is the energy transported per unit area per unit time.

or $\quad I = \left(\frac{1}{A}\right)\frac{\Delta E}{\Delta t} \quad \therefore \frac{\Delta E}{\Delta t} = I.A.$

Substituting in Eq. (ii), $\quad F = \frac{IA}{c}$

or $\quad \frac{F}{A}$ = pressure = $\frac{I}{c}$ or $P_{rad} = \frac{I}{c}$

$\frac{I}{c}$ is also equal to the energy density (energy per unit volume) u.

If absorption and reflection coefficient be 'a' and 'r'

Case 1. a = 1, r = 0

$$P_{rad} = \frac{F}{A} = \frac{IA}{cA} = I/c$$

Case 2. r = 1, a = 0

$$P_{rad} = \frac{F}{A} = \frac{2IA}{cA} = \frac{2I}{c}$$

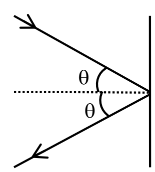
Case 3. 0 < r < 1 a + r = 1

$$P_{rad} = \frac{F}{A} = \frac{IA}{c}(1 + r) \times \frac{1}{A} = \frac{I}{c}(1+r)$$

Case 4. General case When 0 < r < 1

a + r = 1 & angle of incidence makes an angle θ with normal

$$P_{rad} = \frac{F}{A} = \frac{IA}{c}(1 + r) \times \frac{1}{A}\cos\theta = \frac{I}{c}(1 + r)\cos^2\theta$$



Example 3:

The intensity of direct sunlight before it passes through the earth's atmosphere is 1.4 kW/m^2. If it is completely absorbed find the corresponding radiation pressure.

Solution:

For completely absorbing surface,

$$P_{rad} = \frac{I}{c} = \frac{1.4 \times 10^3}{3.0 \times 10^8} = 4.7 \times 10^{-6}\ Nm^{-2}$$

Example 4:

Monochromatic light of wavelength 3000 Å is incident normally on a surface of area 4 cm^2. If the intensity of the light is 15×10^{-2} W/m^2, determine the rate at which photons strike the surface.

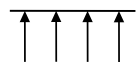
Solution:

Rate at which photons strike the surface

$$= \frac{IA}{hc/\lambda} = \frac{6 \times 10^{-5} J/s}{6.63 \times 10^{-19} J/photon} = 9.05 \times 10^{13} \text{ photon/s.}$$

Example 5:

A plate of mass 10 g is in equilibrium in air due to the force exerted by light beam on plate.



Calculate power of beam. Assume plate is perfectly absorbing.

Solution:

Since plate is in air, so gravitational force will act on this

$F_{gravitational} = mg$ (downward)

$= 10 \times 10^{-3} \times 10 = 10^{-1}$ N

for equilibrium force exerted by light beam should be equal to $F_{gravitational}$.

$F_{photon} = F_{gravitational}$

Let power of light beam be P

$\therefore \quad F_{photon} = \frac{P}{c} \quad \therefore \quad \frac{P}{c} = 10^{-1}$

$P = 3.0 \times 10^{8} \times 10^{-1} \quad \Rightarrow \quad P = 3 \times 10^{7}$ W

Example 6:

Radiation of wavelength 200 nm. propagating in the form of a parallel beam, fall normally on a plane metallic surface. The intensity of the beam is 5 mW and its cross-sectional area is 1.0 mm^2. Find the pressure exerted by the radiation on the metallic surface if the radiation is completely reflected.

Solution:

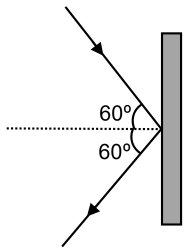
$$I = \frac{P}{A} = \frac{5 \times 10^{-3}}{1 \times 10^{-6}} = 5 \times 10^{-5} \text{ W/m}^2$$

$$p = \frac{2I}{c} = \frac{2 \times 5 \times 10^{3}}{3 \times 10^{8}} = 3.3 \times 10^{-5} \text{ N/m}^2$$

Example 7:

A parallel beam of monochromatic light of wavelength 663 nm is incident on a totally reflected 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.

Solution:



$$F = \frac{2P\cos 60^\circ}{c}$$

$$= \frac{2\times n\frac{hc}{\lambda}\cos 60^\circ}{c} = \frac{10^{19}\times 6.63\times 10^{-34}}{663\times 10^{-19}} = 10^{-8}\ \text{N}$$

Example 8:

A beam of white light is incident normally on a plane surface absorbing 70% of the light and reflection the rest. If the incident beam carries 10 W of power, find the force exerted by it on the surface.

Solution:

F = 2 P/c, if light is completely reflected

F = P/c, if light is completely absorbed

Here, in this problem, 70% light is absorbed and 30% is reflected.

$$F = \frac{70}{100}\times\frac{P}{c} + \frac{30}{100}\times\frac{2P}{c} = 1.3\,\frac{P}{c} = \frac{1.3\times 10}{3\times 10^8} = 4.3\times 10^{-8}\ \text{N}$$

Concept Builder-1

Q.1 The energy of a photon is equal to 3 kilo eV. Calculate its linear momentum?

Q.2 Which colour of photon has greater energy either red or violet?

Q.3 Calculate number of photons passing through a ring of unit area in unit time if light of intensity 100 Wm^{-2} and of wavelength 400 nm is falling normally on the ring.

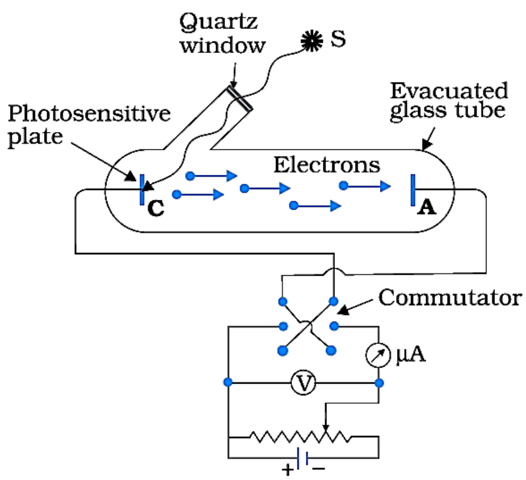
Q.4 A TV station is operated at 100 MW with a signal frequency of 10 MHz. Calculate the number of photons radiated per second by its antenna.

Q.5 A special kind of light bulb emits monochromatic light of wavelength 700 nm. Electrical energy supply to it at the rate of 60 W and the bulb is 50% efficient at converting that energy to light energy. How many photons are emitted by the bulb during its life time of 1 day.

Q.6 A parallel beam of monochromatic light of wave length 500 nm is incident normally on a perfectly absorbing surface. The power through any cross-section of the beam is 10 W. Find
(a) Number of photon absorbed by the surface per second.
(b) The force exerted by light beam on the surface.

4. Photoelectric Effect

When light of an appropriate frequency (or correspondingly of an appropriate wavelength) is incident on a metallic surface, electrons are liberated from the surface. This observation is known as **photoelectric effect**. Photoelectric effect was first observed in 1887 by **Hertz**. Attempts to explain the effect by classical electromagnetic failed. In 1905, Albert Einstein presented an explanation based on the quantum concept of Max Planck. The effect is based on the principle of conservation of energy.



Threshold Frequency (ν_0):

The minimum frequency of incident radiations required to eject the electron from metal surface is known as threshold frequency.

If incident frequency $\nu < \nu_0 \Rightarrow$ No photoelectron emission.

Threshold Wavelength (λ_0):

The maximum wavelength of incident radiations required to eject the electrons from a metallic surface is known as threshold wavelength.

If incident wavelength $\lambda > \lambda_0 \Rightarrow$ No photoelectron emission.

Work Function (W or ϕ):

The minimum energy of incident radiation, required to eject the electrons from metallic surface is known as work function of that surface.

$\phi = h\nu_0$, ν_0 = Threshold frequency ;

$\phi = h\nu_0 = \dfrac{hc}{\lambda_0}$ (Joule) ; ν_0 = Threshold frequency ; λ_0 = Threshold wavelength

$$\phi = \frac{hc}{e\lambda_0} = \frac{12400}{\lambda_0(\text{Å})} \text{ eV}$$

Maximum Kinetic Energy (K_{max}): According to Einstein maximum of kinetic energy is –

$K_{max} = E - \phi$

where E is energy of incident photon and ϕ is work function.

And also $K_{max} = h\nu - h\nu_0$

or $K_{max} = \left(\frac{hc}{\lambda} - \frac{hc}{\lambda_0}\right)$

Stopping Potential (V_0):

At a particular negative potential of Anode no electron will reach the plate and the current will become zero, this negative potential is called stopping potential denoted by V_0.

- If we apply negative potential equal to stopping potential then photoelectric effect takes place but no photo current are observed.

  $\Rightarrow K_{max} = eV_0$

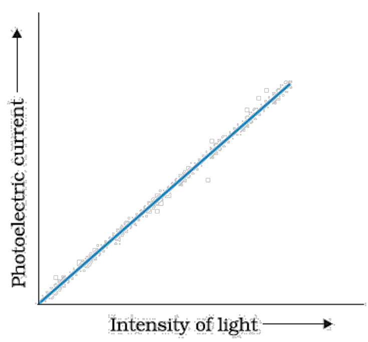
  $\Rightarrow h\nu - h\nu_0 = eV_0$

  $\Rightarrow V_0 = \left(\frac{h\nu}{e} - \frac{h\nu_0}{e}\right)$

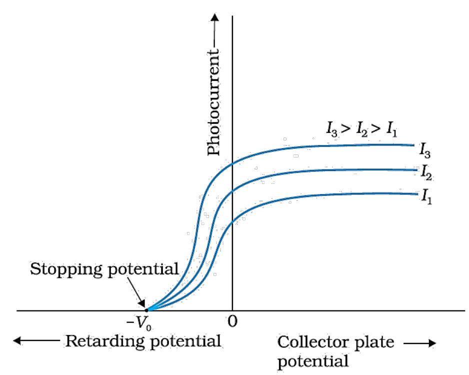
The stopping potential V_0 depends only on the metal and frequency of incident photon and does not depend on the intensity of incident light.

Saturation Current (I_s): This is the current in the circuit for which all the electron emitted by cathode are able to reach anode.

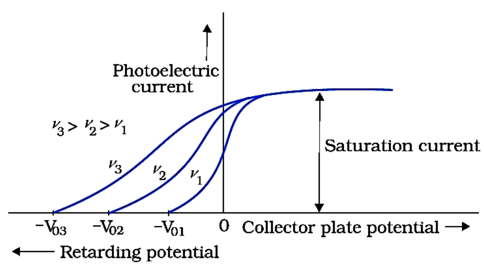
Graphs



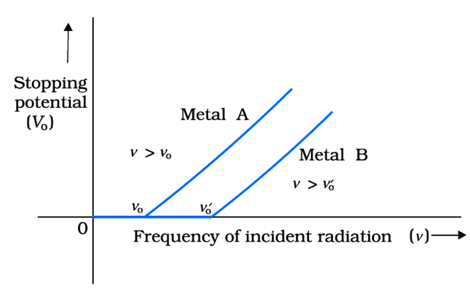
Variation of Photoelectric current with intensity of light.



Variation of photocurrent with collector plate potential for different intensity of incident radiation.



Variation of photoelectric current with collector plate potential for different frequencies of incident radiation.



Variation of stopping potential V_0 with frequency ν of incident radiation for a given photosensitive material.

Example 9:

The kinetic energies of photoelectrons range from zero to 4.0×10^{-19} J when light of wavelength 3000 Å falls on a surface. What is the stopping potential for this light ?

Solution:

$$K_{max} = 4.0 \times 10^{-19} \text{ J} \times \frac{1\text{eV}}{1.6 \times 10^{-19}\text{J}} = 2.5 \text{ eV}.$$

Then, from $eV_s = K_{max}$, $V_s = 2.5$ V.

Example 10:

What is the threshold wavelength for the material in above problem ?

Solution:

$$2.5 \text{ eV} = \frac{12400\text{eV}}{\lambda_{th}\text{Å}} - \frac{12400\text{eV}}{3000\text{Å}}$$

Solving, $\lambda_{th} = 7590$ Å.

Example 11:

In an experiment on photo electric emission, following observations were made;

(i) Wavelength of the incident light = 1.98×10^{-7} m;

(ii) Stopping potential = 2.5 volt.

Find :

(a) Kinetic energy of photoelectrons with maximum speed.

(b) Work function and

(c) Threshold frequency;

Solution:

(a) Since $V_s = 2.5$ V, $K_{max} = eV_s$

so, $K_{max} = 2.5$ eV

(b) Energy of incident photon

$$E = \frac{12400}{1980} = 6.26 \text{ eV}$$

$$W = E - K_{max} = 3.76 \text{ eV}$$

(c) $h\nu_{th} = W = 3.76 \times 1.6 \times 10^{-19}$ J

$$\therefore \quad \nu_{th} = \frac{3.76 \times 1.6 \times 10^{-19}\text{J}}{6.6 \times 10^{-34}} \approx 9.1 \times 10^{14} \text{ Hz}$$

$\approx 9.1 \times 10^{14}$ Hz

Example 12:

A metallic surface is irradiated with monochromatic light of variable wavelength. Above a wavelength of 5000 Å, no photoelectrons are emitted from the surface. With an unknown wavelength, stopping potential is 3V. Find the unknown wavelength.

