1. ATOMIC PHYSICS

SYNOPSIS

I. MODEL OF ATOMS

i) Thomson's model:

a) An atom consists of positively charged core with electrons uniformly distributed over it like seeds in the watermelon.

b) This model failed to explain the observed values of frequencies of spectral lines emitted by Hydrogen atom

ii) Rutherford model :

α-Ray scattering experiment

a) From the experiments on scattering of α-particles from gold foils, Rutherford concluded that the bulk of mass of the atom resides in a tiny space called nucleus and electrons orbit around the nucleus.

b) This model is called nuclear model

c) This failed to explain stability of atoms

d) When a mono energetic beam of α particles is projected towards a thin metal foil, some of the particles are found to deviate from their original path. This phenomenon is called α ray scattering

e) It is caused by coulomb repulsive force between α particles and positive charges in atom.

f) The number of α-particles scattered at an angle is given by $N = \dfrac{Q\,n\,t\,z^2\,e^4}{(8\pi\varepsilon_0)^2\,r^2\,E^2\sin^4\left(\frac{\theta}{2}\right)}$

where Q = Total number of α particles striking the foil ; n = number of atoms per unit volume of the foil ; r = distance of screen from the foil ; t = thickness of the foil; z = Atomic number of the foil atoms; θ = angle of scattering ; E = kinetic energy of α particles

g) $N \propto t$; $N \propto z^2$; $N \propto \dfrac{1}{\sin^4\frac{\theta}{2}}$; $N \propto \dfrac{1}{E^2}$ or $N \propto \dfrac{1}{\upsilon^4}$; where ϑ is the velocity of α particles falling on the foil.

iii) Bohr model : Bohr made the following postulates to support his atomic model.

a) **Circular orbits :** The atom consists of central nucleus, containing the entire positive charge and almost all mass of the atom. The electrons revolve around the nucleus in certain discrete circular orbits.

b) **Stationary orbits :** The allowed orbits for electron are those in which the electron does not radiate energy. These orbits are called stationary orbits.

c) **Quantum condition :** The stationary orbits are those in which angular momentum of electron is an integral multiple of $\dfrac{h}{2\pi}$

$m\vartheta r = \dfrac{nh}{2\pi}$; m = mass of electron ; ϑ = speed of electron in the circular orbit ; r = radius of the circular orbit ; n = principal quantum number

Transition rule : When an electron jumps from a higher energy orbit to lower energy orbit, the difference of energy is emitted as a photon of energy $h\vartheta$ where ϑ is the frequency of radiation emitted.

iv) Results of Bohr model of Atom

a) Radius of the n^{th} orbit : $r_n = \dfrac{n^2h^2\varepsilon_0}{\pi me^2Z}$; $r_n = 0.53\times\dfrac{n^2}{Z}\overset{o}{A}$

For hydrogen like atoms $r_n \alpha \dfrac{n^2}{Z}$

b) Speed of the electron in the nth orbit : $V_n = \dfrac{Ze^2}{2\epsilon_0 nh} \Rightarrow V_n \propto \dfrac{Z}{n}$

c) Time period of revolution of electron in the n^{th} orbit is $T_n = \dfrac{4\epsilon_0{}^2 n^3h^3}{mz^2e^4} \Rightarrow T_n \propto \dfrac{n^3}{z^2}$

d) Frequency of electron in the orbit (f): $f = \dfrac{1}{T} = \dfrac{2\pi\omega_0 z^2}{n^3}$; $f \propto \dfrac{z^2m}{n^3}$; $f = \dfrac{6.62\times10^{15}z^2}{n^3}$

e) Electric current due to electran motion in the orbit $I = \dfrac{e}{T} = \dfrac{e2\pi\omega_0 z^2}{n^3}$; $I \propto \dfrac{z^2m}{n^3}$; $I = \dfrac{1.06\times z^2}{n^3}mA$

f) Magnetic field induction produced at the nucleus due to electron motion in the orbit

$B = \dfrac{\mu_0 I}{2r} = \dfrac{8\pi^4k^3z^3e^7m^2}{n^5h^5}$; $B \propto \dfrac{z^3m^2}{n^5}$; $B = \dfrac{12.58z^3}{n^5}$ tesla

g) Magnetic moment produced due to electron motion in the orbit

$M = IA = \pi r^2 I$; $M = \dfrac{enh}{4\pi m}$; $M = n\times9.26\times10^{-24}\ Am^2$

if $n = 1, M = \dfrac{eh}{4\pi m} = 9.26\times10^{-24}Am^2$

This is known as Bohr magneton.

h) Total energy of electron in the n^{th} orbit : $E_n = -\left(\dfrac{me^4}{8h^2\varepsilon_0^2}\right)\dfrac{z^2}{n^2}$; $E_n = -13.6\times\dfrac{Z^2}{n^2}eV$

As 'n' increases E_n increases

i) Frequency of emitted radiation : When an electron jumps from a higher energy orbit n_2 to a lower energy orbit n_1, the frequency of radiation emitted is

$\upsilon = \dfrac{me^4}{8\varepsilon_0 h^3}\left(\dfrac{1}{n_1^2}-\dfrac{1}{n_2^2}\right)z^2$, $\upsilon = RcZ^2\left(\dfrac{1}{n_1^2}-\dfrac{1}{n_2^2}\right)$ where R is called Rydberg constant.

$R = \dfrac{me^4}{8\varepsilon_0 h^3 c} = 1.097\times10^7 m^{-1}$; Rch =13.6 ev and is called Rydberg energy.

j) The wave length of the emitted radiation is $\dfrac{1}{\lambda} = z^2R\left(\dfrac{1}{n_1^2}-\dfrac{1}{n_2^2}\right)$

k) No of spectral lines

If the electron jumps from higher energy orbit to lower energy orbit, it emits traditions with various spectral lines.

* If the electron falls from n_2 to n_1 then the no. of spectral lines emitted is given by $N_E = \dfrac{(n_2-n_1+1)(n_2-n_1)}{2}$

* If the electron falls from nth orbit to ground state (i.e $n_2 = n_1$, $n_1 = 1$). The no. of spectral lines emitted is given by $N_E = \frac{n(n-1)}{2}$
* Number of absorption lines possible from ground state to n^{th} orbit are (n-1).

v) **Hydrogen spectrum :** Hydrogen in atomic state gives line spectrum in different regions of electromagnetic radiation spectrum.

S. No	Name of the series	Final State (n_1)	Initial State (n_2)	Formula	Series limit	Maximum wavelength	Region
1.	Lyman	$n_1 = 1$	2,3,4,....∞	$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n_2^2}\right)$	$\lambda = \frac{1}{R} = 911A°$	$\lambda = \frac{4}{3R}$	UV
2.	Balmer	$n_1 = 2$	3,4,5....∞	$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n_2^2}\right)$	$\lambda = \frac{4}{R}$	$\lambda = \frac{36}{5R}$	Visible
3.	Paschen	$n_1 = 3$	4,5,6....∞	$\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n_2^2}\right)$	$\lambda = \frac{9}{R}$	$\lambda = \frac{144}{7R}$	Near IR
4.	Brackett	$n_1 = 4$	5,6,7....∞	$\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{n_2^2}\right)$	$\lambda = \frac{16}{R}$	$\lambda = \frac{400}{9R}$	Middle IR
5.	Pfund	$n_1 = 5$	6,7,8....∞	$\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{n_2^2}\right)$	$\lambda = \frac{25}{R}$	$\lambda = \frac{9000}{11R}$	Far IR

Dual nature of matter -deBroglie's hypothesis:

i) According to deBroglie mater behaves both as particles and waves.

ii) This hypothesis is based on the fact that, nature is symmetrical in many ways. The two fundamental forms of nature, matter and energy should also be symmetric.

iii) A moving particle behaves sometimes as a wave and sometimes as a particle. The waves are called deBroglie waves or matter waves. The wavelength associated with matter wave is called deBroglie wavelength.

iv) Matter waves are neither mechanical nor electromagnetic. They are probabilistic waves because these waves represent the probability of finding a particle in space.

v) If a matter particle of mass m is moving with a velocity V, then the deBroglie wavelength associated with the matter wave of that particle is given by $\boxed{\lambda = \frac{h}{mV} = \frac{h}{p} = \frac{h}{\sqrt{2mE}}}$

vi) **deBroglie wave equation :**

a) $\lambda \alpha \frac{1}{\vartheta}$ and if $\vartheta = 0, \lambda = \infty$

The matter waves are associated with material particles only if they are in motion

b) $\lambda \alpha \frac{1}{m}$ smaller the mass of the particle, larger is the wave length associated with it.

c) $\lambda \alpha \frac{1}{p}$, larger the momentum of the particle, shorter is the wave length.

d) Wave length associated with a material particle is independent of the charge of the particle.

e) Davisson and Germer's experiment and G.P Thomson experiments on diffraction of electrons provided the evidence of de Brogle's matter waves.

vii) When a particle of charge q and mass m is accelerated through a potential difference V then $\boxed{\lambda = \frac{h}{\sqrt{2mqV}}}$

for an electron $\boxed{\lambda \approx \frac{12.27}{\sqrt{V}} A^0}$

for a proton $\boxed{\lambda = \frac{0.286}{\sqrt{V}} A^0}$; For deuteron $\lambda = \frac{0.202}{\sqrt{E}} \mathring{A}$;

For α particle $\lambda = \frac{0.101}{\sqrt{V}} \mathring{A}$; For neutron $\lambda = \frac{0.286}{\sqrt{E}} \mathring{A}$

viii) Importance of matter waves

a) Electron microscope is developed by making use of wave nature of electrons. Its magnification is about 10^5 times

b) Dual nature of matter has become the starting point of development of quantum mechanics by Schrodinger

Davisson and Germer's electron diffraction experiment

i) The first experimental evidence of matter wave was given by two American physicists, Davisson and Germer in 1927. They also succeeded in measuring the de-Broglie wave length associated with slow electrons.

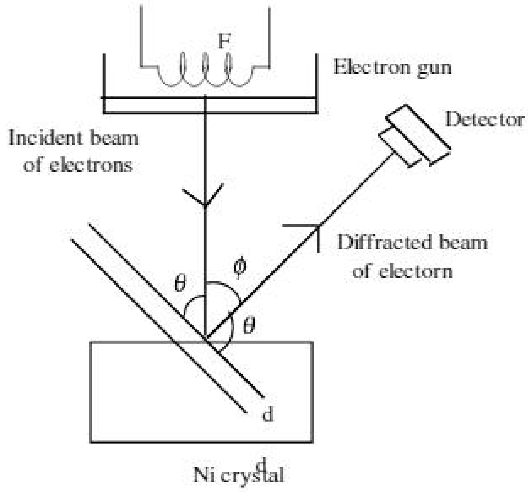
ii) A beam of electron emitted by electron gun is made to fall on nickel crystal cut along cubical axis at a particular angle.

iii) Ni crystal behaves like a three dimensional diffraction grating and it diffracts the electron beam obtained from electron gun.