Solution:

Using equation of photoelectric effect

$K_{max} = E - \phi \qquad (K_{max} = eV_s)$

$\therefore \qquad 3 \text{ eV} = \frac{12400}{\lambda} - \frac{12400}{5000} = \frac{12400}{\lambda} - 2.48 \text{ eV}$

or $\qquad \lambda = 2262$ Å

Example 13:

Illuminating the surface of a certain metal alternately with light of wavelengths $\lambda_1 = 0.35$ μm and $\lambda_2 = 0.54$ μm, it was found that the corresponding maximum velocities of photo electrons have a ratio $\eta = 2$. Find the work function of that metal.

Solution:

Using equation for two wavelengths

$$\frac{1}{2} mv_1^2 = \frac{hc}{\lambda_1} - \phi \qquad ....(i)$$

$$\frac{1}{2} mv_2^2 = \frac{hc}{\lambda_2} - \phi \qquad ....(ii)$$

Dividing Eq. (i) with Eq. (ii), with $v_1 = 2v_2$, we have $\quad 4 = \dfrac{\dfrac{hc}{\lambda_1} - \phi}{\dfrac{hc}{\lambda_2} - \phi}$

$\Rightarrow \qquad 3\phi = 4\left(\frac{hc}{\lambda_2}\right) - \left(\frac{hc}{\lambda_1}\right)$

$\Rightarrow \qquad 3\phi = \frac{4 \times 12400}{5400} - \frac{12400}{3500} = 5.64 \text{ eV}$

$\phi = 1.88$ eV

Example 14:

1 mW of light of wavelength 456 nm is incident on a cesium surface. Calculate the photoelectric current produced, if the quantum efficiency of the surface for photoelectric emission is only 0.5%.

Solution: $\qquad P = n\frac{hc}{\lambda}$, n : number of photons/sec

$n = \frac{P\lambda}{hc}$

Quantum efficiency

$\eta = \frac{\text{number of electron sejected / sec}}{\text{number of photonsincident / sec}} = \frac{n'}{n}$

$n' = \eta n$

Photoelectric current

$i = n'e = (\eta\, n)e = \eta\left(\frac{P\lambda}{hc}\right) e$

$= \left(\frac{0.5}{100}\right) \frac{(10^{-3})(456 \times 10^{-9})}{(6.6 \times 10^{-34})(3 \times 10^{8})} \times 1.6 \times 10^{-19} = 1.84 \times 10^{-6} \text{ A} = 1.84 \text{ μA}$

Example 15:

In a experiment on photoelectric effect, light of wavelength 400 nm is incident on a cesium plate at the rate of 5.0 W. The potential of the collector plate is made sufficiently positive with respect to the emitter so that the current reaches its saturation value. Assuming that on the average one out of every 10^6 photons is able to eject a photoelectron, find the photocurrent in the circuit.

Solution:

Here ; $\eta = \frac{1}{10^6}$; $i = \eta \frac{P\lambda}{hc} e$

$= \frac{1}{10^6} \times \frac{5 \times 400 \times 10^{-9}}{6.6 \times 10^{-34} \times 3 \times 10^8} \times 1.6 \times 10^{-19} = 1.6 \times 10^{-6}$ A = 1.6 μA

Example 16:

Light described at a place by the equation

$E = (100 \text{ V/m}) [\sin (5 \times 10^{15} \text{ s}^{-1}) t + \sin (8 \times 10^{15} \text{ s}^{-1})t]$

falls on a metal surface having work function 2.0 eV. Calculate the maximum kinetic energy of the photoelectrons.

Solution:

The light contains two different frequencies. The one with larger frequency will cause photoelectrons with largest kinetic energy. This larger frequency is

$$v = \frac{\omega}{2\pi} = \frac{8 \times 10^{15} \text{s}^{-1}}{2\pi}$$

The maximum kinetic energy of the photoelectrons is

$K_{max} = h\upsilon - W$

$= (4.14 \times 10^{-15} \text{ eV-s}) \times \left(\frac{8 \times 10^{15}}{2\pi} \text{s}^{-1}\right) - 2.0 \text{ eV} = 5.27 \text{ eV} - 2.0 \text{ eV} = 3.27 \text{ eV}.$

Concept Builder-2

Q.1 A monochromatic light incident on metal 'A' having threshold frequency ν_0. It emits photo electrons of maximum kinetic energy K. Now incident frequency is made three times and fall on a metal 'B' having threshold frequency $2\nu_0$. What will maximum kinetic energy of photo electrons emitted by metal 'B'?

Q.2 A metalic surface of work function hn is illuminated by a radiation beam of frequency 5ν. Stopping potential observed is X. What will be stopping potential if the surface is illuminated by radiations of 7ν frequency?

Q.3 If light of wavelength 4000 Å falls on a metal which has a stopping potential 1.4 volt against photoelectric emission then what is the work function of the metal. [Take $h = 6.6 \times 10^{-34}$ Js and $c = 3 \times 10^8$ ms^{-1}]

Q.4 A light beam of power 1.5 mW and 400 nm wavelength incident on a cathode. If quantum efficiency is 0.1% then, find out obtained photo current and number of photoelectron per second.

Q.5 The kinetic energy of the fastest moving photo electron from a metal of work function 2.8 eV is 2eV. If the frequency of light is doubled, then find the maximum kinetic energy of photo electron.

Q.6 The wavelength of photons in two cases are 4000 Å and 3600 Å respectively what is difference in stopping potential for these two?

Q.7 The work function of a metal is 4 eV if 5000Å wavelength of light is incident on the metal. Is there any photo electric effect?

Q.8 When incident wavelength is λ, stopping potential is 3 V_0. If incident wavelength is 2λ then stopping potential is V_0. Find out threshold wavelength in terms of λ.

Q.9 In a photo cell 4 unit photo electric current is flowing, the distance between source and cathode is 4 unit. Now distance between source and cathode becomes 1 unit. What will be photo electric current now ?

Q.10 Threshold frequency of a surface is ν_0. It is illuminated by 3 ν_0 frequency, then maximum speed of photo electrons is V m/sec. What will be maximum speed if incident frequency is 9 ν_0 ?

5. De-Broglie Wavelength of Matter Wave

As wave behaves like material particles, similarly matter also behaves like waves. According to de-Broglie, a wavelength of the matter wave associated with a particle is given by $\lambda = \frac{h}{p} = \frac{h}{mv}$ $= \frac{h}{\sqrt{2Km}}$, where m is the mass, v is velocity and K is kinetic energy of the particle.

- **de-Broglie wavelength for an electron:**

  If an electron (charge = e) is accelerated by a potential of V volts, it acquires a kinetic energy, K = eV

  Substituting the values of h, m and q in above Eq. we get a simple formula for calculating de-Broglie wavelength of an electron.

  $$\lambda(\text{in Å}) = \sqrt{\frac{150}{V(\text{in volts})}}$$

- **de-Broglie wavelength of a gas molecule:**

  Let us consider a gas molecule at absolute temperature T. Kinetic energy of gas molecule is given by

  K.E. = $\frac{3}{2}$ kT ; k = Boltzmann constant

  $\therefore \quad \lambda_{\text{gas molecule}} = \frac{h}{\sqrt{3mkT}}$

Example 17:

An electron is accelerated by a potential difference of 50 volt. Find the de-Broglie wavelength associated with it.

Solution:

For an electron, de-Broglie wavelength is given by,

$\lambda = \sqrt{\frac{150}{V}} = \sqrt{\frac{150}{50}} = \sqrt{3} = 1.73$ Å

Example 18:

Find the ratio of de-Broglie wavelength of molecules of hydrogen and helium which are at temperatures 27°C and 127°C respectively.

Solution:

de-Broglie wavelength is given by

$\therefore \frac{\lambda_{H_2}}{\lambda_{He}} = \sqrt{\frac{m_{He}T_{He}}{m_{H_2}T_{H_2}}} = \sqrt{\frac{4}{2}.\frac{(127+273)}{(27+273)}} = \sqrt{\frac{8}{3}}$

Example 19:

Find the de Broglie wavelength of a 0.01 kg pellet having a velocity of 10 m/s.

Solution:

$\lambda = h/p = \frac{6.63\times10^{-34}\,J.s}{0.01kg\times10m/s} = 6.63 \times 10^{-23}$ Å.

Example 20:

Determine the accelerating potential necessary to give an electron for de Broglie wavelength of 1 Å, which is the size of the interatomic spacing of atoms in a crystal.

Solution:

$V = \frac{150}{\lambda^2(\text{in Å})} = 150$ V

Concept Builder-3

Q.1 The potential energy of a particle of mass m is given by

$$U(x) = \begin{cases} E_0; & 0 \le x \le 1 \\ 0; & x > 1 \end{cases}$$

λ_1 and λ_2 are the de-Broglie wavelength of the particle, when $0 \le x \le 1$ and $x > 1$, respectively. If the total energy of particle is $2E_0$ the ratio $\frac{\lambda_1}{\lambda_2}$ will be:

(1) 2 (2) 1 (3) $\sqrt{2}$ (4) $\frac{1}{\sqrt{2}}$

Q.2 Find out voltage applied to an electron microscope to produce electron of wavelength 0.6Å.

Q.3 A particle of mass M at rest decays into two particles of masses m_1 and m_2 having non zero velocities. Find out the ratio of the de–Broglie wavelengths of the two particles.

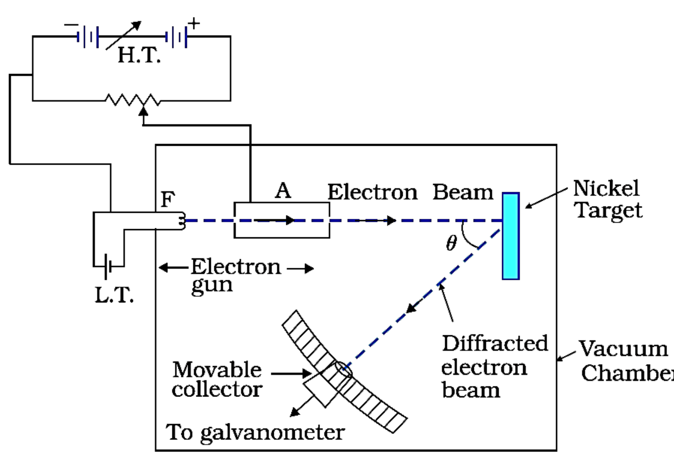
Q.4 de-Broglie wavelength of an electron, accelerated by potential V is λ. What will be de-Broglie wavelength of the electron which is accelerated by 4V potential ?

Q.5 Find out velocity of an electron so that its momentum is equal to that of photon with a wavelength of λ = 5200Å.

Q.6 Find the ratio of de Broglie wavelength of molecules of hydrogen and helium which are at temperatures 27°C and 127°C respectively.

6. Davisson and Germer Experiment

The wave nature of electrons was first experimentally verified by C.J. Davisson and L.H. Germer in 1927 and independently by G.P. Thomson, in 1928, who observed diffraction effects with beams of electrons scattered by crystals. Davisson and Thomson shared the Nobel Prize in 1937 for their experimental discovery of diffraction of electrons by crystals.

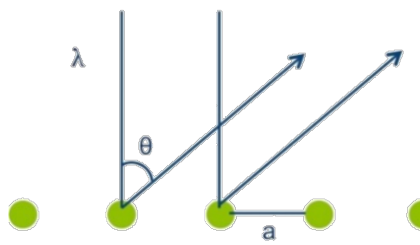


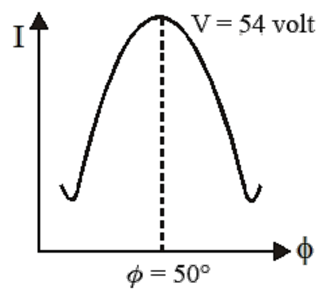
- **Electron Gun:** It is a filament coated with Barium Oxide, which emits electrons via thermionic emission.
- **Electron Beam:** Electrons are accelerated and passed through a cylindrical anode for making a fine beam.
- **Target: Nickel crystal.** It acts as diffraction grating for incoming electrons.

- **Detector:** A detector is used to capture the scattered electrons from the Ni crystal. It can be moved on a semicircular arc.

Nickel Crystal : Diffraction Grating

- A crystal has a regular arrangement of atoms.
- Electron can get diffracted from this grating and show interference pattern.
- Interference pattern is the proof that electron is behaving like a wave.





Electron is a Wave !!!

Theoretically	Experimentally
For $V = 54\,Volts$, Using the de-Broglie relationship $\lambda = \sqrt{\frac{150}{54}}$ Å λ_{Th} = 1.67 Å	For Ni Crystal d = 2.15 Å, θ = 50° Using Bragg's equation (n=1) λ_{Exp} = 1.65 Å

Wave – Particle Duality

- Particle can show wave like properties and wave can show particle like properties.
- It is just a matter of experiment that which property will be revealed.
- Only one of the nature will be revealed in a given experiment.
- Both wave nature and particle nature **will not be** shown simultaneously in a given situation.

7. Atomic Structure

7.1 Thomson's Atomic Model

- Plum-pudding model– In atom positive charge is spread out in space with electron embedded throughout the region.
- He found the charge to mass ratio of electron for atomic structure.

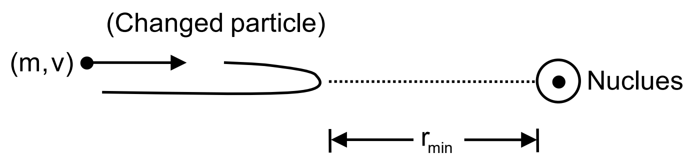
7.2 Rutherford's Model of The Atom

- Performed gold foil experiment on bombarding high speed α-particle on thin gold foil.
- Most of the alpha-particles went straight.
  - conclusion: atoms are mostly empty space.

- Very few alpha particle (1 in 8000) were deflected by more than 90°.
  - conclusion: atoms have a very small, dense positive center called nucleus''.
- Rutherford could not explain
  - Stability of atom
  - Characteristic spectrum/spectral lines.

7.3 Distance of Closest Approach

When a light charged particle is projected directly on heavy nucleus.



If

Z_1e : Charge on projected particle

Z_2e : Charge on nucleus

v_0 : Speed of charged particle at large distance from nucleus.

m : mass of projected charged particle.

r_{min} : Distance of closest approach

At, minimum distance, whole K.E. will be converted into P.E.

$$\frac{1}{2}mv_0^2 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{(Z_1e)(Z_2e)}{r_{min}} \; ; \; r_{min} = \frac{Z_1Z_2e^2}{2\pi\varepsilon_0 mv_0^2}$$

Example 21:

An α-particle with kinetic energy 10 MeV is heading towards a stationary point-nucleus of atomic number 50. Calculate the distance of closest approach.

Solution:

$\because TE_A = TE_B$

$$\therefore 10 \times 10^6 e = \frac{K \times (2e)(50e)}{r_0}$$

$r_0 = 1.44 \times 10^{-14}$ m ; $r_0 = 1.44 \times 10^{-4}$ Å

Example 22:

A beam of α-particles of velocity 2.1×10^7 m/s is scattered by a gold (z = 79) foil. Find out the distance of closest approach of the α-particle to the gold nucleus. The value of charge/mass for α-particle is 4.8×10^7 C/kg.

Solution:

$$\frac{1}{2}m_\alpha V_\alpha^{2} = \frac{K(2e)(Ze)}{r_0} \Rightarrow r_0 = \frac{2K\left(\frac{2e}{m_\alpha}\right)(79e)}{V_\alpha^2} = \frac{2 \times (9 \times 10^9)(4.8 \times 10^7)(79 \times 1.6 \times 10^{-19})}{(2.1 \times 10^7)^2}$$

$r_0 = 2.5 \times 10^{-14}$ m

Example 23:

Calculate the nearest distance of approach of an α-particle of energy 2.5 MeV being scattered by a gold nucleus (Z = 79)

Solution:

$T.E_1 = T.E_2$

$$2.5 \times 10^6 \; e = \frac{1}{4\pi\varepsilon_0} \frac{(2)(79)e^2}{r_{min}}$$

$$\Rightarrow r_{min} = \frac{9 \times 10^9 \times 2 \times 79 \times 1.6 \times 10^{-19}}{2.5 \times 10^6} = 9 \times 10^{-14} \text{ m}$$

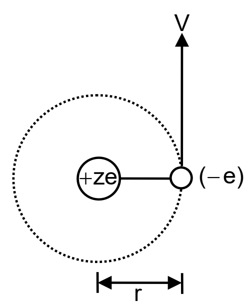
7.4 Bohr's Atomic Theory

- Bohr's theory is applicable for Hydrogen/hydrogen like atoms/ions ($_1H^1$, $_1H^2$, He^+, Li^{++} etc).

According to Bohr's Theory:

- An electron moves in circular orbits; necessary centripetal force is provided by electrostatic attraction between nucleus and electron.

  Mathematically,



$$F_C = \frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Ze.e}{r^2} \qquad ...(1)$$

- The electron revolves only in those (stationary orbits) for which angular momentum of electron is integral multiple of $h/2\pi$ (Bohr's quantisation rule).

  Mathematically,

  $$mvr = \frac{nh}{2\pi} \qquad ...(2)$$

  where n = 1, 2,....

  This is called Bohr's quantum condition.

- The emission or absorption of energy occurs only when an electron jumps from one of its orbit to another. The difference in the total energy of electron in the two permitted orbits is absorbed when the electron jumps from an inner to an outer orbit and emitted when electron jumps from outer to the inner orbit.

  Mathematically,

  $hf = E_2 - E_1$

  This is called Bohr's frequency condition

7.5 Radius of Electron in nth Orbit

Using eq. (1)

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2} \Rightarrow v^2 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze^2}{mr}$$

Putting value of v^2 in eq. (2) after squaring eq (2)

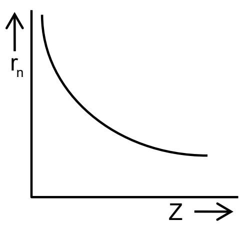
$$m^2\left(\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{mr}\right)r^2 = \left(\frac{nh}{2\pi}\right)^2$$

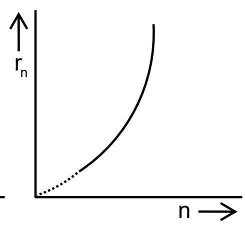
$$\Rightarrow \quad r = r_n = \left(\frac{h^2\varepsilon_0}{\pi me^2}\right)\cdot\frac{n^2}{Z}$$

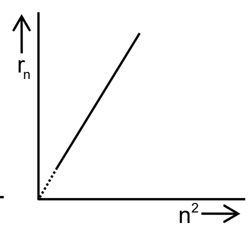
$$= a_0\frac{n^2}{Z} \qquad \left(\text{where } a_0 = \frac{n^2\varepsilon_0}{\pi me^2} = 0.53\text{Å}\right)$$

a_0 is known **Bohr radius** $r_n \propto \frac{n^2}{Z}$, $r_n \propto \frac{1}{m}$

Graphs:







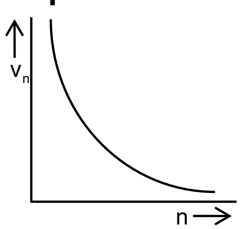
Speed of Electron in nth Orbit

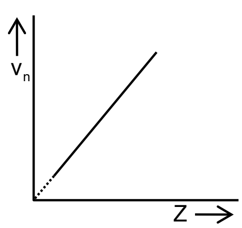
On Solving eq (1) & (2)

$$v_n = \left(\frac{e}{2h\varepsilon_0}\right)\frac{Z}{n} = (2.2\times10^6)\ \frac{Z}{n}\ \text{m/s}$$

$$v_n \propto \frac{Z}{n} \qquad\qquad v_n \propto m^0$$

Graphs





Energy of Electron in nth Orbit

Kinetic energy $K = \frac{1}{2}mv^2 = \frac{Ze^2}{8\pi\varepsilon_0 r}$

Potential energy $U = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(-e)}{r} = -\frac{Ze^2}{4\pi\varepsilon_0 r}$

Total energy $E = K + U = -\frac{Ze^2}{8\pi\varepsilon_0 r}$

$$E = -\frac{Ze^2}{8\pi\varepsilon_0 r}$$

Putting value of r

$$E = -\left(\frac{me^4}{8h^2\varepsilon_0^2}\right)\cdot\frac{Z^2}{n^2}$$

$$= -13.6\,\frac{z^2}{n^2}\text{ eV} = -\text{Rhc}\,\frac{z^2}{n^2}$$

Where, $R = \frac{13.6}{hc} = \frac{me^4}{8h^3\varepsilon_0^2 c} = 1.097 \times 10^7\ m^{-1}$

R is called **Rydberg constant.**

Rhc = 13.6 eV is known as Rydberg energy.

$$E_n \propto \frac{z^2}{n^2},\ E_n \propto m$$

$$K_n = -E_n,\ U_n = 2\,E_n = -2K_n$$

Time Period of Revolution

$$T_n = \frac{2\pi r_n}{v_n} = \frac{2\pi}{\omega_n}$$

Since, $r_n \propto \frac{n^2}{Z},\ v_n \propto \frac{Z}{n}$

$$T_n \propto \frac{n^3}{Z^2},\ \omega_n \propto \frac{Z^2}{n^3}$$

Angular Momentum of Electron in n^{th} Orbit

$$L_n = \frac{nh}{2\pi}$$

Angular momentum is independent of Z.

Example 24:

Find the radius of Li^{++} ions in its ground state assuming Bohr's model to be valid.

Solution:

For H-like ions the radius of the n^{th} orbit is

$$r_n = \frac{z^2 r_0}{Z}$$

For Li^{++}, Z = 3 and in ground state n = 1

The radius is

$$r_1 = \frac{1^2 \times 53 \times 10^{-12}}{3}\ m\ ;\ r_1 = 18 \times 10^{-2}\ m$$

Example 25:

Find the maximum angular speed of the electron of a hydrogen atom in a stationary orbit.

Solution:

$$w_n = \frac{v_n}{r_n} = \frac{2.2 \times 10^6 \frac{Z}{n} m/sec}{0.53 \frac{n^2}{Z} Å}$$

For hydrogen atom Z = 1 and ω_n will be maximum for n = 1

$$\omega_{max} = \frac{2.2 \times 10^6}{0.53 \times 10^{-10}} = 4.1 \times 10^{16} \text{ rad/sec}$$

Example 26:

Average lifetime of a H atom excited to n = 2 state is 10^{-8} sec. Find the number of revolutions made by the electron on the average before it jumps to the ground state.

Solution:

Time period of revolution of electron in n = 2, Z = 1

$$T_n = \frac{2\pi r_n}{v_n} = \frac{2\pi}{\omega_n} = \frac{2\pi}{\frac{2.2 \times 10^6}{0.53 \times 10^{-10}} \frac{Z^2}{n^3}} = \frac{2\pi n^3}{4.1 \times 10^{16} Z^2}$$

$$T_2 = \frac{2\pi (2)^3}{4.1 \times 10^{16}} = \frac{16\pi}{4.1 \times 10^{16}} = 12.25 \times 10^{-16} \text{ sec}$$

Number of revolutions = $\frac{t}{T_2}$

$$= \frac{10^{-8}}{12.25 \times 10^{-16}} = 8.2 \times 10^6$$

Example 27:

A small particle of mass m moves in such a way that the potential energy $U = ar^2$ where a is a constant and r is the distance of the particle from the origin. Assuming Bohr's model of quantization of angular momentum and circular orbits, find the radius of n^{th} allowed orbit.

Solution:

The force at a distance r is,

$$F = -\frac{dU}{dr} = -2ar$$

Suppose r be the radius of n^{th} orbit. The necessary centripetal force is provided by the above force. Thus,

$$\frac{mv^2}{r} = 2ar$$

Further, the quantization of angular momentum gives,

$$mvr = \frac{nh}{2\pi}$$

Solving Eqs. (i) and (ii) for r, we get

$$r = \left(\frac{n^2 h^2}{8am\pi^2}\right)^{1/4}$$

Example 28:

An electron rotates in a circle around a nucleus with positive charge Ze. How is the electrons' velocity related to the radius of its orbit ?

Solution:

The force on the electron due to the nucleus provides the required centripetal force

$$\frac{1}{4\pi\varepsilon_0}\frac{Ze.e}{r^2} = \frac{mv^2}{r} \Rightarrow v = \sqrt{\frac{Ze^2}{4\pi\varepsilon_0 rm}}$$

Example 29:

Calculate the magnetic dipole moment corresponding to the motion of the electron in the ground state of a hydrogen atom.

Solution:

Magnetic dipole moment M or μ = i A

$$i = \frac{q}{T} = \frac{e}{2\pi r / v} = \frac{ev}{2\pi r}$$

$$A = \pi r^2$$

$$M = \frac{ev}{2\pi r}\pi r^2 = \frac{erv}{2}$$

$$v_n = 2.2 \times 10^6 \frac{Z}{n} \text{ m/sec}$$

$$r_n = 0.53 \frac{n^2}{Z} \text{ Å} = 0.53 \times 10^{-10} \frac{n^2}{Z} \text{ m}$$

For hydrogen Z = 1, ground state n = 1

$$M = \frac{ev_1r_1}{2} = \frac{1.6\times10^{-19}\times2.2\times10^6\times0.53\times10^{-10}}{2} = 9.2 \times 10^{-24} \text{ A.m}^2$$

Concept Builder-4

Q.1 Calculate the nearest distance of approach of Li^+ ion of energy 5 MeV being scattered by a gold nucleus (Z = 79)

Q.2 A proton with kinetic energy 5 MeV is heading towards a stationary point-nucleus of atomic number 50. Calculate the distance of closest approach.

Q.3 The innermost orbit of the hydrogen atom has a diameter 1.06 Å. Then find diameter of tenth orbit.

Q.4 When an electron in hydrogen atom is excited, from its 4^{th} to 5^{th} stationary orbit, the change in angular momentum of electron is (Planck's constant: $h = 6.6 \times 10^{-34}$ J-s)

Q.5 In Bohr model of hydrogen atom, the ratio of periods of revolution of an electron in n = 2 and n = 1 orbits is

Q.6 In an atom, the two electrons move round the nucleus in circular orbits of radii R and 4R. Find the ratio of the time taken by them to complete one revolution.

Q.7 If the atom ${}_{100}Fm^{257}$ follows the Bohr model and the radius of ${}_{100}Fm^{257}$ is n times the Bohr radius, then find n.

Energy in Atom

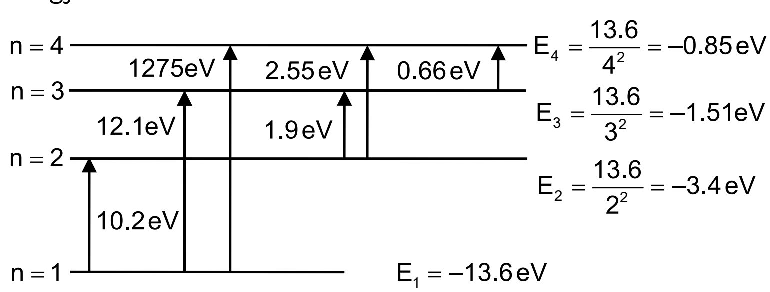
- **Excitation Energy:** The energy needed to jump an electron to higher orbit.

- **Excitation Potential:** The potential through which an electron should be accelerated to acquire higher state is known as excitation potential.