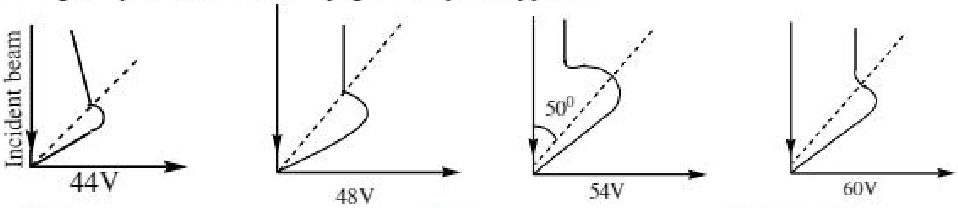
iv) The diffracted beam of electrons received by the detector which can be positioned at any angle by rotating about the point of incidence.

v) The energy of the incident beam of electron can also be varied by changing the applied voltage to the electron gun.

vi) According to classical physics, the intensity of scattered beam of electrons was not the same but different at different angles of scattering. It is maximum for diffracting angle 50^0 at 54 volt P.D.



vii) It is seen that a bump begins to appear in the curve for 44 volt electrons. With increasing potential in the bump moves upwards and becomes most prominent in the curve for 54 volt electrons at $\phi = 50^0$. At higher potential the bump gradually disappears.



viii) If the de Broglie waves are associated with electron, then these should be diffracted like x-rays. using the Bragg's formula $2d\sin\theta = n\lambda$, we can determine the wavelength of these waves. Where 'd' is the distance between the diffracting planes.

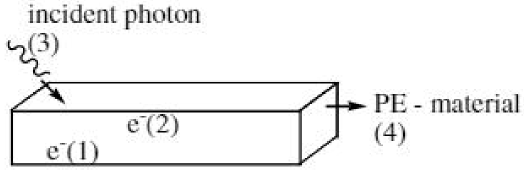
$\theta = \left[\dfrac{180-\phi}{2}\right]$ = glancing angle for incident beam = Bragg's angle.

ix) The distance between diffracting planes in Ni - crystal for this experiment is $d = 0.91A^0$ and for $n = 1$ $\lambda = 2\times0.91\times10^{-10}$ sin 65 = $1.65A^0$. Now de Broglie wave length can also be determined using the formula $\lambda = \dfrac{12.27}{\sqrt{V}} = \dfrac{12.27}{\sqrt{54}} = 1.67A^0$. Thus the deBroglie hypothesis is verified.

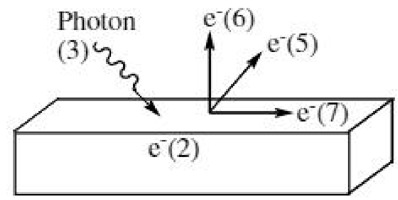
II. PHOTOELECTRIC EFFECT

Mechanism of ejection due to absorption of photons in PE material

- ❖ PEE is a phenomenon of conservation of energy (quantization)
- ❖ When photons are incident on the PE matieral, the photons may strike any part of the material both far interior to the surface or nearer to the surface.
- ❖ Some work may be required to bring the photoelectrons from the far-interior to the exterior.
- ❖ In the process, electrons may or may not be ejected from the material.
- ❖ If a single photon collides an electron and which is at far interior of the material and ejects it out of the PEE material, then
  $E_{photon} = W_{interior-exterior} + \Phi + KE_{electron}$
- ❖ If a single photon collides an electron and which almost at the exterior of the material and ejectrs it out of the PEE material, then
  $E_{photon} = \Phi + KE_{electron}$
- ❖ However, energy absorbed by an electron may not appear in the form of kinetic energy of the electron in the material.
- ❖ The electron may undergo several collisions within the material to reach the surface.
- ❖ In the process of PEE, there is no time lag.
- ❖ The time interval between the incidentce of photon and the ejectron of photoelectron is of the order of 10^{-9} second.
- ❖ Once photoelectrons are ejected from PEE material,the resideual acquires positive charge, In some instances this itself may act as retarding potential for the photo-electrons which would be ejected later.
- ❖ An uncharged metal plate acquires +ve charge after photoelectrons are ejected.



e^- (1) : Electron-1 at far-interior
e^- (2) : Electron-1 at exterior (or) nearer to surface
(3) : incident photon beam
(may be monochromatic (or) polychromatic beam)
(4) : photoelectric material



$e^-(5)$; $e^-(6)$; $e^-(7)$: are scattered electrons after being ejected from surface.

Range of e^- scatterred $0 \le KE \le KE_{max}$

❖ **A positively charged plate** acquires more positive charge after the ejection of photo- electrons.

❖ **Ejected photoelectrons from photoelectric material**

- ✔ May or may not emerge perpendicular to the surface,
- ✔ May emerge/get scattered in random directions.
- ✔ Different photoelectrons may have different speeds
- ✔ Will get influenced under the influence of electric field as per the equation $\vec{F} = q\vec{E}$ (particle behavior). The path of the electron in electric field may be linear or non-linear.

✔ Will get influenced under the influence of magnetic field as per the equation $\vec{F} = q(\vec{V} \times \vec{B})$ (particle behavior). The path of the electron can be circular, spiral...... Can collide with a H-atom in ground state or higher excited states and exchange momentum and thus excite and electron of H-atom and cause spectral series (particle nature) ✔ Can collide with a H-atom in ground state of higher excited states and exchange momentum and thus excite and electron of H-atom and cause spectral series (particle nature)	✔ Can collide with a H-atom in ground state or higher excited states and exchange momentum and thus excitre an electron of H-atom and cause spectal series (particle nature) ✔ Can act as a coherent source in YDSE experiment (wave nature) ✔ Can undergo diffraction effects (Wave nature)

Photoelectric effect & effect on material, surrounding space

Neutral PEE material: Acquires + ve charge after ejection of photo-electrons. Initially, there will be no electric field in the surrounding space of the material. Hence, no electric potential difference. Now, charge acquired on it is q = y(e) Where 'y' is the number of photoelectrons ejected and 'e' is the charge of the electron. $e = 1.6\times10^{-19}$ coulomb Geometry of PEE material Metal Plate : $q_{initial} = 0$ (neutral) $q_{final} = y(e)$ (at any instant) $E = \frac{\sigma}{\varepsilon_0}$ (after ejection) Where σ is the surface change density of the material $\sigma_{plate} = \frac{q}{area}$; Note: Potential is not defined for a metal plate, but potential difference is defined **Electrostatics applications.**	**Conducting Sphere:** $q_{initial} = 0$ $q_{final} = y(e)$ (at any istant) $E_{external} = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r^2}\right);\{r \geq R\}$ $V_{external} = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r}\right);\{r \geq R\}$ If the electric field produced in the surrounding space is too high, there may be a situation where PEE may stop completely. This positive potential itself may act as the stopping potential or regarding potential. $V_{stopping} = \frac{E_{photon} - \phi}{e}$

PEE PHENOMENA

PEE Equation	
Incident Photon on PEE material Energy(E) Wavelength (λ) Frequency (ν) $E=\frac{hc}{\lambda}=h\upsilon$	Units used in PEE **Energy** Ev (electron volt) 1 Ev = 1.6 x 10^{-19} J (joule) **Wavelegth: °A(angstrom)** 1 °A = 10^{-10} metre **Frequency : hertz** **Potential : volt** $\lambda=\left\{\frac{12420}{\text{energy(eV)}}\right\}$ in °A
Work Function (φ) Or Threshold energy $\varphi=\frac{hc}{\lambda_o}=h\upsilon_o$	**Photo-electric current - i** The electric current generated in the external circuit of PEE set-up due to photoelectrons. i = y(e) Where 'y' is number of e^- Incident on the detector
Kinetic energy of electron (KE)	Saturation Photoelectric current (i_s) $i_s=y_{max}(e)$
Maximum Kinetic energy of ELECTRON (KE_{MAX})	Threshold Energy (φ) or Work Function
Stopping Potential or Retarding Potential (V_s)	**Monochromatic beam** of photons (single wavelength)
Threshold Wavelength (λ_0)	**Bi-chromatic beam** of photons (two wavelengths)
Threshold Frequency (ν_0)	**Poly-chromatic beam** of photons (two or more wavelength)

How do you identify a poly-chromatic beam?

- By the mentioned wavelengths $\lambda_1,\lambda_2,\lambda_3,\lambda_4$,.... By equation of EM waves & principle of superposition
  $E=E_1Sin(\omega_1t)+E_2Sin(\omega_2t)+....$
  Here, $\omega=2\pi\nu=\frac{2\pi}{\lambda}$;
  $$\Rightarrow \nu_1=\frac{\omega_1}{2\pi} \text{ \& } \nu_2=\frac{\omega_2}{2\pi};\ \lambda_1=\frac{2\pi}{\omega_1} \text{ \& } \lambda_2=\frac{2\pi}{\omega_2}$$
- If $E=2E_0Sin(\omega_At)Sin(\omega_Bt)$ then
  $$\Rightarrow \nu_1=\frac{\omega_A+\omega_B}{2\pi} \text{ \& } \nu_2=\frac{\omega_A-\omega_B}{2\pi}$$

REQUIREMENTS OF PEE

INCIDENT PHOTON(s)

❖ **Monochromatic beam** should have energy greater than or equal to work function, otherwise photo-electric effect will not take place

$E_{incident-photon}\geq\phi$ PEE takes place

$E_{incident-photon}\leq\phi$

PEE does not takes place

❖ **Bi-chromatic beam**

(two wavelengths λ_1 and λ_2)

Photons should have energy greater than or equal to work function, otherwise photoelectric effect will not take place

First wavelength λ_1

$E_1\geq\phi$ (wavelength λ_1)

PEE takes place

$E_1\leq\phi$ (wavelength λ_1)

PEE does not takes place

Second wavelength λ_2

$E_2\geq\phi$ (wavelength λ_2)

PEE takes place

$E_2\leq\phi$ (wavelength λ_2)

PEE does not takes place

Note 1 : PEE may take place due to both λ_1 and λ_2

Note 2 : PEE may not take place due to both λ_1 and λ_2

Note 3 : PEE may take place due to $\lambda_1$only

Note 4 : PEE may take place due to $\lambda_2$only

❖ **Poly-chromatic beam (multiple wavelengths two/ more)**

$E_i^{th}\geq\phi$ (wavelength λ_i)

PEE takes place

$E_i^{th}\leq\phi$ (wavelength λ_i)

PEE does not takes place

Note : Incident photons are preferably from UV region of electromagnetic spectrum

PEE MATERIAL

It is preferably an ALKALI metal.

Photo electric effect (PEE)

Various forms of equation for photons striking an electron inside the material and nearer to the surface

$E = E_{incident-photon} = \phi + KE_{max}$
$h\upsilon = h\upsilon_o + KE_{max}$
$\frac{hc}{\lambda} = \frac{hc}{\lambda_o} + KE_{max}$ Where $\upsilon = \frac{c}{\lambda}$; $\upsilon_o = \frac{c}{\lambda_o}$
$KE_{max} = h(\upsilon - \upsilon_o) = hc\left\{\frac{1}{\lambda} - \frac{1}{\lambda_o}\right\}$
Also $KE_{max} = eV_S = \frac{1}{2}mv^2$ $(vel)_{max} = \sqrt{\frac{2\{h(\upsilon - \upsilon_o)\}}{m}}$ **Range of KE** $0 \le KE \le KE_{max}$

Regulators:

Note 1: For a given material at a given temperature φ is a constant.

Note 2: As frequency of incident radiation increases **or** wavelength of incident radiation decreases KE of ejected electron increases.

Vice-versa

As frequency of incident radiation decreases **or** wavelength of incident radiation increases KE of ejected electron decreases.

Notations :

"i" be the photo electric current

x_o : number of photons emitted from source .

x : number of photons striking the source .

y : number of electrons ejected from the PEE material after the incidence of photons

efficiency or conversion (η)

Note : (η = 1)

Photons: (η_o)

Released from source and arriving at PEE material

$\eta_o = \frac{x}{x_o} (\le 1)$

Photoelectrons in PEE (η)

$\eta = \frac{y}{x} (\le 1)$

Result:

$y = (\eta x) = (\eta\eta_o x)$

Note 1: η_0 depends on geometry of arrangement and other factors

Note 2: η depends factors within the photoelectric material

Intensity of photons released from source

I : intensity of the given source of light received at a given point.

P / P_{source} : Power of photons released from the source

E : energy of each photon released from the source

If the given source of photons is a point source and "d" is the distance of the point source from the PEE material, we apply **INVERSE SQUARE LAW** to find intensity at a point

$I = \frac{P_{source}}{4\pi d^2} \Rightarrow I = \frac{x(\text{Eeach photon})}{4\pi d^2}$

$\Rightarrow I = \frac{x(h\nu)}{4\pi d^2}$

$\Rightarrow I \alpha \frac{1}{d^2}$; $I \alpha x$; $I \alpha \nu$

$\Rightarrow \frac{I_1}{I_2} = \left(\frac{x_1}{x_2}\right)\left(\frac{\nu_1}{\nu_2}\right)\left(\frac{d_2^2}{d_1^2}\right)$

Power received by the PEE material :

$P_{received} = (I_{received})(area)$

Also

$P_{received} = \eta(E_{each\ photon})$

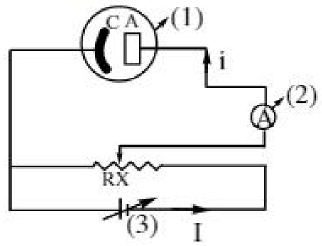
Lenard's Experiment & Observations (Anode at +ve potential w.r.t. cathode)

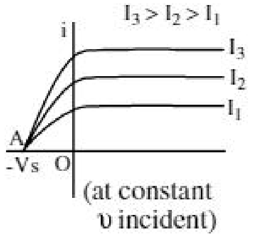
($V_{Anode} > V_{cathode}$) W-E theorem can be applied between cathode and anode,

$\{KE_{Anode} > KE_{Cathode}\}$

$W_{CA} = +ve = KE_{Anode} - KE_{Cathode}$

$KE_{Cathode} = h\upsilon - h\upsilon_o$ (from PEE)





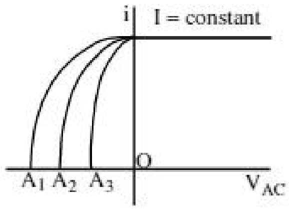
i - photoelectic current

I - intensity of incident beam

V_{AC}- Potential difference between anode and cathode (may be + ve, -ve or zero)

OA = -Vs(stopping potential)

for I_2, I_2, I_3; same at given υ invident



$OA_1 = -Vs_1$

$OA_2 = -Vs_2$

$OA_3 = -Vs_3$

* Different stopping potentials.

Laws of Photo electric emission & Graphs:

i) The maximum velocity and maximum kinetic energy of photoelectrons linearly increases with frequency of the incident radiation, but independent of the intensity of incident radiation.

ii) For a given frequency of incident radiation, the photo electric current is proportional to the intensity of incident radiation.

iii) For a given metal there exists a certain minium frequency of incident radiation called threshold frequency below which there is no photo electric emission.

iv) The photoelectric effect is an instantaneous phenomenon. The time lag between incidence of radiation and emission of photoelectrons is very small.

v) The graph between stopping potential (Vs) and incident frequency (υ) is a straight line with slope $\frac{h}{e}$ the intercept on x axis gives υ_0 and the intercept on the negative Y axis gives $\frac{w}{e}$

vi) The graph between $K.E_{max}$ and incident frequency (υ) is a straight line with slope h, the intercept on the negative Y-axis gives W.

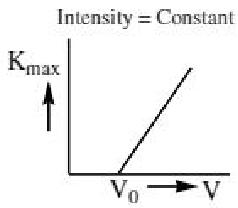
$OB_1 = \upsilon_{01}$; $OC_1 = -\phi_1$; $OB_2 = \upsilon_{02}$; $OC_2 = -\phi_2$; $OB_3 = \upsilon_{03}$; $OC_3 = -\phi_3$

υ_0 - threshold frequency

ϕ - work function of photo electric material.

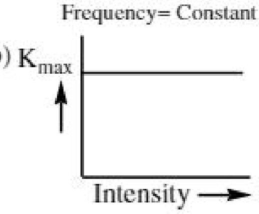
Intensity = Constant

(ia)



Frequency= Constant

(ib)



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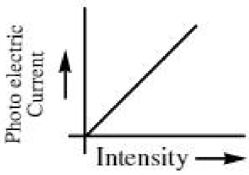

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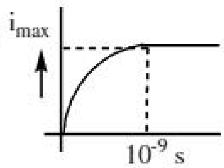

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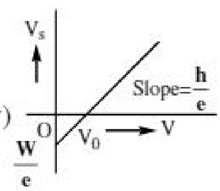
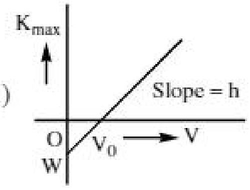


(vi)



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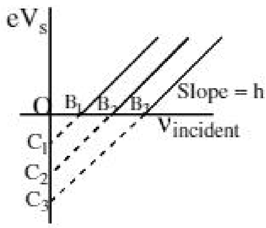


III. X-RAYS

Roentgen discovered the X-rays.

i) Most commonly x-rays are produced by the deceleration of high energy electrons bombarding a hard metal target.

ii) The target should have (a) high atomic weight, (b) high melting point, (c) high thermal conductivity

iii) They are electromagnetic waves of very short wavelength. i.e., order of wavelength 0.1A° to 100A°, order of frequency 10^{16}Hz to 10^{19} Hz, order of energy 124eV to 124keV

iv) Most of the kinetic energy of electrons is converted into heat and only a fraction is used in producing x-rays (less than 1% x-rays and more than 99% heat).

v) Intensity of x-rays depends on the number of electrons striking the target which in turn depends on filament current.

vi) Quality of x-rays (hard /soft) depends on P.D applied to x-rays tube.

vii) High frequency x-rays are called hard x-rays

viii) Low frequency x-rays are called soft x-rays

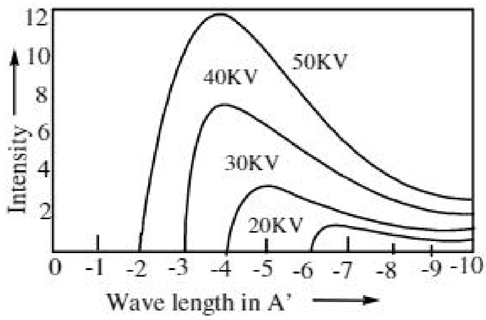
ix) Penetrating power of x-rays is a function of potential difference between cathode and target.

x) Interatomic distance in crystals is of the order of the wavelength of x-rays hence crystals diffract x-rays.

xi) Production of x-rays is converse of photoelectric effect.

X-RAY SPECTRUM:

i) Continuous X-ray spectrum:



a) It is produced when high speed electrons are suddenly stopped by a metal target.

b) It contains all wave lengths above a minimum wavelength λ_m. ($\therefore$ continuous spectrum) For a given accelerating potential, λ_m is called cut off wave length.

c) Properties of continuous x-rays spectra are independent of nature of target metal and they depend only on accelerating potential.

d) $\boxed{\lambda_{min} = \dfrac{hc}{eV} = \dfrac{12400}{V} A^0}$ $\therefore \lambda_{min} \alpha \dfrac{1}{V}$ it is Duane and Hunt's law

e) Maximum frequency of emitted x - ray photon is $\boxed{\nu_{max} = \dfrac{ev}{h}}$

f) In this spectrum intensity first increases, reaches a maximum value I_{max} and then decreases.

g) Every spectrum starts with certain minimum wave length called limiting wave length or cut off wave length λ_{min}.