- **Binding Energy of Atom:** Energy required to separate electron from nucleus to a large distance. The binding energy of hydrogen atom in ground state is 13.6 eV.

Absorption Spectrum

When an electron absorbs a photon it goes to higher orbit. The spectrum of photon is called absorption spectrum. It means electron can absorb only certain specific value, which is difference of energy of two orbits.



- If case of H-atom absorption spectrum will be of energy 10.2 eV, 12.1 eV etc.
- On moving up energy differences decreases.

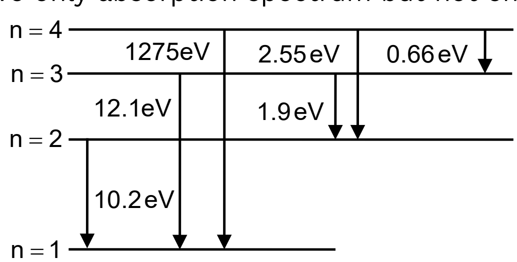
Excitation of Atom(S) During Collision

- During collision energy loss can only be used to exited the atoms.
- Minimum loss is zero during elastic collision.
- Maximum loss is during perfectly inelastic collision.
- Collision will be inelastic if electron can jump to higher orbit.

Emission Spectrum

Excited electron remains in higher orbit for a time about 10^{-8} s, then it tries to return to ground state by emitting photon. In this way we get emission spectrum.

- For n = 1, we can have only absorption spectrum but not emission spectrum.



- Possible transition of an electron if it returns n = 4 to n = 1

  $4 \rightarrow 3,\ 4 \rightarrow 2,\ 4 \rightarrow 1$

  $3 \rightarrow 2,\ 3 \rightarrow 1$

  $2 \rightarrow 1$

  Total no. of possible emission spectrum = 6
- No. of possible emission spectrum from $n_i = n$ to $n_f = 1 = \frac{n(n-1)}{2}\ {}^nC_2$
- No. of possible emission spectrum from $n_i = n_1$ to $n_f = n_2 = \frac{(n_1 - n_2)(n_1 - n_2 + 1)}{2}$

Wavelength of Emitted Radiation

If electron jumps from initial state n_i to a final state n_f then wavelength of radiation λ is given by $E_i - E_f = \frac{hc}{\lambda}$

$$\frac{hc}{\lambda} = z^2\ Rhc\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

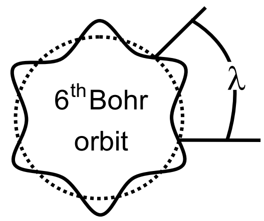
$$\Rightarrow \qquad \frac{1}{\lambda} = R\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right) z^2$$

Series Limit : Line of any group having maximum energy of photon is called series limit. In Balmer series first line is known as H_α line and second line as H_β line and so on.

	Initial state	Final State	Wavelength formula	First Member Second Member	Series Limit $n_i \rightarrow \infty$ To n_f	Maximum wavelegth $(n_i + 1)$ To n_f	Lines found in
Lyman	$n = 2, 3, 4, 5, 6, ..$	$n_f = 1$	$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n_i^2}\right)$	$n_i = 2$ to $n_f = 1$ $n_i = 3$ to $n_f = 1$	From ∞ to 1 $\lambda = \frac{1}{R}$ $\lambda = 911Å$	From 2 to 1 $\lambda = \frac{4}{3R}$ $\lambda = 1216Å$	UV Region
Balmer	$n = 3, 4, 5, 6, 7, ..$	$n_f = 2$	$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n_i^2}\right)$	$n_i = 3$ to $n_f = 2$ $n_i = 4$ to $n_f = 2$	From ∞ to 2 $\lambda = \frac{4}{R}$ $\lambda = 3646Å$	From 3 to 2 $\lambda = \frac{36}{5R}$ $\lambda = 6563Å$	Visible Region
Paschen	$n = 4, 5, 6, 7, 8..$	$n_f = 3$	$\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n_i^2}\right)$	$n_i = 4$ to $n_f = 3$ $n_i = 5$ to $n_f = 3$	From ∞ to 3 $\lambda = \frac{9}{R}$ $\lambda = 8204Å$	From 4 to 3 $\lambda = \frac{144}{7R}$ $\lambda = 18753Å$	IR Region
Brackett	$n = 5, 6, 7, 8, 9, ..$	$n_f = 4$	$\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{n_i^2}\right)$	$n_i = 5$ to $n_f = 4$ $n_i = 6$ to $n_f = 4$	From ∞ to 4 $\lambda = \frac{16}{R}$ $\lambda = 14585Å$	From 5 to 4 $\lambda = \frac{400}{9R}$ $\lambda = 40515Å$	IR Region
Pfund	$n = 6, 7, 8, 9, 10, ..$	$n_f = 5$	$\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{n_i^2}\right)$	$n_i = 6$ to $n_f = 5$ $n_i = 7$ to $n_f = 5$	From ∞ to 5 $\lambda = \frac{25}{R}$ $\lambda = 22790Å$	From 6 to 5 $\lambda = \frac{900}{11R}$ $\lambda = 74583Å$	Far IR Region

Explanation of Bohr Quantization

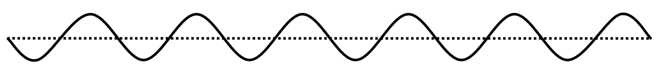
According to de Broglie electron revolves round the nucleus in the form of stationary waves (i. e. wave packet) in the similar



fashion as stationary waves in a vibrating string. Electron can stay in those circular orbits whose circumference is an integral multiple of de–Broglie wavelength associated with the electron, $2\pi r = n\lambda$

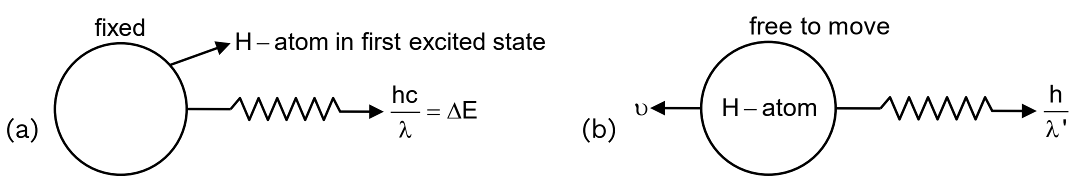
$\because\ \lambda = \dfrac{h}{mv}$ and $2\pi r = n\lambda$ $\quad\therefore\ mvr = \dfrac{nh}{2\pi}$

This is the Bohr quantization's condition.



8. Calculation of Recoil Speed of Atom on Emission of a Photon

Momentum of photon = mc = $\dfrac{h}{\lambda}$



m - mass of atom

According to momentum conservation

$mv = \dfrac{h}{\lambda'}$

$mv = \Delta E/c$

recoil speed of atom (v) = $\Delta E/mc$

Example 30:

First excitation potential of a hypothetical hydrogen like atom is 15 volt. Find third excitation potential of the atom.

Solution:

Let energy of ground state = E_0

$E_0 = -13.6\ Z^2$ eV and $E_n = \dfrac{E_0}{n^2}$

$n = 2,\ E_2 = \frac{E_0}{4}$ given $\frac{E_0}{4} - E_0 = 15$

$-\frac{3E_0}{4} = 15$ for $n = 4,\ E_4 = \frac{E_0}{16}$

third excitation energy = $\frac{E_0}{16} - E_0$

$= -\frac{15}{16}E_0 = -\frac{15}{16}\cdot\left(\frac{-4\times 15}{3}\right) = \frac{75}{4}$ eV

$\therefore$ third excitation potential is $\frac{75}{4}$ V

Example 31:

Calculate the energy of a He^+ ion in its first excited state.

Solution:

The energy is $E_n = \frac{-RhcZ^2}{n^2} = \frac{-(13.6\,eV)Z^2}{n^2}$

For He^+ ion, Z = 2 and for the first excited state, n = 2 so that the energy of He^+ ion.

$$E_2 = \frac{-13.6eV \times 2^2}{2^2}$$

$E_2 = -13.6$ eV

Example 32:

Calculate (a) the wavelength and (b) the frequency of the H_β line of the Balmer series for hydrogen.

Solution:

(a) H_β line of Balmer series corresponds to the transition from n = 4 to n = 2 level.

The corresponding wavelength for H_β line is,

$$\frac{1}{\lambda} = (1.097 \times 10^7)\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = 0.2056 \times 10^7$$

$\therefore \lambda = 4.9 \times 10^{-7}$ m

(b) $\nu = \frac{c}{\lambda} = \frac{3.0\times 10^8}{4.9\times 10^{-7}} = 6.12 \times 10^{14}$ Hz

Example 33:

Find the largest and shortest wavelengths in the Lyman series for hydrogen. In what region of the electromagnetic spectrum does each series lie?

Solution:

The transition equation for Lyman series is given by,

$$\frac{1}{\lambda} = R\left[\frac{1}{(1)^2} - \frac{1}{n^2}\right] \qquad n = 2, 3, ...$$

for largest wavelength, n = 2

$$\frac{1}{\lambda_{max}} = 1.097 \times 10^{7}\left(\frac{1}{1}-\frac{1}{4}\right) = 0.823 \times 10^{7}$$

$\therefore$ $\lambda_{max} = 1.2154 \times 10^{-7}$ m = 1215 Å

The shortest wavelength corresponds to n = ∞

$$\therefore\ \frac{1}{\lambda_{max}} = 1.097 \times 10^{7}\left(\frac{1}{1}-\frac{1}{\infty}\right)$$

or $\lambda_{min} = 0.911 \times 10^{-7}$ m = 911 Å

Both of these wavelengths lie in ultraviolet (UV) region of electromagnetic spectrum.

Example 34:

Find the kinetic energy, potential energy and total energy in first and second orbit of hydrogen atom if potential energy in first orbit is taken to be zero.

Solution:

$E_1 = -13.60$ eV

$K_1 = -E_1 = 13.60$ eV

$U_1 = 2E_1 = -27.20$ eV

$$E_2 = \frac{E_1}{(2)^2} = -3.40 \text{ eV}$$

$K_2 = 3.40$ eV

and $U_2 = -6.80$ eV

Now $U_1 = 0$, i.e., potential energy has been increased by 27.20 eV while kinetic energy will remain unchanged. So values of kinetic energy, potential energy and total energy in first orbit are 13.60 eV, 0, 13.60 respectively and for second orbit these values are 3.40 eV, 20.40 eV and 23.80 eV.

Example 35:

Calculate the wavelength of radiation emitted when He^{+} makes a transition from the state n = 3 to the state n = 2.

Solution:

The wavelength λ is given by

$n_i = 3$, $n_f = 2$, $Z = 2$, $R = 1.097 \times 10^{7}$ /m

$$\Rightarrow \quad \frac{1}{\lambda} = 4R\left(\frac{1}{4}-\frac{1}{9}\right) \quad \Rightarrow \quad \frac{1}{\lambda} = \frac{5}{9}R$$

$$\Rightarrow \quad \lambda = \frac{9}{5R} = 164.0 \text{ nm}$$

Example 36:

If the difference of energies of an electron in the second and the fourth orbits of an atom is E. Find the ionisation energy of that atom.

Solution:

Energy of the atom in n^{th} excited state.

$$E_n = \frac{-13.6eV \cdot Z^2}{n^2}$$

$$E_4 = \frac{-13.6eV}{16} Z^2$$

$$E_2 = \frac{-13.6eV}{4} \cdot Z^2$$

$$E = E_4 - E_2$$

$$E = 13.6eV \times Z^2 \times \frac{3}{16}$$

$$\text{Ionisation energy} = 13.6 \text{ eV} \times Z^2 = \frac{16E}{3}$$

Example 37:

The excitation energy of a hydrogen-like ion in is first excited state is 40.8 eV. Find the energy needed to remove the electron from the ion.

Solution:

The excitation energy in the first excited state is

$$E = 13.6(eV)Z^2\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

$$= E = 13.6(eV)Z^2\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

$$E = 13.6 \times Z^2 \frac{3}{4} \times eV$$

Given that E = 40.8 eV

$$\Rightarrow \quad 40.8 \text{ eV} = 13.6 \times Z^2 \times \frac{3}{4}$$

$$\Rightarrow \quad Z = 2$$

So, the ion in question is He^+. The energy in the ground state is n = 1

$$E = \frac{13.6(eV)Z^2}{n^2} = \frac{-13.6 \times 2^2}{1^2}$$

$$E = -54.4 \text{ eV}$$

Thus 54.4 eV is required to remove the electron from the ion.

Example 38:

How many different photons can be emitted by hydrogen atoms that undergo transitions to the ground state from the n = 5 state ?

Solution:

No. of possible transition from n = 5 are 10

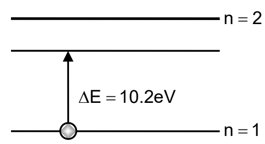
Example 39:

A moving hydrogen atom makes a head on collision with a stationary hydrogen atom. Before collision both atoms are in ground state and after collision they move together. What is the minimum value of the kinetic energy of the moving hydrogen atom, such that one of the atoms reaches one of the excitation state.

Solution:

Let K be the kinetic energy of the moving hydrogen atom and K', the kinetic energy of combined mass after collision.

From conservation of linear momentum,



p = p' or $\sqrt{2Km} = \sqrt{2K'(2m)}$ or $K = 2K'$ ....(i)

From conservation of energy, $K = K' + \Delta E$ ....(ii)

Solving Eqs. (i) and (ii), we get $\Delta E = \frac{K}{2}$

Now minimum value of ΔE for hydrogen atom is 10.2 eV.

or $\Delta E \geq 10.2$ eV

$\therefore \quad \frac{K}{2} \geq 10.2 \quad \therefore \quad K \geq 20.4$ eV

Therefore, the minimum kinetic energy of moving hydrogen is 20.4 eV

Example 40:

The total energy of electron in the first excited state of hydrogen is about −3.4eV. Find kinetic energy and potential energy of electron in this state.