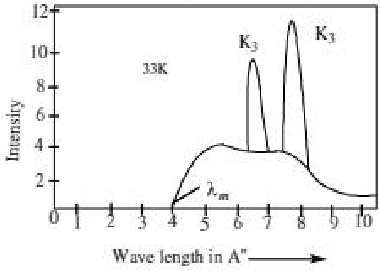
h) With the increase in target potential, λ_{min} and wavelength corresponding to maximum intensity λ_0 shifts towards minimum wavelength side.

i) At a given potential the range of wave length of continues x-rays produced is λ_{min} to ∞.

j) Efficiency of x-ray tube $\eta = \dfrac{\text{out put power}}{\text{input power}} x 100$

input power P = VI. Where V is P.D applied to x-ray tube I = anode current

ii) Characteristic X-ray spectrum:

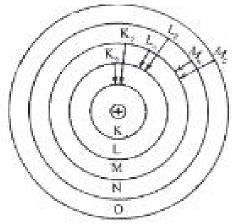


a) Produced due to transition of electrons from higher energy level to lower energy level in target atoms

b) Wavelengths of these x-rays depend only on atomic number of the target element and independent of target potential.

c) Characteristic x-rays of an element consists of K, L, M and N series.

d) K-series of lines are obtained when transition takes place from higher levels to k shell



e) This spectrum is useful in identifying the elements by which they are produced.

f) Relation among the energies $E_{k\alpha} < E_{k\beta} < E_{k\gamma}$, $E_{k\alpha} > E_{L\alpha}$

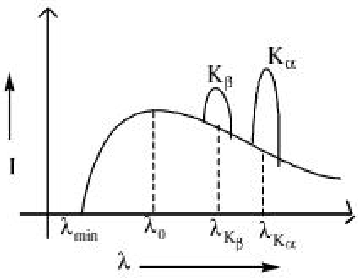
g) Intensity of x - rays $I_{k\alpha} > I_{k\beta} > I_{k\gamma}$

h) Relation among frequencies $\nu_{k\alpha}, \nu_{k\beta}$ and $\nu_{L\alpha}$ is $\nu_{k\beta} = \nu_{k\alpha} + \nu_{L\alpha} \Rightarrow \frac{1}{\lambda_{K\beta}} = \frac{1}{\lambda_{K\alpha}} + \frac{1}{\lambda_{L\alpha}}$

i) $E_K - E_L = h\nu_{K\alpha} = \frac{hc}{\lambda_{K\alpha}}$; $E_K - E_M = h\nu_{K\beta} = \frac{he}{\lambda_{K\beta}}$; $E_L - E_M = h\nu_{L\alpha} = \frac{he}{\lambda_{K\alpha}}$

iii) Intensity and wavelength $(I-\lambda)$ graph

As target potential V is increased



a) $(\lambda_0 - \lambda_{min})$ decreases

b) Wavelength of k_α remains constant.

c) difference between λ_{k_α} and λ_{min} increases

d) difference between λ_{k_α} line and λ_{k_β} line remains constant.

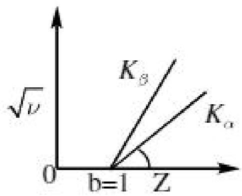
e) difference between $\lambda_{k\alpha} - \lambda_0$ increases.

MOSELEY'S LAW

i) The square root of frequency (ϑ) of the spectral line of the characteristic x-rays spectrum is directly proportional to the atomic number (z) of the target element. $\sqrt{\nu} \propto Z$ or $\sqrt{\nu} = a(Z-b)$

ii) The slope (a) of $\sqrt{\nu}$ -Z curve varies from series to series and also from line to line of a given series.

For K series $\sqrt{\frac{\nu_1}{\nu_2}} = \left(\frac{Z_1-1}{Z_2-1}\right) \Rightarrow \sqrt{\frac{\lambda_2}{\lambda_1}} = \left(\frac{Z_1-1}{Z_2-1}\right)$



iii) $a_{k\gamma} > a_{k\beta} > a_{k\alpha}$

iv) The intercept on 'Z' axis gives the screening constant 'b' and it is constant for all spectral lines in given series but varies with the series.

b = 1 for k series $(k_\alpha / k_\beta / k_\gamma)$; b = 7.4 for L series

v) The wavelength of characteristic X-rays is given by $\frac{1}{\lambda}$ $R(Z-b)^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

vi) Ratio of k_α and k_β lines from a given target is $\frac{\lambda_{k\alpha}}{\lambda_{k\beta}} = \frac{32}{27}$

vii) **Significance :**

a) The elements must be arranged in the periodic table as per their atomic numbers but not on their atomic weights.

b) Helped to discover new elements like masurium (43) and illinium (61) etc.

c) Decided the positions and atomic numbers of rare earth metals.

LECTURE SHEET

EXERCISE-I

(Bohr's Model of an atom)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. The radius of second stationary orbit in Bohr's atom is R. The radius of the third orbit in the same atom will be

1) 3R 2) 9R 3) $\frac{5}{4}R$ 4) $\frac{9}{4}R$

2. In a Bohr atom the electron is replaced by a particle of mass 150 times the mass of the electron and the same charge. If a_0 is the radius of the first Bohr orbit of the orbital atom, then that of the new atom will be

1) 150 a_0 2) $\sqrt{150}a_0$ 3) $\frac{a_0}{\sqrt{150}}$ 4) $\frac{a_0}{150}$

3. The ratio between total acceleration of the electron in singly ionized Helium atom and doubly ionized Lithium atom (both in ground state) is

1) 2/3 2) 4/9 3) 8/27 4) 1

4. The circumference of first orbit of hydrogen atom is 's'. Then the Broglie wavelength of electron in that orbit is

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

5. If an electron revolves around a proton, then its time period T is : (R = radius of orbit)

1) $\propto R^2$ 2) $\propto R^{3/2}$ 3) $\propto R^3$ 4) $\propto R$

6. Magnetic moment due to the motion of the electron in the n^{th} energy state of hydrogen atom is proportional to:

1) n 2) n^0 3) n^5 4) n^3

7. The ratio of the areas within the electron orbits for the first excited state to the ground state for the hydrogen atom is:

1) 2:1 2) 4:1 3) 8:1 4) 16:1

8. E_n and J_n denote the total energy magnitude and the angular momentum of an electron in the nth allowed orbit of a Both atom. Then:

1) $E_n \propto J_n$ 2) $E_n \propto \frac{1}{J_n}$ 3) $E_n \propto J_n^2$ 4) $E_n \propto \frac{1}{J_n^2}$

9. By introducing the concept of reduced mass $[\mu = mM/(M+m)]$ Bohr's theory of hydrogen atom can be further improved for:

1) introduction of non-circular orbits

2) explanation of fine structure of the spectrum a little better

3) better quantum conditions 4) none of the above

10. When the hydrogen atom emits a photon in going from n = 5 to n = 1 state, its recoil speed is nearly:

1) 10^{-4} m/s 2) 2×10^{-2} m/s 3) 4 m/s 4) 8×10^{2} m/s

11. Energy required to remove one electron from neutral helium atom is E_1eV. Energy required to remove both electrons form a neutral helium atom is

1) $2E_1$ 2) $3E_1$ 3) $(E_1+54.4)$ eV 4) $(E_1+13.6)$ eV

12. An electron in a hydrogen atom makes a transition from $n = n_1$ to $n = n_2$. The time period of the electron in the initial state is eight times that in the final state. The possible values of n_1 and n_2 are:

1) $n_1 = 4$ to $n_2 = 2$ 2) $n_1 = 8$ to $n_2 = 2$ 3) $n_1 = 8$ to $n_2 = 1$ 4) $n_1 = 6$ to $n_2 = 4$

13. When the electron in hydrogen atom jumps from the second orbit to the first orbit, the wavelength of the radiation emitted is λ. When the electron jumps from the third to the first orbit, the wavelength of the radiation emitted is:

1) $\frac{9}{4}\lambda$ 2) $\frac{4}{9}\lambda$ 3) $\frac{27}{32}\lambda$ 4) $\frac{32}{27}\lambda$

14. An electron in a hydrogen atom makes a transition $n_1 \to n_2$, where n_1 and n_2 are principal quantum numbers of the states. Assume the Bohr's model to be valid. The time period of the electron in the initial states is eight times to that of final state. What is ratio of $\frac{n_1}{n_2}$

1) 8 : 1 2) 4 : 1 3) 2 : 1 4) 1 : 2

15. In a sample of hydrogen like atoms all which are in the ground state, a photon beam containing of photons of various energies is passed. In absorption spectrum five dark lines are observed. The number of bright lines in the emission spectrum will be.. (assume all transitions take place)

1) 5 2) 10 3) 15 4) 12

16. Let ϑ_1 be the frequency of the series limit of the Lyman series and ϑ_2 be the frequency of the first line of the Lyman series and ϑ_3 be the frequency of the series limit of Balmar series, then

1) $\vartheta_1 - \vartheta_2 = \vartheta_3$ 2) $\vartheta_2 - \vartheta_1 = \vartheta_3$ 3) $2\vartheta_3 = \vartheta_1 + \vartheta_2$ 4) $\vartheta_1 + \vartheta_2 = \vartheta_3$

17. A hydrogen atom is in excited state of principle quantum number n. If it emits a photon of wavelength λ when it returns to the ground state, the value of n is

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

18. In a certain electronic transition from the quantum level, 'n' to the ground state in atomic hydrogen in one or more steps, no line belonging to the Bracket series is observed. The wave numbers which may be observed in the Balmer series are [R = Rydberg constant]

1) $\frac{8R}{9}, \frac{5R}{36}$ 2) $\frac{3R}{16}, \frac{8R}{9}$ 3) $\frac{5R}{36}, \frac{3R}{16}$ 4) $\frac{3R}{4}, \frac{3R}{16}$

Numerical Value Type Questions

19. If the ionisation potential of hydrogen atom is 13.6 eV, the energy required to remove the electron from the third orbit of hydrogen atom is nearly in eV.

20. Monochromatic radiation of wavelength λ is incident on a hydrogen sample containing in ground state. Hydrogen atoms absorb the light and subsequently emit radiations of ten different wavelengths. The value of λ in nm.

21. An H atom in ground state is moving with initial kinetic energy K. It collides head on with a He^+ ion in ground state kept at rest but free to move. Find minimum value of K so that both the particles can excite to their first excited state in eV.

22. Electrons are emitted from an electron gun at almost zero velocity and are accelerated by an electric field E through a distance of 1.0 m. The electrons are now scattered by an atomic hydrogen sample in ground state. What should be the minimum value of E so that light of wavelength 656.3 nm may be emitted by the hydrogen in V/m?

LEVEL-II (ADVANCED)

Straight Objective Type Questions

1. A beam of light having wavelengths distributed uniformly between 450 nm to 550 nm passes through a sample of hydrogen gas. Which wavelength will have the least intensity in the transmitted beam?

a) 487 nm b) 383 nm c) 720 nm d) 183 nm

2. Suppose in an imaginary world the angular momentum is quantized to be even integral multiples of $\frac{h}{2\pi}$. The longest wavelength emitted by hydrogen atoms in visible range in such a world according to Bohr's model is:

a) 487 nm b) 450 nm c) 653 nm d) 350 nm

3. The Earth revolves round the sun due to gravitational attraction. Suppose that the sun and the earth are point particles with their existing masses and that Bohr's quantization rule for angular momentum is valid in the case of gravitation. Calculate the minimum radius the earth can have for its orbit. (take $M_E = 6 \times 10^{24}$ kg and $M_S = 2 \times 10^{30}$ kg)

a) 1.66×10^{138} m b) 6.2×10^{-129} m c) 2.3×10^{-138} m d) 9.2×10^{-131} m

4. Consider a neutron and an electron bound to each other due to gravitational force. Assuming Bohr's quantization rule for angular momentum to be valid in this case, expression for the total energy of the neutron-electron system is

a) $\frac{-4\pi^2G^2m_n^2m_e^{\ 3}}{2h^2n^2}$ b) $\frac{-3\pi^2G^2m_n^2m_e^{\ 3}}{2h^2n^2}$ c) $\frac{-\pi^2G^2m_n^2m_e^{\ 3}}{2h^2n^2}$ d) $\frac{-5\pi^2G^2m_n^2m_e^{\ 3}}{2h^2n^2}$

5. A small particle of mass m moves in such a way that the potential energy is $U = \frac{1}{2}m^2\omega^2r^2$, where ω 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, Radius of the n^{th} allowed orbit is proportional to

a) n b) $\sqrt{n}$ c) $n^{1/3}$ d) n^2

6. The average kinetic energy of molecules in a gas at temperature T is 1.5 kT. Find the temperature at which the average kinetic energy of the molecules of hydrogen equals the binding energy of its atoms. Take $k = 8.62 \times 10^{-5}$eV/K

a) 3×10^{-6} K b) 1.77×10^{-6} K c) 1.05×10^5 K d) 1.9×10^5 K

7. Suppose the electron in a hydrogen atom makes a transition from n = 3 to n = 2 state in 10^{-8} sec. The order of the torque acting on the electron in this period, using the relation between torque are angular momentum as discussed in rotational mechanics is:

a) 10^{-34} N-m b) 10^{-27} N-m c) 10^{-42} N-m d) 10^{-8} N-m

8. Balmer gives an equation for the wavelength of visible radiation of H-spectrum as $\lambda = \frac{Kn^2}{n^2-4}$. The value of k in terms of Rydberg's constant, R, is:

a) R b) 4 R c) $\frac{R}{4}$ d) $\frac{4}{R}$

9. If doubly ionised lithium atom is hydrogen-like with atomic number 3, the wavelength of radiation required to excite the electron 3, the wavelength of radiation required to excite the electron in Li^{++} from the first to the third Bohr orbit and the number of different spectral lines observed in the emission spectrum of the above excited system are:

a) $296\overset{o}{A},6$ b) $114\overset{o}{A},3$ c) $1026\overset{o}{A},6$ d) $8208\overset{o}{A},3$

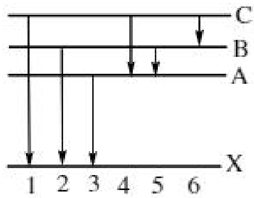
10. Energy level A,B,C of a certain atom correspond to increasing values of energy i.e., $E_A < E_B < E_c$. If $\lambda_1, \lambda_2, \lambda_3$ are the wavelengths of radiation corresponding to the transitions C to B,B to A and C to A respectively, which of the following relations is correct?

a) $\lambda_3 = \lambda_1 + \lambda_2$ b) $\lambda_3 = \frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}$ c) $\lambda_1 + \lambda_2 + \lambda_3 = 0$ d) $\lambda_2^3 + \lambda_1^2 + \lambda_2^2$

11. Find the maximum wavelength λ_0 of light which can ionize a hydrogen atom in its ground state. Light of wavelength λ_0 is incident on a hydrogen atom which is in its first excited state. Also, find the kinetic energy of the electron coming out

a) 96.5 nm, 13.4 eV b) 85.3 nm, 13.6 eV c) 56.5 nm, 10.2 eV d) 91.3 nm, 10.2 eV

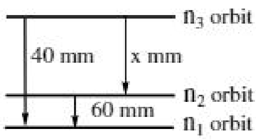
12. The figure indicates the energy level diagram of an atom and the origin of six spectral lines in emission (e.g., line number 5 arises from the transition from level B to A) which of the spectral lines will also occur in the absorption spectra?



a) 1, 2, 3 b) 1, 4, 6

c) 4, 5, 6 d) 1, 2, 3, 4, 5, 6

13. For an atom of ion having single electron, the following wavelengths are observed. What is the value of missing wavelength, x?



a) 20 mm b) 40 mm c) 60 mm d) 120 mm

More than One correct answer Type Questions

14. Suppose the potential energy between electron and proton at a distance r is given by $-\frac{Ke^2}{3r^3}$. Application of Bohr's theory to hydrogen atom in this case shows that

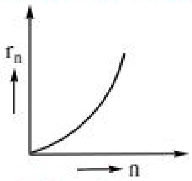
a) energy in the n^{th} orbit is proportional to n^6

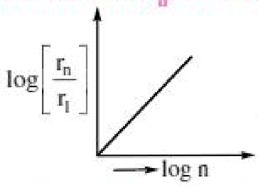
b) energy is proportional to m^{-3} (m = mass of electron)

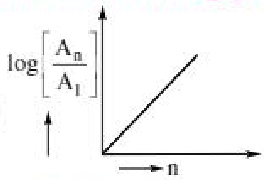
c) energy of the n^{th} orbit is proportional to n^{-2}

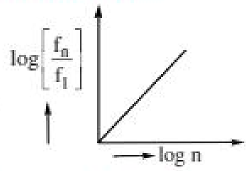
d) energy is proportional to m^3 (m = mass of electron)

15. If, in a hydrogen atom radius of nth Bohr orbit is r_n, frequency of revolution of electron in nth orbit is f_n and area enclosed by nth orbit is A_n, then which of the following graphs are correct?

a) 

b) 

c) 

d) 

16. A single electron orbits around a stationary nucleus. If 47.2 eV is required to excite the electron from the second orbit to third orbit. (Assume the model is, Bohr's atomic model) Then, mark the correct options.

a) Number of protons in the nucleus is five

b) Total energy of electron is in ground state 340 eV

c) Kinetic energy of electron in ground state is 340 eV

d) Potential energy of electron in ground state is –680 eV

17. An ionised H-molecule consists of an electron and two protons. The protons are separated by a small distance of the order of angstrom. In the ground state:

a) the electron would not move in circular orbits

b) the energy would be $(2)^4$ times that of a H-atom

c) the electron's orbit would go around the protons

d) the molecule will soon decay into a proton and H-atom

18. Let $E_n = -(me^4/8\epsilon_0^2\ n^2\ h^2)$ be the energy of the nth level of H-atom. If all the H-atoms are in the ground state and radiation of frequency $(E_2 - E_1)/h$ falls on it:

a) it will not be absorbed at all

b) some of atoms will move to the first excited state

c) all atoms will be excited to the n = 2 state

d) no atoms will make a transition to the n = 3 state

Linked Comprehension Type Questions

Passage :

An electron is orbiting in a circular orbit of radius r under the influence of a constant magnetic field B. Assume that Bohr's postulate regarding the quantization of angular momentum holds good for this electron. (h = Planck's constant, e = charge of electron and m = mass of electron)

19. Radius of n^{th} orbit of the electron will be :

a) $\sqrt{\dfrac{2nh}{\pi Be}}$ b) $\sqrt{\dfrac{nh}{2\pi Be}}$ c) $\sqrt{\dfrac{neh}{2\pi Be}}$ d) $\sqrt{\dfrac{2neh}{\pi Be}}$

20. Kinetic energy of the electron in n^{th} orbit will be:

a) $\dfrac{nhBe}{4\pi m}$ b) $\dfrac{nhBe}{2\pi m}$ c) $\dfrac{nhB}{2\pi em}$ d) $\dfrac{nhB}{2\pi em}$

21. The potential energy of interaction between the magnetic moment of the orbital current due to the electron moving in its n^{th} orbit and the magnetic field is :

a) $\frac{nhB}{2\pi em}$ b) $-\frac{nhBe}{2\pi m}$ c) $-\frac{nhB}{2\pi me}$ d) $-\frac{nhBe}{4\pi m}$

Matrix Matching Type Questions

22. Excitation energy of hydrogen atom is 13.6 eV. Match the following:

Column-I	Column-II
A) Energy of second excited state of hydrogen	p) –3.4eV
B) Energy of fourth state of He^{+}	q) –108.9eV
C) Energy of first excited state of Li^{2+}	r) –1.5eV
D) Energy absorbed when the electron in Li^{2+} makes transition from 3^{rd} to 1^{st} orbit	s) –30.6 eV

23. A monochromatic light incident on a sample of hydrogen gas. Column-I shows the transition of electron by absorbing the photon in different cases. Match the Column-I and Column-II

Column-I	Column-II
A) n = 1 to n = 4	p) some of the emitted photons are having the energy more than the incident photons
B) n = 2 to n = 4	q) some of the emitted photons are having the energy less than the incident photons
C) n = 3 to n = 4	r) six different wavelengths are present in the radiation
D) n = 1 to n = 3	s) three different wavelengths are present in the radiation

Integer Type Questions

24. Radius of H-atom in its ground state is 5.03×10^{-11}m. After collision with an electron it is found to have a radius of 20.12×10^{-11}m. The principal quantum number 'n' of the final state of the atom is___

25. Three photons coming from excited atomic-hydrogen sample are picked up. Their energies are 12.1 eV, 10.2 eV and 1.9 eV. These photons must come from minimum of ____atoms

EXERCISE-II

(Photoelectric effect)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. The work function for a metal is 4 eV. To eject the photo electrons with zero velocity the wavelength of the incident light should be

1) 2700 A° 2) 1700 A° 3) 5900 A° 4) 3100 A°

2. The energies of the incident photons are 3, 4, 5 eV. The work functions of the metals are 0.5, 1.5, 2.5 eV. The maximum K.E.s of the photoelectrons are in the ratio

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

3. In a photoemissive cell, with exciting wavelgnth λ, the maximum kinetic energy of the electron is K. If the exciting wavelength is changed to $\frac{3\lambda}{4}$, the kinetic energy of teh fastest emitted electron will be