Solution:

We know kinetic energy of electron = $\frac{KZe^2}{2r}$ and potential energy of electron = $\frac{-KZe^2}{r}$

P.E. = −2 (K.E.)

Total energy = K.E. + P.E. = K.E. −2 K.E. = −K.E.

$\Rightarrow$ K.E. = − Total Energy = − (− 3.4eV)

K.E. = 3.4 eV

Potential Energy = −2 × KE = −2 × (3.4eV) = −6.8 eV

Example 41:

Find the ratio of magnetic moment of an electron to its angular momentum in an orbit.

Solution:

Magnetic moment M = IA

$M = \frac{e}{T} \cdot\ pr^2$ ......(i)

We know that velocity of electron $v = \frac{2\pi r}{T}$

or $T = \frac{2\pi r}{v}$

Putting the value of T in equation (i)

$\Rightarrow \quad M = e\frac{\pi r^2}{2\pi / v}$

$M = \frac{evr}{2}$

Angular momentum of an electron in n^{th} orbit

L = mvr

$\therefore \quad \frac{M}{L} = \frac{evr}{2 \times mvr}$

$\frac{M}{L} = \frac{e}{2m}$

ANSWER KEY FOR CONCEPT BUILDERS

CONCEPT BUILDER-1

1. 1.6×10^{-24} kg-m/s **2.** Violet

3. 2×10^{20} **4.** 1.5×10^{34}

5. 9×10^{24}

6. (a) 2.5×10^{19} (b) 3.33×10^{-8} N

CONCEPT BUILDER-2

1. $3K + h\nu_0$ **2.** 1.5 X

3. 1.7 eV **4.** $0.48\,\mu A,\ 3 \times 10^{12}$

5. 6.8 eV **6.** 0.34 V

7. No **8.** 4λ

9. 64 unit **10.** 2V

CONCEPT BUILDER-3

1. (3) **2.** 416.6 volt

3. 1 : 1 **4.** $\frac{\lambda}{2}$

5. 1400 **6.** $\lambda_{H_2} : \lambda_{He} = \sqrt{8} : \sqrt{3}$

CONCEPT BUILDER-4

1. 6.82×10^{-14} m **2.** 1.44×10^{-14} m

3. 106 Å **4.** 1.05×10^{-34} J-s

5. $T_2 = 8T_1$ **6.** 1/8 **7.** 1/4

Exercise - I

Photoelectric Effect and Photon Theory

1. Momentum of photon of energy 3 keV in kg-m/s will be

(1) 1.6×10^{-19} (2) 1.6×10^{-21}

(3) 1.6×10^{-24} (4) 1.6×10^{-27}

2. The wavelength of photon is 0.01 Å, its momentum in Kg m/sec is

(1) 6.6×10^{-22} (2) 6.6×10^{-20}

(3) 6.6×10^{-46} (4) 6.6×10^{-27}

3. The wavelength of photon is 5000 Å, its energy will be :

(1) 2.5 eV (2) 50 eV

(3) 5.48 eV (4) 7.48 eV

4. Photon of frequency ν has a momentum associated with it. If c is the velocity of light, the momentum is

(1) $h\nu / c$ (2) ν / c

(3) $h \nu c$ (4) $h\nu / c^2$

5. Photo electric effect is the phenomenon in which

(1) Photons come out of a metal when it is hit by a beam of electrons.

(2) Photons come out of the nucleus of an atom under the action of an electric field.

(3) Electrons come out of metal with a constant velocity depending on frequency and intensity of incident light.

(4) Electrons come out of a metal with different velocity not greater than a certain value which depends only on the frequency of the incident light wave and not on its intensity.

6. When an electro–magnetic radiation is incident on the surface of metal, maximum kinetic energy of photoelectron depends on–

(1) Frequency of radiation

(2) Intensity of radiation

(3) Both the frequency and intensity

(4) Polarization of radiation

7. The work functions of tungsten and sodium are 5.06 eV and 2.53 eV respectively. If the threshold wavelength for sodium is 5896 Å, then the threshold wavelength for the tungsten will be

(1) 11792 Å (2) 5896 Å

(3) 4312 Å (4) 2948 Å

8. If the threshold wavelength for sodium is 5420 Å, then the work function of sodium is

(1) 4.58 eV (2) 2.28 eV

(3) 1.14 eV (4) 0.23 eV

9. Light of wavelength 4000 Å is incident on a metal plate whose work function is 2eV. What is maximum kinetic energy of emitted photoelectron?

(1) 0.5 eV (2) 1.1 eV

(3) 2.0 eV (4) 1.5 eV

10. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then the ratio of threshold wavelengths is nearest to:

(1) 1 : 2 (2) 4 : 1

(3) 2 : 1 (4) 1 : 4

11. The work function of a metal is :

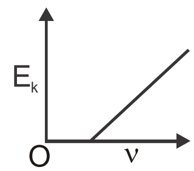
(1) the energy for the electron to enter into the metal

(2) the energy for producing X-ray

(3) the minimum energy for the electron to come out from metal surface

(4) none of these

12. Graph is plotted between maximum kinetic energy (E_K) of electron with frequency of incident photon (ν) in Photo electric effect. The slope of curve will be–



(1) Charge of electron
(2) Work function of metal
(3) Planck's constant
(4) Ratio of Planck constant and charge of electron

13. When a certain metallic surface is illuminated with monochromatic light of wavelength λ, the stopping potential for photo electric current is 6 V_0. When the same surface is illuminated with light of wavelength 2λ, the stopping potential is $2V_0$. The threshold wavelength of this surface for photoelectric effect is–

(1) 6 λ (2) $4\lambda/3$
(3) 4λ (4) 8λ

14. A photo sensitive metallic surface has work function $h\nu_0$. If photons of energy $2h\nu_0$ fall on this surface, the electrons come out with a maximum velocity of 4×10^6 m/s. When the photon energy is increased to 10 $h\nu_0$, then maximum velocity of photo electrons will be–

(1) 2×10^6 m/s (2) 2×10^7 m/s
(3) 8×10^5 m/s (4) 12×10^6 m/s

15. A metal surface is illuminated by a light of given intensity and frequency to cause photoemission. If the intensity of illumination is reduced to one fourth of its original value, then the maximum kinetic energy of the emitted photoelectrons would be :

(1) unchanged
(2) $1/8^{th}$ of original value
(3) twice the original value
(4) four times the original value

16. If the threshold wavelength of light for photoelectric effect from sodium surface is 6800 A° then, the work function of sodium is

(1) 1.8 eV
(2) 2.9 eV
(3) 1.1 eV
(4) 4.7 eV

17. When the distance of a point light source from a photocell is r_1, photoelectric current is I_1, If the distance becomes r_2, then the current is I_2, The ratio ($I_1 : I_2$) is equal to

(1) $r_2^2 : r_1^2$
(2) $r_2 : r_1$
(3) $r_1^2 : r_2^2$
(4) $r_1 : r_2$

18. The maximum energy of the electrons released in photocell is independent of

(1) Frequency of incident light
(2) Intensity of incident light
(3) Nature of cathode surface
(4) None of these

19. In photoelectric effect, we assume the photon energy is proportional to its frequency and is completely absorbed by the electrons in the metal. Then the photoelectric current ($\upsilon > \nu_{th}$)

(1) Decreases when the frequency of the incident photon increases.
(2) Increases when the frequency of the incident photon increases.
(3) Does not depend on the photon frequency but only on the intensity of the incident beam.
(4) Depends both on the intensity and frequency of the incident beam.

20. When stopping potential is applied in an experiment on photoelectric effect, no photocurrent is observed. This means that

(1) the emission of photoelectrons is stopped.

(2) the photoelectrons are emitted but are reabsorbed by the emitter metal.

(3) the photoelectrons are accumulated near the collector plate.

(4) the photoelectrons are dispersed from the sides of the apparatus.

21. If the frequency of light in a photoelectric experiment is doubled then stopping potential will

(1) be doubled

(2) be halved

(3) become more than double

(4) become less than double

22. Let p and E denote the linear momentum and the energy of a photon. For another photon of smaller wavelength (in same medium)

(1) both p and E increase

(2) p increases and E decreases

(3) p decreases and E increases

(4) both p and E decreases

23. Two identical photocathodes receive light of frequencies f_1 and f_2. If the velocities of the photo electrons (of mass m) coming out are respectively v_1 and v_2, then

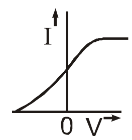
(1) $v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$

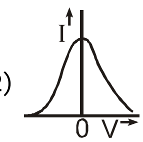
(2) $v_1 + v_2 = \left[\frac{2h}{m}(f_1 + f_2)\right]^{1/2}$

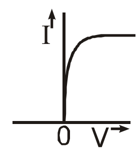
(3) $v_1^2 + v_2^2 = \frac{2h}{m}(f_1 + f_2)$

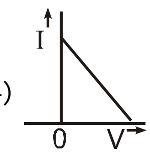
(4) $v_1 - v_2 = \left[\frac{2h}{m}(f_1 - f_2)\right]^{1/2}$

24. Which one of the following graphs in figure shows the variation of photoelectric current (I) with voltage (V) between the electrodes in a photoelectric cell?

(1)


(2)


(3)


(4)


25. The collector plate in an experiment on photoelectric effect is kept vertically above the emitter plate. Light source is put on and a saturation photocurrent is recorded. An electric field is switched on which has vertically downward direction

(1) The photocurrent will increase

(2) The kinetic energy of the electrons will increase

(3) The stopping potential will decrease

(4) The threshold wavelength will increase

26. A point source of light is used in a photoelectric effect. If the source is removed farther from the emitting metal, the stopping potential

(1) will increase

(2) will decrease

(3) will remain constant

(4) will either increase or decrease

27. The photoelectrons emitted from a metal surface:

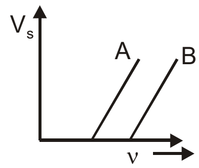
(1) Are all at rest

(2) Have the same kinetic energy

(3) Have the same momentum

(4) Have speeds varying from zero up to a certain maximum value

28. The stopping potential as a function of frequency of incident radiation is plotted for two different photo electric surfaces A and B. The graphs show the work function of A is



(1) Greater than that of B
(2) Smaller than that of B
(3) Same as that of B
(4) No comparison can be done from given graphs

29. Light of wavelength 5000 Å falls on a sensitive plate with photoelectric work function of 1.9 eV. The kinetic energy of the photoelectron emitted will be :

(1) 0.58 eV (2) 2.48 eV
(3) 1.24 eV (4) 1.16 eV

30. In an electron gun electron are accelerated through a potential difference V. If e = charge of electron and m = mass of electron then maximum electron velocity will be

(1) 2eV/m (2) $\sqrt{2eV/m}$
(3) $\sqrt{2m/eV}$ (4) V^2 /2em

31. When intensity of incident light increases :

(1) photo - current increases
(2) photo - current decreases
(3) kinetic energy of emitted photoelectrons increases
(4) kinetic energy of emitted photoelectrons decreases

32. The stopping potential necessary to reduce the photoelectric current to zero-

(1) is directly proportional to wavelength of incident light.
(2) uniformly increases with the wavelength of incident light.
(3) directly proportional to frequency.
(4) uniformly increases with the frequency.

33. The work function for aluminium surface is 4.2 eV. If intensity of photon beam is doubled without changing numbers of photons striking per second. Find new cut-off wavelength.