1) $\frac{3K}{4}$ 2) $\frac{4K}{3}$ 3) less than $\frac{4K}{3}$ 4) more than $\frac{4K}{3}$

4. If the wavelength of the incident radiation changes from λ_1 to λ_2, then the maximum kinetic energy of the emitted photo electrons changes from K_1 to K_2, then the work function of the emitter surface is

1) $\frac{\lambda_1 K_1 - \lambda_2 K_2}{\lambda_2 - \lambda_1}$ 2) $\frac{\lambda_1 K_2 - \lambda_2 K_1}{\lambda_1 - \lambda_2}$ 3) $\frac{K_2 - K_1}{\lambda_1 K_1 - \lambda_2 K_2}$ 4) $\frac{\lambda_2 - \lambda_1}{\lambda_2 K_1 - \lambda_1 K_2}$

5. A beam of light consists of five wavelengths $4000A^0$, $4800A^0$, $6000A^0$, $7000A^0$ and $7800A^0$. The light beam is falling normally over a metal surface of area 10^{-4} m^2 with a work function of 1.9 eV. Intensity of light beam is 7.5×10^{-3} Wm^{-2}, which is equally divided among the constituent wavelengths. If there is no loss of light energy, number of photoelectrons emitted per second is

1) 1.12×10^{12} 2) 3.15×10^{12} 3) 1.77×10^{12} 4) 4.062×10^{12}

6. $K_1$and K_2 are the maximum kinetic energies of the photo electrons emitted when light of wave lengths λ_1 and λ_2 respectively are incident on a metallic surface. If $\lambda_1 = 3\lambda_2$ then

1) $K_1 > \frac{K_2}{3}$ 2) $K_1 < \frac{K_2}{3}$ 3) $K_1 > 3K_2$ 4) $K_2 = 3K_1$

7. A photon of energy 'E' ejects a photoelectron from a metal surface whose work functions is W_0. If this electron enters into a uniform magnetic field of induction 'B' in a direction perpendicular to the field and describes a circular path of radius 'r', then the radius 'r' is given by, (in the usual notation)

1) $\sqrt{\frac{2m(E-W_0)}{eB}}$ 2) $\sqrt{2m(E-W_0)eB}$ 3) $\frac{\sqrt{2e(E-W_0)}}{mB}$ 4) $\frac{\sqrt{2m(E-W_0)}}{eB}$

8. For a certain metal the threshold frequency is ν_0. If light of frequency $2\nu_0$ is incident on it the electron comes out with a maximum velocity of 4×10^6 m/s. If light of frequency of $5\nu_0$ is incident on it the maximum velocity of the photo electron will be

1) 8×10^6 m/s 2) 16×10^6 m/s 3) 2×10^6 m/s 4) 12×10^6 m/s

9. Light of frequency 1.5 times the threshold frequency is incident on a photosensitive material, photo electric current is emitted. If the frequency of light is halved and intensity is doubled, the photoelectric current becomes

1) 4 times the original current 2) 2 times the original current
3) half the original current 4) zero

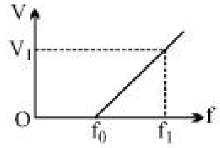
10. A photo cell is illuminated by a small bright source placed 1m away. When the same source of light is placed $\frac{1}{2}$m away. Which of the following is true about the electrons emitted by the photo cathode

1) Each carry one quarter of their previous energy
2) Each carry one quarter of their previous momenta
3) Are half as numerous 4) Four time as numerous

11. A graph is drawn between stopping potential (y-axis) and incident frequency (x-axis). The intercept OA on x-axis gives 0.5×10^{15} Hz. The K.E. of photo electron emitted from the metal when the energy of incident photon is 5eV is.

1) 7 eV 2) 3 eV 3) 1.5 eV 4) 6 eV

12. In a photoelectric experiment, the potential difference V that must be maintained between the illuminated surface and the collector so as just to prevent any electron from reaching the collector is determined for different frequencies f of the incident illumination. The graph obtained is shown. The maximum kinetic energy of the electrons emitted at frequency f_1 is



1) hf_1 2) $\frac{V_1}{(f_1 - f_0)}$ 3) $h(f_1 - f_0)$ 4) $eV_1(f_1 - f_0)$

13. Photo electric emission is observed from a metallic surface for frequencies ν_1 and ν_2 of the incident light rays ($\nu_1 > \nu_2$). If the maximum values of kinetic energy of the photo electrons emitted in the two cases are in the ratio of 1:K, then the threshold frequency of the metallic surface is

1) $\frac{\nu_2 - \nu_1}{K-1}$ 2) $\frac{K\nu_1 - \nu_2}{K-1}$ 3) $\frac{K\nu_2 - \nu_1}{K-1}$ 4) $\frac{\nu_2 - \nu_1}{K}$

14. In a photo emissive cell the exciting wavelength λ, the fastest electron has a speed v. If the exciting wavelength is changed to $3\lambda/4$, the speed of the fastest emitted electron will be

1) $v\left(\frac{3}{4}\right)^{\frac{1}{2}}$ 2) $v\left(\frac{4}{3}\right)^{\frac{1}{2}}$ 3) less than $v\left(\frac{4}{3}\right)^{\frac{1}{2}}$ 4) greater than $v\left(\frac{4}{3}\right)^{\frac{1}{2}}$

15. Stopping potentials are V_1 and V_2. The value of $(V_1 - V_2)$, if λ_1 and λ_2 are wavelengths of incident lights respectively is

1) $\frac{hc}{e}\left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right]$ 2) $\frac{hc}{e}\left[\frac{1}{\lambda_1} + \frac{1}{\lambda_2}\right]$ 3) $\frac{e}{hc}\left[\frac{1}{\lambda_1} + \frac{1}{\lambda_2}\right]$ 4) $\frac{e}{hc}\left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right]$

16. Light of wavelength λ strikes a photo emissive surface and electrons are ejected with kinetic energy E. If the kinetic energy is to be increased to 2E, the wavelength must be changed to λ' where

1) $\lambda' = \lambda/2$ 2) $\lambda' = 2\lambda$

3) $\lambda/2 < \lambda' < \lambda$ 4) $\lambda' > \lambda$

Numerical Value Type Questions

17. Light of wavelength 5000°A falls on a sensitive plate with photo electric work function 1.9eV. The kinetic energy of the photo electrons emitted will be in eV.

18. Radiations of two different frequencies whose photon energies are 3.4 eV and 8.2 eV successively illuminate a metal surface whose work function is 1.8eV. The ratio of the maximum speeds of the emitted electrons will be

19. In a photo electric experiment, photon of energy 5 eV are incident on a metal surface. They liberate electrons which are just stopped by an electrode at a potential of -3.5V with respect to the metal. The work function of the metal in eV is

20. A light beam, $E = 100[\sin(\omega_1 t) + \sin(\omega_2 t)]Vm^{-1}$ with $\omega_1 = 5 \times 10^{15} s^{-1}$ and $\omega_2 = 8 \times 10^{15} s^{-1}$, falls on a metal surface of work function 2.0 eV. Maximum KE of emitted photoelectrons in eV.

21. The electric field at a point associated with a light wave is
$E=(100\,V/m)\sin[(3.0\times10^{15}s^{-1})t]\sin[(6.0\times10^{15}s^{-})t]$.

If this light falls on a metal surface having a work function of 2.0 eV, what will be the maximum kinetic energy of the photoelectrons (in eV) ?

22. Silver has a work function of 4.7eV. when ultraviolet light of wavelength 100nm is incident upon it, a potential of 7.7 volts is required to stop the photoelectrons from reaching the collector plate. How much potential will be required to stop the photoelectrons when light of wavelength 200nm is incident upon silver (nearly) in Volts.

LEVEL-II (ADVANCED)

Straight Objective Type Questions

1. The surface of Lithium of work ϕ function is illuminated by electromagnetic radiation whose electric field component varies with time as $E=a(1+\cos\omega t)\cos\omega_0 t$. The maximum kinetic energy of photoelectron liberated from surface is:

a) $\frac{h}{2\pi}\omega-\phi$ b) $\frac{h\omega_0}{2\pi}-\phi$ c) $\frac{h}{2\pi}(\omega+\omega_0)-\phi$ d) $\frac{h}{2\pi}(\omega-\omega_0)-\phi$

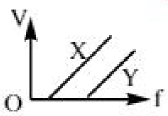
2. A monochromatic light of λ wavelength is incident on an isolated metallic sphere of radius *a*. The threshold wavelength is λ_0 which is larger than λ. Find the number of photoelectrons emitted before the emission of photoelectron will stop.

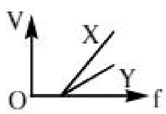
a) $\frac{2\pi\varepsilon_0 ahc}{e^2}\left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)$ b) $\frac{3\pi\varepsilon_0 ahc}{e^2}\left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)$ c) $\frac{4\pi\varepsilon_0 ahc}{e^2}\left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)$ d) $\frac{\pi\varepsilon_0 ahc}{e^2}\left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)$

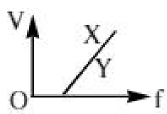
3. A small metal plate (work function φ) is kept at a distance d from a singly ionized, fixed ion. A monochromatic light beam is incident on the metal plate and photoelectrons are emitted. Find the maximum wavelength of the light beam so that some of the photoelectrons may go round the ion along a circle.

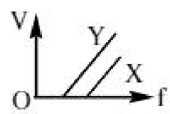
a) $\frac{8\pi\varepsilon_0 dhc}{e^2+8\pi\varepsilon_0\varphi d}$ b) $\frac{\pi\varepsilon_0 dhc}{e^2-8\pi\varepsilon_0\varphi d}$ c) $\frac{2\pi\varepsilon_0 dhc}{e^2+8\pi\varepsilon_0\varphi d}$ d) $\frac{5\pi\varepsilon_0 dhc}{e^2+\pi\varepsilon_0\varphi d}$

4. In a photoelectric experiment, electrons are ejected from metals X and Y by light of intensity I and frequency f. The potential difference V required to stop the electrons is measured for various frequencies. If Y has a greater work function than X ; which one of the following graphs best illustrates the expected results?

a) 

b) 

c) 

d) 

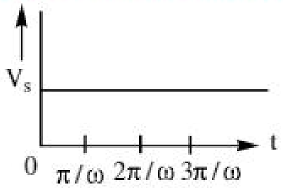
5. In an experiment on photoelectric effect, the stopping potential is measured for monochromatic light beams corresponding to different wavelengths. The data collected are as follows :

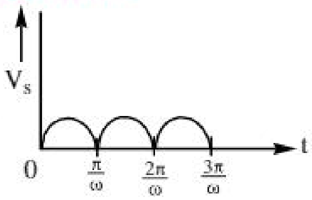
Wavelength (nm):	350	400	450	500	550
Stopping potential (V):	1.45	1.00	0.66	0.38	0.16

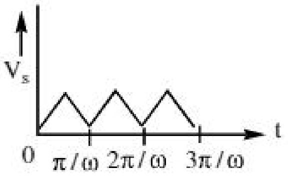
Find the Planck's constant

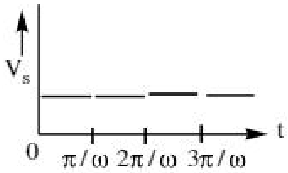
a) 1.5×10^{-15}eV.s b) 4.2×10^{-15}eV.s c) 2.2×10^{-16}eV.s d) 3.5×10^{-15}eV.s

6. A light beam coming from a monochromatic source of variable intensity $I = I_0 |\sin\omega t|$ is incident on a metallic plate of work function w_0. The curve correctly shows minimum potential required to stop the ejection of electron from the surface with respect to time is

a) 

b) 

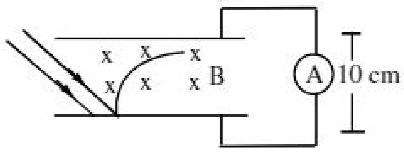
c) 

d) 

7. The stopping potential for the photo electrons emitted from a metal surface of work function 1.7 eV is 10.4 V. Identify the energy levels corresponding to the transitions in hydrogen atom which will result in emission of wavelength equal to that of incident radiation for the above photoelectric effect

a) n = 3 to 1 b) n = 3 to 2 c) n = 2 to 1 d) n = 4 to 1

8. In an experiment on photoelectric effect, the emitter and the collector plates are placed at a separation of 10 cm and are connected through an ammeter without any cell. A magnetic field B exists parallel to the plates. The work function of the emitter is 2.39 eV and the light incident on it has wavelengths between 400 nm and 600 nm. Find the minimum value of B for which the current registered by the ammeter is zero. Neglect any effect of space charge.



a) 4.92×10^{-5}T b) 1.85×10^{-6} T c) 2.85×10^{-5} T d) 0.66×10^{-5} T

9. In photoelectric effect, the number of electrons ejected per second is

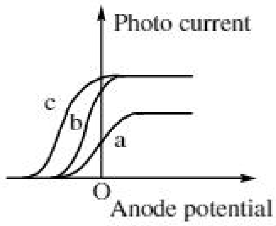
a) proportional to the wavelength, of light

b) proportional to the intensity of light

c) proportional to the work function of the metal

d) proportional to the frequency of light

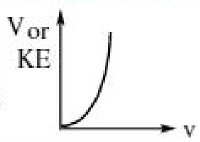
10. The figure shows the variation of photo current with anode potential for a photo-sensitive surface for three different radiations. Let I_a, I_b and I_c be the intensities and f_a, f_b and f_c be the frequencies for the curves a,b and c respectively:

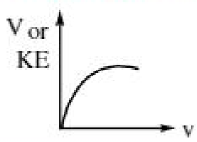


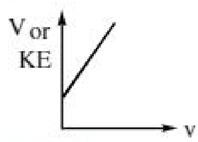
a) $f_a = f_b$ and $I_a \neq I_b$ b) $f_a = f_c$ and $I_a = I_c$

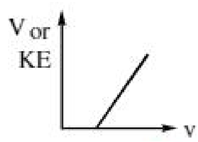
c) $f_a = f_b$ and $I_a = I_b$ d) $f_b = f_c$ and $I_b = I_c$

11. For a photoelectric cell, the graph showing the variation of cut-off voltage or maximum KE of ejected photoelectrons with frequency of incident is

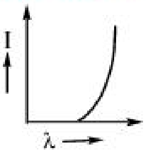
a) 

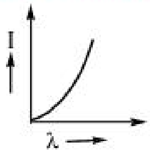
b) 

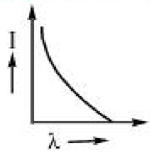
c) 

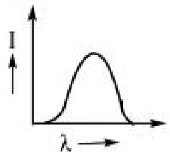
d) 

12. The anode voltage of a photocell is kept fixed. The wavelength λ of the light falling on the cathode is gradually change. The plate current I of the photocell varies as given ahead:

a) 

b) 

c) 

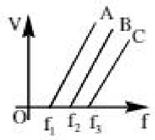
d) 

13. There is no photoelectric current when stopping potential is applied to the photoelectric cell. This implies that:
   a) there is no emission of the photoelectrons
   b) the photoelectrons are emitted but these photoelectrons accumulate near the collector plate
   c) the photoelectrons are emitted but may be reabsorbed by the emitter plate (or) fail to reach anode
   d) the electrons are annihilated

More than One correct answer Type Questions

14. A beam of ultraviolet light of all wavelengths passes through hydrogen gas at room temperature, in the x-direction. Assume that all photons emitted due to electron transition inside the gas emerge in the y-direction. Let A and B denote the lights emerging from the gas in the x and y directions respectively.
   a) Some of the incident wavelengths will be absent in A.
   b) Only those wavelengths will be present in B which are absent in A.
   c) B will contain some visible light.
   d) B will contain some infrared light.

15. A photoelectric experiment is performed by with three metal plates A, B and C for a particular light intensity and frequency f. The figure shows a graph plotted between stopping potential V and the frequency f for the three metals. From graph his friend concludes that



   a) f_1, f_2 and f_3 are the threshold frequencies for the metals A, B and C respectively
   b) Every metal plate has unique value of threshold frequency.
   c) Work functions of A,B and C are ordered as $W_A > W_B > W_C$
   d) Work function of A,B are ordered as $W_A < W_B$

16. In the above question, which of the following statements are true?
   a) For every metal, the stopping potential is proportional to threshold frequency
   b) For every metal, the stopping potential is proportional to the frequency of light
   c) Slope of the graph is constant for every metal surface
   d) Slope of the graph is (h/e) for all metal surfaces.

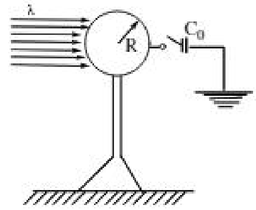
17. If the wavelength of light in an experiment on photoelectric effect is doubled,
   a) the photoelectric emission will not take place
   b) the photoelectric emission may or may not take place
   c) the stopping potential will increase
   d) the stopping potential will decrease

18. When a monochromatic point-source of light is at a distance of 0.2m from photoelectric cell, the cut off voltage and the saturation current are respectively 0.6 volt and 18.0 mA. If the same source is placed 0.6m away from the photoelectric cell, then:
   a) the stopping potential will be 0.2 volt
   b) the stopping potential will be 0.6 volt
   c) the saturation current will be 6.0 mA
   d) the saturation current will be 2.0 mA

Linked Comprehension Type Questions

Passage-I :

An insulated conducting shell is exposed to a radiation of wavelength λ. The threshold wavelength of the conducting shell is $\lambda_0 > \lambda$. Since energy of incident photon is greater than threshold energy, the emission of photoelectrons will occur and due to it sphere gets charged and its potential becomes V_0 and at this moment emission of photoelectrons stops. (e is the magnitude of charge of electron)



19. Value of V_0 is

a) $hc\left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)$ b) $\frac{hc}{e}\left(\frac{1}{\lambda_0}-\frac{1}{\lambda}\right)$ c) $\frac{hc}{e}\left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)$ d) Data insufficient

20. By closing the switch a capacitor is connected to the sphere (as shown in the figure). "Find the charge on the capacitor after a long time", (assume if it was uncharged initially).

a) $C_0\left(\frac{hc}{e}\right)\left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)$ b) $C_0\left(\frac{hc}{e}\right)\left(\frac{1}{\lambda_0}-\frac{1}{\lambda}\right)$

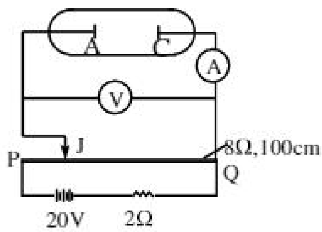
c) $C_0(hc)\left(\frac{1}{\lambda}-\frac{1}{\lambda_0}\right)$ d) Data insufficient

21. When potential of sphere is $V_0/2$, the energy of emitted photo electron will be

a) $\frac{3V_0e}{2}$ b) $\frac{hc}{\lambda}-\frac{V_0e}{2}$ c) $\frac{hc}{\lambda}-\frac{hc}{\lambda_0}-eV_0$ d) $\frac{hc}{2\lambda}-\frac{hc}{2\lambda_0}$

Passage-II :

An experimental setup of verification of photoelectric effect is shown in the diagram. The voltage across the electrodes is measured with the help of an ideal voltmeter, and can be varied by moving jockey J on the potentiometer wire. The battery used in potentiometer circuit is of 20V and its internalresistance is 2Ω. The resistance of 100 cm long potentiometer wire is 8Ω. The photocurrent is measured with the help of an ideal ammeter. Two plates of potassium oxide of area $50cm^2$ at separation 0.5 mm are used in the vacuum tube. Photo current in the circuit is very small so we can treat potentiometer circuit an independent circuit. The wavelength of various colours are as follows :



	1	2	3	4	5	6
Light	Violet	Blue	Green	Yellow	Orange	Red
λ in A°	4000–4500	4500–5000	5000–5500	5500–6000	6000–6500	6500–7000

22. The number of electrons appeared on the surface of the cathode plate, when the jockey is connected at the end P of the potentiometer wire. Assume that no radiation is falling on the plates.

a) 8.85×10^6 b) 11.0625×10^9

c) 8.85×10^9 d) 0

23. When radiation falls on the cathode plate a current of $2\mu A$ is recorded in the ammeter. Assuming that the vacuum tube setup follows ohm's law, the equivalent resistance of vacuum tube operating in this case when jockey is at end P, is

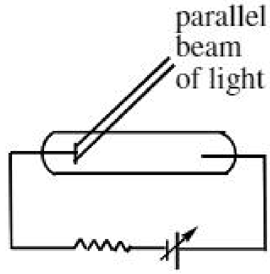
a) $8\times10^{8}\Omega$ b) $16\times10^{6}\Omega$ c) $8\times10^{6}\Omega$ d) $10\times10^{6}\Omega$

24. It is found that ammeter current remains unchanged $(2\mu A)$ even when the jockey is moved from the end P to the middle point of the potentiometer wire. Assuming all the incident photons eject electron and the power of the light incident is 4×10^{-6}W. Then the colour of the incident light is

a) green b) violet c) red d) orange

Matrix Matching Type Questions

25. In the shown experiment setup to study photoelectric effect, two conducting electrodes are enclosed in an evacuated glass-tube a shown. A parallel beam of monochromatic light falls on photosensitive electrodes. The emf of battery shown is high enough such that all photoelectrons ejected from left electrode will reach the right electrode. Under initial conditions photoelectrons are emitted. As change are made in each situation of Column-I; Match the statement in Column-I with results in Column-II.