(1) 1000 Å (2) 2000 Å
(3) 2955 Å (4) 4200 Å

34. The slope of a graph drawn between threshold frequency and stopping potential is:

(1) e (2) h
(3) h/e (4) he

35. If wavelength = 5400 Å is threshold value for a certain metal, then its work function would be:

(1) 2.3 eV (2) 0.025 eV
(3) 10 eV (4) 0.23 eV

36. A light of wavelength 5000 Å falls on a sensitive plate with photoelectric work function 1.90 eV. Kinetic energy of the emitted photoelectrons will be (Given, $h = 6.62 \times 10^{-34}$ J - s)

(1) 0.1 eV (2) 2 eV
(3) 0.58 eV (4) 1.581 eV

37. The maximum wavelength of radiation that can produce photoelectric effect in a certain metal is 200 nm. The maximum kinetic energy acquired by electron due to radiation of wavelength 100 nm will be

(1) 12.4 eV (2) 6.2 eV
(3) 3.4 eV (4) 7.0 eV

38. The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately

(1) 540 nm (2) 400 nm
(3) 310 nm (4) 220 nm

39. The photoelectric work function of a metal is 3.3 eV. The threshold frequency for this metal is approximately :

(1) 3.3×10^{13} Hz (2) 8.0×10^{14} Hz
(3) 1.65×10^{15} Hz (4) 9.9×10^{15} Hz

40. The emission of electrons is possible by

(1) photoelectric effect
(2) thermionic effect
(3) both (1) and (2)
(4) none of the above

De–Broglie Wave (Matter Waves)

41. The ratio of de-Broglie wavelengths of a proton and an alpha particle of same energy is

(1) 1 (2) 2
(3) 4 (4) 0.25

42. The ratio of de broglie wavelengths of a proton and an alpha particle moving with the same velocity is

(1) 1 (2) 2
(3) 4 (4) 0.25

43. The ratio of de Broglie wavelengths of a proton and a neutron moving with the same velocity is nearly

(1) 1 (2) $\sqrt{2}$
(3) $1/\sqrt{2}$ (4) None

44. Two particles have identical charges. If they are accelerated through identical potential differences, then the ratio of their de-Broglie wavelength would be

(1) $\lambda_1 : \lambda_2 = 1 : 1$
(2) $\lambda_1 : \lambda_2 = m_2 : m_1$
(3) $\lambda_1 : \lambda_2 = \sqrt{m_2} : \sqrt{m_1}$
(4) $\lambda_1 : \lambda_2 = \sqrt{m_1} : \sqrt{m_2}$

45. If the velocity of a moving particle is reduced to half, then percentage change in its wavelength will be

(1) 100% decrease (2) 100% increase
(3) 50% decrease (4) 50% increase

46. An electron and a proton are possessing same amount of kinetic energies. The de-Broglie wavelength is greater for :

(1) electron (2) proton
(3) equal (4) can't say

47. The de Broglie wavelength of an electron moving with a velocity 1.5×10^{8} ms^{-1} is equal to that of a photon. The ratio of the kinetic energy of the electron to that of the energy of photon is :

(1) 2 (2) 4
(3) $\frac{1}{2}$ (4) $\frac{1}{4}$

48. Which one of the following statements is NOT true for de Broglie waves ?

(1) All atomic particles in motion have waves of a definite wavelength associated with them
(2) The higher the momentum, the longer is the wavelength
(3) The faster the particle, the shorter is the wavelength
(4) For the same velocity, a heavier particle has a shorter wavelength

49. The wavelength associated with an electron accelerated through a potential difference of 100 V is of the order of :

(1) 1.2Å (2) 10.5 Å

(3) 100 Å (4) 1000 Å

50. A particle of mass 11×10^{-12} kg is moving with a velocity 6×10^{-7} m/s. Its de–Broglie wavelength is nearly :

(1) 10^{-20} m (2) 10^{-16} m

(3) 10^{-12} m (4) 10^{-8} m

51. The de-Broglie wavelength λ :

(1) is proportional to mass

(2) is proportional to impulse

(3) inversely proportional to impulse

(4) does not depend on impulse

Bohr's Atomic Model Of H-Atom and H-Like Species (Properties)

52. The Lyman series of hydrogen spectrum lies in the region

(1) Infrared (2) visible

(3) Ultraviolet (4) of x – rays

53. Which one of the series of hydrogen spectrum is in the visible region ?

(1) Lyman series (2) Balmer series

(3) paschen series (4) Bracket series

54. The Rutherford α–particle experiment Shows that most of the α–particles pass through almost unsceptered while some are scattered through large angles. What information does it give about the structure of the atom:

(1) Atom is hollow

(2) The whole mass of the atom is concentrated in a small centre called nucleus

(3) Nucleus is positively charged

(4) All the above

55. The energy required to knock out the electron in the third orbit of a hydrogen atom is equal to

(1) 13.6 eV (2) $\frac{13.6}{9}$ +eV

(3) $-\frac{13.6}{3}$ eV (4) $-\frac{3}{13.6}$ eV

56. An electron makes a transition from orbit n= 4 to the orbit n = 2 of a hydrogen atom. The wave number of the emitted radiation (R = Rydberg's constant) will be

(1) $\frac{16}{3R}$ (2) $\frac{2R}{16}$

(3) $\frac{3R}{16}$ (4) $\frac{4R}{16}$

57. If a_0 is the Bohr radius, the radius of the n = 2 electronic orbit in triply ionized beryllium is:

(1) $4a_0$ (2) a_0

(3) $a_0/4$ (4) $a_0/16$

58. Which energy state of doubly ionized lithium (Li^{++}) has the same energy as that of the ground state of hydrogen ? Given Z for lithium = 3 :

(1) n = 1 (2) n = 2

(3) n = 3 (4) n = 4

59. In Bohr's model of hydrogen atom, the centripetal force is provided by the Coulomb attraction between the proton and the electron. If a_0 is the radius of the ground state orbit, m is the mass and e the charge of an electron and ε_0 is the vacuum permittivity, the speed of the electron is :

(1) zero (2) $\frac{e}{\sqrt{\varepsilon_0 a_0 m}}$

(3) $\frac{e}{\sqrt{4\pi\varepsilon_0 a_0 m}}$ (4) $\frac{\sqrt{4\pi\varepsilon_0 a_0 m}}{e}$

60. The energy of an electron in the excited state of H-tom is –1.5 eV, then according to Bohr' model, its angular momentum will be:

(1) 3.15×10^{-34} J-sec (2) 2.15×10^{-34} J-sec

(3) 5.01×10^{-30} J-sec (4) 3.15×10^{-33} J-sec

61. The ground State energy of helium atom is – 54.4 eV. What is the potential energy of the electron in this state

(1) 54.4 ev (2) –108.8 eV

(3) 108.8 eV (4) –54.4 eV

62. According to Bohr's model of hydrogen atom, relation between principal quantum number n and radius of stable orbit:

(1) $r \propto \frac{1}{n}$ (2) $r \propto n$

(3) $r \propto \frac{1}{n^2}$ (4) $r \propto n^2$

63. The radius of first Bohr orbit is 0.5Å, then radius of fourth Bohr orbit will be:

(1) 0.03 Å (2) 0.12 Å

(3) 2.0 Å (4) 8.0 Å

Electronic Transition in The H/H-Like Atom/Spec

64. The ionization energy of helium atom is 54.4 eV. Helium atoms in the ground state are excited by electromagnetic radiation of energy 51 eV. How many spectral lines will be emitted by the Helium atoms?

(1) two (2) four

(3) six (4) eight

65. The wavelength of the first line in Balmer series in the hydrogen spectrum is λ. What is the wavelength of the second line :

(1) $\frac{20\lambda}{27}$ (2) $\frac{3\lambda}{16}$

(3) $\frac{5\lambda}{36}$ (4) $\frac{3\lambda}{4}$

66. The wavelength of light emitted due to transition of electron from second orbit to first orbit in hydrogen atom is

(1) 6563 Å (2) 4102 Å

(3) 4861 Å (4) 1215 Å

67. When an electron in an hydrogen atom makes a transition from first Bohr orbit to second Bohr orbit, how much energy it absorbs ?

(1) 3.4 eV (2) 10.2 eV

(3) 13.6 eV (4) 1.51 eV

68. If the binding energy of the electron in a hydrogen atom is 13.6 eV the energy required to remove the electron from the first excited state of Be^{3+} is

(1) 30.6 eV (2) 13.6eV

(3) 3.4 eV (4) 54.4 eV

69. An electron makes a transition from orbit n = 4 to the orbit n = 2 of a hydrogen atom. The wave number of the emitted radiation (R = Rydberg's constant) will be

(1) 16/3R (2) 2R/16

(3) 3R/16 (4) 4R/16

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Ans.	3	1	1	1	4	1	4	2	2	3	3	3	3	4	1	1	1	2	3	2	3	1	1	1	2
Que.	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Ans.	3	4	2	1	2	1	4	3	3	1	3	2	3	2	3	2	3	1	3	2	1	4	2	1	2
Que.	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69						
Ans.	3	3	2	4	2	3	2	3	3	1	2	4	4	3	1	4	2	4	3						

Exercise - II

1. A radiation of energy E falls normally on a perfectly reflecting surface. The momentum transferred to the surface is-

(1) E/c (2) 2E/c

(3) Ec (4) E/c^2

2. According to Einstein's photoelectric equation, the plot of the kinetic energy of the emitted photoelectrons from a metal Vs the frequency, of the incident radiation gives a straight line whose slope-

(1) depends on the nature of the metal used

(2) depends on the intensity of the radiation

(3) depends both on the intensity of the radiation and the metal used

(4) is the same for all metals and independent of the intensity of the radiation

3. The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately-

(1) 540 nm (2) 400 nm

(3) 310 nm (4) 220 nm

4. A photocell is illuminated by a small bright source placed 1 m away. When the same source of light is place $\frac{1}{2}$ m away, the number of electrons emitted by photocathode would-

(1) decrease by a factor of 4

(2) increase by a factor of 4

(3) decrease by a factor of 2

(4) increase by a factor of 2

5. If the kinetic energy of a free electron doubles, its de-Broglie wavelength changes by the factor-

(1) $\frac{1}{2}$ (2) 2

(3) $\frac{1}{\sqrt{2}}$ (4) $\sqrt{2}$

6. The threshold frequency for a metallic surface corresponds to an energy of 6.2 eV and the stopping potential for a radiation incident on this surface is 5V. The incident radiation lies in-

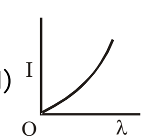
(1) ultra-violet region

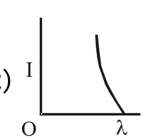
(2) infra-red region

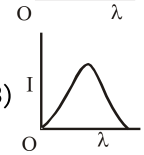
(3) visible region

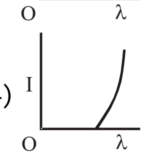
(4) X-ray region

7. The anode voltage of a photocell is kept fixed. The wavelength λ of the light falling on the cathode is gradually changed. The plate current I of the photocell varies as follows :

(1) 

(2) 

(3) 

(4) 

8. The surface of a metal is illuminated with the light of 400 nm. The kinetic energy of the ejected photoelectrons was found to be 1.68 eV. The work function of the metal is : (hc = 1240 eV-nm)

(1) 1.51 eV (2) 1.68 eV

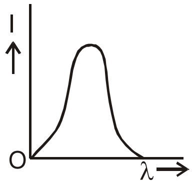
(3) 3.09 eV (4) 1.42 eV

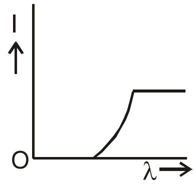
9. If a source of power 4kW produces 10^{20} photons/second, the radiation belongs to apart of the spectrum called:

(1) γ-rays (2) X-rays

(3) ultraviolet rays (4) microwaves

10. The anode voltage of photocell is kept fixed. The wavelength λ of the light falling on the cathode is gradually changed. The plate current I of the photocell varies as follows :

(1)


(2)


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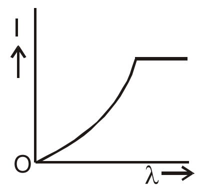
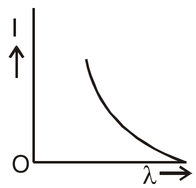
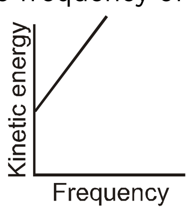
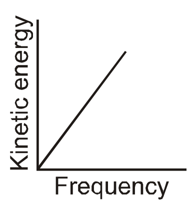
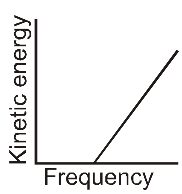


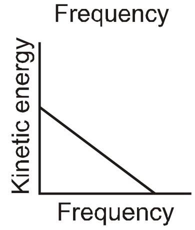
(4)


11. According to Einstein's photoelectric equation, the graph between the kinetic energy of photoelectrons ejected and the frequency of incident radiation is

(1)


(2)


(3)


(4)


12. Energy E of a hydrogen atom with principal quantum number n is given by $E = \frac{-13.6}{n^2}$ eV. The energy of a photon ejected when the electron jumps from n = 3 state to n = 2 state of hydrogen is passionately:

(1) 0.85 eV (2) 3.4 eV

(3) 1.9 eV (4) 1.5 eV

13. The work functions for metals A, B and C are respectively 1.92 eV, 2.0 eV and 5eV According to Einstein's equation, the metals which will emit photo electrons for a radiation of wavelength 4100 Å is /are:

(1) None

(2) A only

(3) A and B only

(4) All the three metals

14. A photosensitive metallic surface has work function, $h\nu_0$. If photons of energy $2h\nu_0$ fall on this surface, the electrons come, out with a maximum velocity of 4×10^6 m/s. when the photon energy is increased to $5h\nu_0$, then maximum velocity of photo electrons will be:

(1) 4×10^7 m/s (2) 2×10^7 m/s

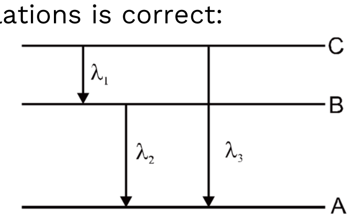
(3) 8×10^5 m/s (4) 8×10^6 m/s

15. The total energy of an electron in the first excited state of hydrogen atom is about - 3.4 eV. Its kinetic energy in this state is:

(1) −6.8 eV (2) 3.4 eV

(3) 6.8 eV (4) −3.4 eV

16. Energy levels A, B and C of a certain atom correspond to increasing values of energy i.e., $E_A < E_B < E_C$. If λ_1, λ_2 and λ_3 are wave lengths of radiations corresponding to transitions C to B, to A and C to A respectively, which of the following relations is correct:



(1) $\lambda_3 = \lambda_1 + \lambda_2$ (2) $\lambda_1 = \lambda_2 + \lambda_3$

(3) $\lambda_3^2 = \lambda_1^2 + \lambda_2^2$ (4) $\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$

17. Light of wavelength $\lambda = 4000$ Å is incident on a metal surface. If stopping potential needed to stop the ejected photoelectrons is 1.4 volt, then find out the work function of metal surface.

(1) 1.69 eV (2) 2.69 eV
(3) 3.09 eV (4) None of these

18. Ionization potential of hydrogen atom is 13.6eV. hydrogen atoms in the ground state are excited by monochromatic radiation of photon energy 12.1 eV. According to Bohr's theory, the spectral lines emitted by hydrogen will be:

(1) Two (2) Three
(3) Four (4) One

19. When photons of energy $h\nu$ fall on an aluminium plate (of work function E_0), photoelectrons of maximum kinetic energy K are ejected. If the frequency of the radiation is doubled, the maximum kinetic energy of the ejected photoelectrons will be:

(1) $K + E_0$ (2) 2K
(3) K (4) $K + h\nu$

20. The momentum of a photon of energy 1 Me V is kg m/s, will be:

(1) 0.33×10^{6} (2) 7×10^{-24}
(3) 10^{-22} (4) 5×10^{-22}

21. A photocell employs photoelectric effect to convert

(1) change in the frequency of light into a change in electric voltage
(2) change in the intensity of illumination into a change in photoelectric current
(3) change in the intensity of illumination into a change in the work function of the photocathode
(4) change in the frequency of light into a change in the electric current.

22. A 5 W source emits monochromatic light of wavelength 5000 Å. When placed 0.5 m away, it liberates photoelectrons from a photosensitive metallic surface, When the source is moved to a distance of 1.0 m, the number of photoelectrons liberated will be reduced by a factor of:

(1) 4 (2) 8
(3) 16 (4) 2

23. The total energy of electron in the ground state of hydrogen atom is –13.6 eV. The kinetic energy of an electron in the first excited state is:

(1) 3.4 eV (2) 6.8 eV
(3) 13.6 eV (4) 1.7 eV

24. Monochromatic light of frequency 6.0×10^{14} Hz is produced by a a laser. The power emitted is 2×10^{-3} W. The number of photons emitted, on the average, by the source per second is:

(1) 5×10^{15} (2) 5×10^{16}
(3) 5×10^{17} (4) 5×10^{14}

25. The work function of a surface of a photosensitive material is 6.2 eV. The wavelength of the incident radiation for which the stopping potential is 5 V lies in the:

(1) ultraviolet region (2) visible region
(3) infrared region (4) X-ray region

26. A particle of mass 1 mg has the same wavelength as an electron moving with a velocity of 3×10^{6} ms^{-1}. The velocity of the particle is (Mass of electron = 9.1×10^{-31} kg)

(1) 2.7×10^{-18} ms^{-1} (2) 9×10^{-2} ms^{-1}
(3) 3×10^{-31} ms^{-1} (4) 2.7×10^{-21} ms^{-1}

27. A particle moving with velocity that is three times that of velocity of electron. If ratio of the de-Broglie wavelength of particle with respect to electron is 1.8×10^{-4}. Find of mass of particle ($m_e = 9.1 \times 10^{-31}$ kg)

(1) 1.6×10^{-27} kg (2) 1.3×10^{-13} kg

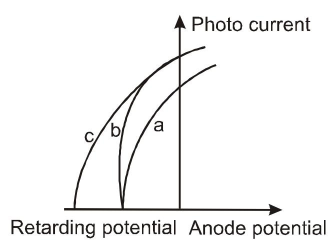
(3) 2.6×10^{-27} kg (4) 6.63×10^{-34} kg

28. Monochromatic light of wavelength 667 nm is produced by a helium neon laser. The power emitted is 9 mW. The number of photons arriving per second on the average at a target irradiated by this beam is:

(1) 9×10^{17} (2) 3×10^{16}

(3) 9×10^{15} (4) 9×10^{19}

29. The figure shows a plot of photo current versus anode potential for a photo sensitive surface for three different radiations. Which one of the following is a correct statement ?



(1) Curves a and b represent incident radiations of different frequencies and different intensities

(2) Curves a and b represent incident radiations of same frequencies but of different intensities

(3) Curves b and c represent incident radiations of different frequencies and different intensities

(4) Curves b and c represent incident radiations of same frequencies having same intensity

30. The number of photoelectrons emitted for light of a frequency ν is proportional to (higher than the threshold frequency ν_0)

(1) $\nu - \nu_0$

(2) threshold frequency (ν_0)

(3) intensity of light

(4) frequency of light (ν)

31. The ionization energy of the electron in the hydrogen atom in its ground state is 13.6 eV. The atoms are excited to higher energy levels to emit radiations of 6 wavelengths. Maximum wavelength of emitted radiation corresponds to the transition between

(1) n = 3 to n = 2 states

(2) n = 3 to n = 1 states

(3) n = 2 to n = 1 states

(4) n = 4 to n = 3 states

32. Sodium lamp emits 3.14×10^{20} photons per second. Calculate the distance from sodium lamp where flux of photon is one photon per second per cm^2:

(1) 1×10^9 cm (2) 3×10^9 cm

(3) 5×10^9 cm (4) 4×10^9 cm

33. In a hydrogen atom, electron moves from second excited state to first excited state and then from first excited state to ground state. Find ratio of wavelengths obtained.

(1) $\frac{27}{5}$ (2) $\frac{5}{27}$

(3) $\frac{1}{27}$ (4) None of these

34. The ground state energy of hydrogen atom is –13.6 eV. When its electron is in the first excited state, its excitation energy is:

(1) 3.4 eV (2) 6.8 eV

(3) 10.2 eV (4) zero

35. In a Rutherford scattering experiment when a projectile of charge Z_1 and mass M_1 approaches a target nucleus of charge Z_2 and mass M_2, the distance of closest approach is r_0. The energy of the projectile is:
(1) directly proportional to $M_1 \times M_2$
(2) directly proportional to Z_1Z_2
(3) inversely proportional to Z_1
(4) directly proportional to mass M_1

36. The energy of a hydrogen atom in the ground state is –13.6 eV. The energy of a He^+ ion in the first excited state will be:
(1) – 13.6 eV (2) – 27.2 eV
(3) – 54.4 eV (4) – 6.8 eV

37. A source S_1 is producing 10^{15} photons per second of wavelength 5000Å. Another sorce S_2 is producing 1.02×10^{15} photons per second of wavelength 5100 Å. Then (power of S_2)/(power of S_1) is equal to:
(1) 1.00 (2) 1.02
(3) 1.04 (4) 0.98

38. The potential difference that must be applied to stop the fastest photoelectrons emitted by a nickel surface, having work function 5.01 eV, when ultraviolet light of 200 nm falls on it, must be:
(1) 2.4 V (2) –1.2 V
(3) – 2.4 V (4) 1.2 V

39. When monochromatic radiation of intensity I falls on a metal surface, the number of photoelectrons and their maximum kinetic energy are N and T respectively. If the intensity of radiation is 2I, the number of emitted electrons and their maximum kinetic energy are respectively
(1) N and 2T (2) 2N and T
(3) 2N and 2T (4) N and T

40. The electron in the hydrogen atom jumps from excited state (n = 3) to its ground state (n = 1) and the photons thus emitted irradiate a photosensitive material. If the work function of the material is 5.1 eV, the stopping potential is estimated to be (the energy of the electron in n^{th} state $E_n = -\frac{13.6}{n^2}$eV)
(1) 5.1 V (2) 12.1 V
(3) 17.2 V (4) 7V

41. An alpha nucleus of energy $\frac{1}{2}mv^2$ bombards a heavy nuclear target of charge Ze. Then the distance of closest approach for the alpha nucleus will be proportional to-
(1) $\frac{1}{Ze}$ (2) v^2
(3) $\frac{1}{m}$ (4) $\frac{1}{v^4}$

42. If 13.6 eV energy is required to ionize the hydrogen atom, then the energy required to remove an electron from n = 2 is-
(1) 10.2 eV (2) 0 eV
(3) 3.4 eV (4) 6.8 eV

43. If the binding energy of the electron in a hydrogen atom is 13.6 eV, the energy required to remove the electron from the first excited state of Li^{2+} is-
(1) 30.6 eV (2) 13.6 eV
(3) 3.4 eV (4) 122.4 eV

44. Which of the following transitions in hydrogen atoms emit photons of highest frequency ?
(1) n = 2 to n = 6 (2) n = 6 to n = 2
(3) n = 2 to n = 1 (4) n = 1 to n = 2

45. Suppose an electron is attracted towards the origin by a force $\frac{k}{r}$ where 'k' is a cosntant and 'r' is the distance of the electron from the origin. By applying Bohr model to this sytem, the radius of the n^{th} orbital of the electron is found to be 'r_n' and the kinetic energy of the electron to be 'T_n'. Then which of the following is true?

(1) $T_n \propto \frac{1}{n^2}, r_n \propto n^2$

(2) T_n independent of n, $r_n \propto n$

(3) $T_n \propto \frac{1}{n}, \; r_n \propto n$

(4) $T_n \propto \frac{1}{n}, \; r_n \propto n^2$

46. The transition from the state n = 4 to n = 3 in a hydrogen like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition from :

(1) $4 \rightarrow 2$ (2) $5 \rightarrow 4$

(3) $2 \rightarrow 1$ (4) $3 \rightarrow 2$

47. Energy required for the electron excitation in Li^{++} from the first to the third Bohr orbit is:-

(1) 108.8 eV (2) 122.4 eV

(3) 12.1 eV (4) 36.3 eV

48. Hydrogen atom is excited from ground state to another state with principal quantum number equal to 4. Then the number of spectral lines in the emission spectra will be :

(1) 6 (2) 2

(3) 3 (4) 5

49. In a hydrogen like atom electron makes transition from an energy level with quantum number n to another with quantum number (n–1). If n>>1, the frequency of radiation emitted is proportional to

(1) $\frac{1}{n}$ (2) $\frac{1}{n^2}$

(3) $\frac{1}{n^{3/2}}$ (4) $\frac{1}{n^3}$

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Ans.	2	4	3	2	3	1	2	4	2	4	3	3	3	4	2	4	1	2	4	4	2	1	1	1	1
Que.	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	
Ans.	1	1	2	2	3	4	3	1	3	2	1	1	2	2	4	3	3	1	3	2	2	1	1	4	

Exercise – III (Previous Year Question)

1. The threshold frequency for a photosensitive metal is 3.3×10^{14} Hz. If light of frequency 8.2×10^{14} Hz is incident on this metal, the cut-off voltage for the photoelectric emission is nearly: **[AIPMT 2011]**

(1) 2V (2) 3V
(3) 5V (4) 1V

2. An electron in the hydrogen atom jumps from excited state n to the ground state. The wavelength so emitted illuminates a photosensitive material having work function 2.75 eV. If the stopping potential of the photoelectronic 10 V, the value of n is : **[AIPMT 2011]**

(1) 3 (2) 4
(3) 5 (4) 2

3. Out of the following which one is not a possible energy for a photon to be emitted by hydrogen atom according to Bohr's atomic model ? **[AIPMT 2011]**

(1) 1.9 eV (2) 11.1 eV
(3) 13.6 eV (4) 0.65 eV

4. Photoelectric emission occurs only when the incident light has more than a certain minimum: **[AIPMT-2011]**

(1) power (2) wavelength
(3) intensity (4) frequency

5. The wavelength of the first line of Lyman series for hydrogen atom is equal to that of the second line of Balmer series for a hydrogen like ion. The atomic number Z of hydrogen like ion is: **[AIPMT-2011]**

(1) 3 (2) 4
(3) 1 (4) 2

6. In the Davisson and Germer experiment, the velocity of electrons emitted from the electron gun can be increased by: **[AIPMT-2011]**

(1) increasing the potential difference between the anode and filament
(2) increasing the filament current
(3) decreasing the filament current
(4) decreasing the potential difference between the anode and filament

7. The decreasing order of wavelength of infrared, microwave, ultraviolet and gamma rays is: **[AIPMT-2011]**

(1) microwave, infrared, ultraviolet, gamma rays
(2) gamma rays, ultraviolet, infrared, microwaves
(3) microwaves, gamma rays, infrared, ultraviolet
(4) infrared, microwave, ultraviolet, gamma rays

8. Light of two different frequencies whose photons have energies 1 eV and 2.5 eV respectively illuminate a metallic surface whose work function is 0.5 eV successively. Ratio of maximum speeds emitted electrons will be: **[AIPMT-2011]**

(1) 1 : 4 (2) 1 : 2
(3) 1 : 1 (4) 1 : 5

9. Electrons used in an electron microscope are accelerated by a voltage of 25 kV. If the voltage is increased to 100kV then the de-Broglie wavelength associated with the electrons would: **[AIPMT-2011]**

(1) increases by 2 times
(2) decrease by 2 times
(3) decrease by 4 times
(4) increases by 4 times

10. In photoelectric emission process from a metal of work function 1.8 eV, the kinetic energy of most energetic electrons is 0.5 eV. The corresponding stopping potential is: **[AIPMT-2011]**

(1) 1.8 V (2) 1.2 V

(3) 0.5 V (4) 2.3 V

11. Electron in hydrogen atom first jumps from third excited state to second excited state and then from second excited to the first excited state. The ratio of the wavelength $\lambda_1 : \lambda_2$ emitted in the two cases is: **[AIPMT Pre-2012]**

(1) 7/5 (2) 27/20

(3) 27/5 (4) 20/7

12. A 200 W sodium street lamp emits yellow light of wavelength 0.6 μm. Assuming it to be 25% efficient in converting electrical energy to light, the number of photons of yellow light it emits per second is: **[AIPMT Pre-2012]**

(1) 1.5×10^{20} (2) 6×10^{18}

(3) 62×10^{20} (4) 3×10^{19}

13. An electron of a stationary hydrogen atom passes from the fifth energy level to the ground level. The velocity that the atom acquired as a result of photon emission will be: **[AIPMT Pre-2012]**

(1) $\frac{24hR}{25m}$ (2) $\frac{25hR}{24m}$

(3) $\frac{25m}{24hR}$ (4) $\frac{24m}{25hR}$

(m is the mass of atom, R, Rydberg constant and h Planck's constant)

14. Monochromatic radiation emitted when electron on hydrogen atom jumps from first excited to the ground state irradiates a photosensitive material. The stopping potential is measured to be 3.57 V. The threshold frequency of the materials is: **[AIPMT Pre-2012]**

(1) 4×10^{15} Hz (2) 5×10^{15} Hz

(3) 1.6×10^{15} Hz (4) 2.5×10^{15} Hz

15. An α-particle moves in a circular path of radius 0.83 cm in the presence of a magnetic field of 0.25 Wb/m^2. The de Broglie wavelength associated with the particle will be: **[AIPMT Pre-2012]**

(1) 1 Å (2) 0.1 Å

(3) 10 Å (4) 0.01 Å

16. If the momentum of electron is changed by P, then the de Broglie wavelength associated with it changes by 0.5%. The initial momentum of electron will be: **[AIPMT 2012 [Mains]]**

(1) 200 P (2) 400 P

(3) $\frac{P}{200}$ (4) 100 P

17. Two radiations of photons energies 1 eV and 2.5 eV, successively illuminate a photosensitive metallic surface of work function 0.5 eV. The ratio of the maximum speeds of the emitted electrons is: **[AIPMT 2012 [Mains]]**

(1) 1 : 4 (2) 1 : 2

(3) 1 : 1 (4) 1 : 5

18. The transition from the state n = 3 to n = 1 in a hydrogen like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition from : **[AIPMT 2012 [Mains]]**

(1) $2 \rightarrow 1$ (2) $3 \rightarrow 2$

(3) $4 \rightarrow 2$ (4) $4 \rightarrow 3$

19. For photoelectric emission from certain metal the cutoff frequency is ν. If radiation of frequency 2ν impinges on the metal plate the maximum possible velocity of the emitted electron will be (m is the electron mass): **[NEET 2013]**

(1) $\sqrt{h\nu / m}$ (2) $\sqrt{2h\nu / m}$

(3) $2\sqrt{h\nu / m}$ (4) $\sqrt{h\nu / (2m)}$

20. The wavelength λ_e of an electron and λ_p of a photon of same energy E are related by: **[NEET 2013]**

(1) $\lambda_p \propto \lambda_e$ (2) $\lambda_p \propto \sqrt{\lambda_e}$

(3) $\lambda_p \propto \frac{1}{\sqrt{\lambda_e}}$ (4) $\lambda_p \propto \lambda_e^2$

21. When the energy of the incident radiation is increased by 20%, the kinetic energy of the photoelectrons emitted from a metal surface increased from 0.5 eV to 0.8 eV. The work function of the metal is: **[AIPMT 2014]**

(1) 0.65 eV (2) 1.0 eV

(3) 1.3 eV (4) 1.5 eV

22. If the kinetic energy of the particle is increased to 16 times its previous value, the percentage change in the de-Broglie wavelength of the particle is:

[AIPMT 2014]

(1) 25 (2) 75

(3) 60 (4) 50

23. Hydrogen atom in ground state is excited by a monochromatic radiation of λ = 975 Å. Number of spectral lines in the resulting spectrum emitted will be

[AIPMT 2014]

(1) 3 (2) 2

(3) 6 (4) 10

24. Consider 3rd orbit of He^+ (Helium), using non-relativistic approach, the speed of electron in this orbit will be:

[Given : K = 9×10^9 constant, Z = 2 and h (Planck's Constant) = 6.6×10^{-34} J s]

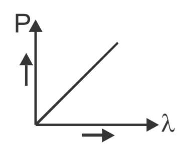
[AIPMT 2015]

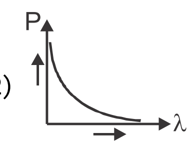
(1) 1.46×10^6 m/s (2) 0.73×10^6 m/s

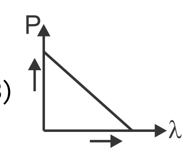
(3) 3.0×10^8 m/s (4) 2.92×10^6 m/s

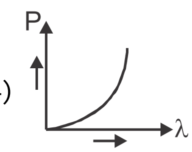
25. Which of the following figures represent the variation of particle momentum and the associated de-Broglie wavelength ?

[AIPMT 2015]

(1) 

(2) 

(3) 

(4) 

26. Light of wavelength 500 nm is incident on a metal with work function 2.28 eV. The de Broglie wavelength of the emitted electron is: **[AIPMT 2015]**

(1) $\leq 2.8 \times 10^{-12}$ m (2) $< 2.8 \times 10^{-10}$ m

(3) $< 2.8 \times 10^{-9}$ m (4) $\geq 2.8 \times 10^{-9}$ m

27. A photoelectric surface is illuminated successively by monochromatic light of wavelength λ and λ/2. If the maximum kinetic energy of the emitted photoelectrons in the second case is 3 times than in the first case, the work function of the surface of the material is (h = Plank's constant, c = speed of light)

[AIPMT 2015]

(1) $\frac{hc}{3\lambda}$ (2) $\frac{hc}{2\lambda}$

(3) $\frac{hc}{\lambda}$ (4) $\frac{2hc}{\lambda}$

28. In the spectrum of hydrogen, the ratio of the longest wavelength in the Lyman series to the longest wavelength in the Balmer series is: **[AIPMT 2015]**

(1) $\frac{5}{27}$

(2) $\frac{4}{9}$

(3) $\frac{9}{4}$

(4) $\frac{27}{5}$

29. Given the value of Rydberg constant is $10^7\ m^{-1}$, the wave number of the last line of the Balmer series in hydrogen spectrum will be: **[NEET 2016]**

(1) $0.025 \times 10^4\ m^{-1}$ (2) $0.5 \times 10^7\ m^{-1}$

(3) $0.25 \times 10^7\ m^{-1}$ (4) $2.5 \times 10^7\ m^{-1}$

30. When an α-particle of mass 'm' moving with velocity 'v' bombards on a heavy nucleus of charge 'Ze', its distance of closest approach from the nucleus depends on m as: **[NEET 2016]**

(1) $\frac{1}{m}$ (2) $\frac{1}{\sqrt{m}}$

(3) $\frac{1}{m^2}$ (4) m

31. An electron of mass m and a photon have same energy E. The ratio of de-Broglie wavelengths associated with them is: **[NEET 2016]**

(1) $\frac{1}{c}\left(\frac{E}{2m}\right)^{\frac{1}{2}}$ (2) $\left(\frac{E}{2m}\right)^{\frac{1}{2}}$

(3) $c(2mE)^{1/2}$ (4) $\frac{1}{c}\left(\frac{2m}{E}\right)^{\frac{1}{2}}$

(c is velocity of light)

32. When a metallic surface is illuminated with radiation of wavelength λ, the stopping potential is V. If the same surface is illuminated with radiation of wavelength 2λ, the stopping potential is $\frac{V}{4}$. The threshold wavelength for the metallic surface is: **[NEET 2016]**

(1) 3λ (2) 4λ

(3) 5λ (4) $\frac{5}{2}\lambda$

33. The photoelectric threshold wavelength of silver is 3250×10^{-10} m. The velocity of the electron ejected from a silver surface by ultraviolet light of wavelength 2536×10^{-10} m is: **[NEET 2017]**

(Given : $h = 4.14 \times 10^{-15}$ eVs and $c = 3 \times 10^8\ ms^{-1}$)

(1) $\approx 6 \times 10^5\ ms^{-1}$ (2) $\approx 0.6 \times 10^6\ ms^{-1}$

(3) $\approx 61 \times 10^3\ ms^{-1}$ (4) $\approx 0.3 \times 10^6\ ms^{-1}$

34. The ratio of wavelengths of the last line of Balmer series and the last line of Lyman series is: **[NEET 2017]**

(1) 2

(2) 1

(3) 4

(4) 0.5

35. The de-Broglie wavelength of a neutron in thermal equilibrium with heavy water at a temperature T (Kelvin) and mass m, is: **[NEET 2017]**

(1) $h/\sqrt{3mkT}$

(2) $2h/\sqrt{3mkT}$

(3) $2h/\sqrt{mkT}$

(4) $h/\sqrt{mkT}$

36. When the light of frequency $2\nu_0$ (where ν_0 is threshold frequency), is incident on a metal plate, the maximum velocity of electrons emitted is v_1. When the frequency of the incident radiation is increased to $5\nu_0$, the maximum velocity of electrons emitted from the same plate is v_2. The ratio of v_1 to v_2 is: **[NEET 2018]**

(1) 1 : 2 (2) 1 : 4

(3) 4 : 1 (4) 2 : 1

37. An electron of mass 'm' with an initial velocity $\vec{v} = v_0\hat{i}$ $(v_0 > 0)$ enters an electric field $\vec{E} = -E_0\hat{i}$ (E_0 = content > 0) at t = 0. If λ_0 is its de-Broglie wavelength initially, then its de-Broglie wavelength at time t is: **[NEET 2018]**

(1) $\dfrac{\lambda_0}{\left(1+\dfrac{eE_0}{mv_0}t\right)}$ (2) $\lambda_0\left(1+\dfrac{eE_0}{mv_0}t\right)$

(3) $\lambda_0 t$ (4) λ_0

38. An electron is accelerated through a potential difference of 10,000 V. Its de Broglie wavelength is (nearly):
($m_e = 9 \times 10^{-31}$ kg) **[NEET 2019]**

(1) 12.2×10^{-14} m (2) 12.2 nm

(3) 12.2×10^{-13} m (4) 12.2×10^{-12} m

39. The total energy of an electron in an atom in an orbit is –3.4 eV. Its kinetic and potential energies are respectively : **[NEET 2019]**

(1) 3.4 eV, –6.8 eV

(2) 3.4 eV, 3.4 eV

(3) –3.4 eV, –3.4 eV

(4) –3.4 eV, –6.8 eV

40. An LED is constructed from a p-n junction diode using GaAsP. The energy gap is 1.9 eV. The wavelength of the light emitted will be equal to: **[NEET 2019]**

(1) 10.4×10^{-26} m (2) 654 nm

(3) 654 Å (4) 654×10^{-11} m

41. The work function of a photosensitive material is 4.0 eV. This longest wavelength of light that can cause photon emission from the substance is (approximately) **[NEET 2019]**

(1) 3100 nm (2) 966 nm

(3) 31 nm (4) 310 nm

42. A proton and an α-particle are accelerated from rest to the same energy. The de Broglie wavelengths λ_p and λ_α zare in the ratio: **[NEET 2019]**

(1) 2 : 1 (2) 1 : 1

(3) $\sqrt{2}$: 1 (4) 4 : 1

43. Light of frequency 1.5 times the threshold frequency is incident on a photosensitive material. What will be the photoelectric current if the frequency is halved and intensity is doubled ? **[NEET 2020]**

(1) one-fourth (2) zero

(3) doubled (4) four times

44. The energy required to break one bond in DNA is 10^{-20}J. This value in eV is nearly: **[NEET 2020]**

(1) 0.06 (2) 0.006

(3) 6 (4) 0.6

45. Light with an average flux of 20 W/cm^2 falls on a non-reflecting surface at normal incidence having surface area 20 cm^2. The energy received by the surface during time span of 1 minute is: **[NEET 2020]**

(1) 24×10^3 J (2) 48×10^3 J

(3) 10×10^3 J (4) 12×10^3 J

46. The de Broglie wavelength of an electron moving with kinetic energy of 144 eV is nearly: **[NEET Covid 2020]**

(1) $10^2 \times 10^{-3}$ nm (2) $10^2 \times 10^{-4}$ nm

(3) $10^2 \times 10^{-5}$ nm (4) $10^2 \times 10^{-2}$ nm

47. The wave nature of electrons was experimentally verified by: **[NEET Covid 2020]**

(1) de Broglie
(2) Hertz
(3) Einstein
(4) Davisson and Germer

48. The number of photons per second on an average emitted by the source of monochromatic light of wavelength 600 nm, when it delivers the power of 3.3×10^{-3} watt will be :

($h = 6.6 \times 10^{-34}$ Js) **[NEET 2021]**

(1) 10^{18} (2) 10^{17}

(3) 10^{16} (4) 10^{15}

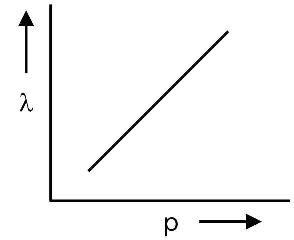
49. Let T_1 and T_2 be the energy of an electron in the first and second excited states of hydrogen atom, respectively. According to the Bohr's model of an atom, the ratio $T_1 : T_2$ is: **[NEET 2022]**

(1) 1 : 4 (2) 4 : 1

(3) 4 : 9 (4) 9 : 4

50. The graph which show the variation of the de-Broglie wavelength (λ) of a particle and its associated momentum (p) is:

[NEET 2022]

(1)


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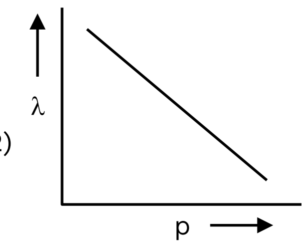

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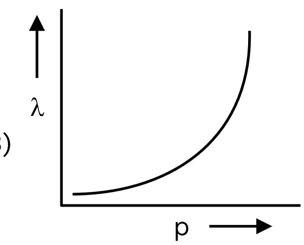
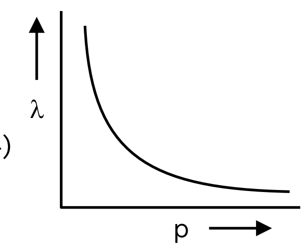


(4)


ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Ans.	1	2	2	4	4	1	1	2	2	3	4	1	1	3	4	1	2	4	2	4	2	2	3	1	2
Que.	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Ans.	4	2	1	3	1	1	1	1	3	1	1	1	4	1	2	4	1	2	1	1	1	4	3	4	4