Column-I	Column-II
A) If frequency of incident light increased keeping number of photons pre-second constant	p) magnitude of stopping potential will increases
B) If frequency of incident light is increased and number of photons per second is decreased	q) current through circuit may stop
C) If work function of photo sensitive electrode increases	r) maximum kinetic energy of ejected is increased photoelectrons will increase
D) If number of photons per second of incident light in increased keeping its frequency constant	s) saturation current will increase
	t) saturation current will decreases

26. One of the most important discoveries in modern physics was that of X-rays. The study of production of X-rays as photons reveals certain phenomenon mentioned in Column-I. These phenomenon are defined in Column-II. Match the correct columns:

Column-I	Column-II
A) Photoelectric effect	p) Emission of photons due to slowing down of accelerated electrons, when they strike the target
B) Inverse photoelectric effect	q) The phenomenon in which when electromagnetic radiations are made incident on a sensitive surface electrons are emitted
C) Inner photoelectric effect	r) Accelerated electron striking the target looses whole of its kinetic energy to the bound electrons which emit photon
D) Bremsstrahlung	s) Sometimes bound electron absorbs energy of incident X-ray photon and gets excited. The excited electron during desiccation transfers its energy to other electron which is emitted

EXERCISE-III

(X-rays)

LEVEL-I (MAIN)

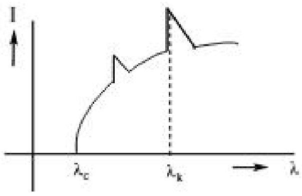
Straight Objective Type Questions

1. The cut-off wavelength when a potential difference of 25 KV is applied to an x-ray tube, is
   1) $0.248\ A^0$ 2) $0.496\ A^0$ 3) $0.124\ A^0$ 4) $4.96\ A^0$

2. In order that the short wavelength limit of the continuous x-ray spectrum be $1\ A^0$, the potential difference through which electron must be accelerated is
   1) 124 KV 2) 1.24 KV 3) 12.4 KV 4) 1240 KV

3. Ratio of K_α and K_β wavelength of X-rays specturm is
   1) same for all target materials
   2) constant for a particular target material
   3) depends on filament current
   4) depends on accelerating voltage of targetting electrons

4. Intensity of X-rays from a Coolidge Tube is plotted against wavelength λ as shown in figure. The minimum wavelength found is λ_c and the wavelength of k_α lines is λ_k. As accelerating voltage is increased



   1) $\lambda_k - \lambda_c$ increases
   2) $\lambda_k - \lambda_c$ decreases
   3) λ_k increases
   4) λ_k decreases

5. Electrons with energy 80 keV are incident on tungsten target of an X-ray tube. K shell electrons of tungsten have 72.5 keV energy. X-ray emitted by tube contain only
   1) Continuous X-ray spectrum (Bremsstrah - lung with a minimum wavelength of $0.155\ \mathring{A}$
   2) In continuous X-ray spectrum (Bremsstrah-lung) with all wavelengths
   3) The characteristic X-ray spectrum of tungsten
   4) A continuous X-ray spectrum (Bremsstrah-lung) with a minimum wavelength $0.155\ \mathring{A}$ and characteristic X-ray spectrum of tungsten

6. $\Delta\lambda$ is the difference between the wave length of K_α line and the minimum wavelength of the continuous x-ray spectrum when the x-rays tube is operated at a voltage. 'V'. If the operating voltage is changed to $\frac{V}{3}$, then the above difference is $\Delta\lambda'$ then
   1) $\Delta\lambda' = 5\Delta\lambda$ 2) $\Delta\lambda' = 4\Delta\lambda$ 3) $\Delta\lambda' = 3\Delta\lambda$ 4) $\Delta\lambda' < 3\Delta\lambda$

7. If λ_{K_α}, λ_{K_β} and λ_{L_α} are the wavelengths of K_α, K_β and L_α lines, then
   1) $\lambda_{K_\beta} = \frac{\lambda_{K_\alpha}\lambda_{L_\alpha}}{\lambda_{K_\alpha} + \lambda_{L_\alpha}}$ 2) $\lambda_{L_\alpha} = \frac{\lambda_{K_\alpha}\lambda_{K_\beta}}{\lambda_{K_\alpha} + \lambda_{K_\beta}}$ 3) $\lambda_{L_\alpha} = \frac{\lambda_{K_\alpha}\lambda_{K_\beta}}{\lambda_{K_\beta} - \lambda_{K_\alpha}}$ 4) $\lambda_{K_\beta} = \frac{\lambda_{K_\alpha}\lambda_{L_\alpha}}{\lambda_{K_\alpha} - \lambda_{L_\alpha}}$

8. A graph of $\sqrt{\nu}$ and Z is plotted. The intercept of the graph on the Z-axis is 1 and the slope of the graph is $0.5\times10^3 (Hz)^{1/2}$. Find the frequency of K_α line for an element of atomic number 41.
   1) 2×10^6Hz 2) 3×10^7 Hz 3) 4×10^8 Hz 4) 5×10^9 Hz

9. An X-ray tube is operating at 150 KV and 10mA. If only 1% of the electric power supplied is converted into x-rays, the rate at which the target is heated in calories per second is

1) 3.55 2) 35.5 3) 355 4) 3550

10. The wavelength for K_β for X-ray of certain material A is 12.42 pm. It takes 10 keV to remove the electron from M shell of A. The minimum accelerating potential that should be applied across X-ray tube with target material A, so that a K_α X-ray would be produced, is

1) 10 kV 2) 100 kV 3) 110 kV 4) 80 kV

11. An X–ray tube operates at 50 kV. Consider that at each collision, an electron converts 50% of its energy into photons and 10% energy would be dissipated as thermal energy due to the collision, then the wavelength of emitted photons during 2nd collision is [Take hc = 1242 eV-nm]

1) 1.242 nm 2) 1.242 $\mathring{A}$ 3) 4.968 nm 4) 4.968 $\mathring{A}$

12. In a Coolidge tube experiment, the minimum wavelength of the continuous X-ray spectrum is equal to 66.3 pm, then

1) electrons accelerate through a potential difference of 12.75 kV in the Coolidge tube

2) electrons accelerate through a potential difference of 18.75 kV in the Coolidge tube

3) de-Broglie wavelength of the electrons reaching the anticathode is of the order of 10mm

4) de-Broglie wavelength of the electrons reaching the anticathode is 0.01 $\mathring{A}$

Numerical Value Type Questions

13. When p.d applied across an X-ray tube reduced by 23kV the minimum wavelength of the continuous X-rays spectrum emitted by this tube is doubled. What was the original value of the minimum wavelength in A^0 ?

14. The x-ray wavelength of L_α line of platinum (Z = 78) is 1.3 A^0. The x-ray wavelength of L_α line of molybdenum (Z = 42) is (constant b = 7.4) in A^0

15. The wavelength of the characteristic x-ray k_α line emitted by a hydrogen like atom is 0.31 A^0. The wavelength of k_β line emitted by the same material in A^0

16. The wavelength of K_α X-ray of tungsten is 21.3 pm. It takes 11.3 keV to knock out an electron from the L shell of a tungsten atom. What should be the minimum accelerating voltage across an X-ray tube having tungsten target which allows production of K_α X-ray in KV ?

LEVEL-II (ADVANCED)

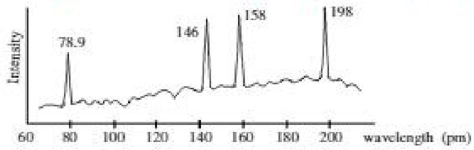
Straight Objective Type Questions

1. An X-ray tube operates at 40 kV. Suppose the electron converts 70% of its energy into a photon at each collision. Find the lowest three wavelength emitted from the tube. Neglect the energy imparted to the atom with which the electron collides.

a) 34.3 pm, 160 pm, 430 pm b) 44.3 pm, 148 pm, 493 pm

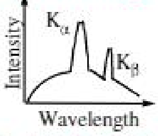
c) 54.3 pm, 180 pm, 420 pm d) 24.3 pm, 120 pm, 392 pm

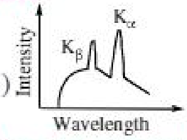
2. Continuous X-rays are made to strike a tissue paper soaked with polluted water. The incoming X-rays excite the atoms of the sample by knocking out the electrons from the inner shells. Characteristic X-rays are subsequently emitted. The emitted X-rays are analysed and the intensity is plotted against the wavelength. Assuming that only K_α intensities are detected, list the elements present in the sample from the plot. Use Moseley's equation $\upsilon = (25\times10^{14}\ Hz)\ (Z-1)^2$

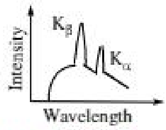


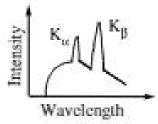
a) Zr, He, Cu, Pb b) Zr, Zn, Cu, Fe c) Pb, Zr, H, Ne d) P, Ca, Mn, Br

3. Choose the correct graph representing the variation of intensity with wavelength of X rays coming from a coolidge's X-ray tube

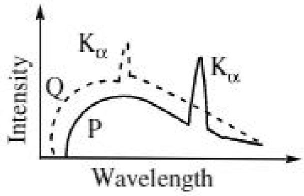
a) 

b) 

c) 

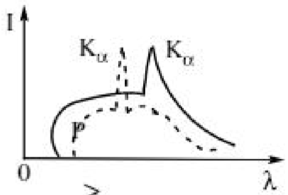
d) 

4. The accelerating potential in a certain coolidge tube P is V_p and atomic number of the target metal is Z_p. The corresponding quantities for another Coolidge tube Q are V_Q and Z_Q respectively. The intensity versus wavelength of the emitted X-rays as shown in Fig. It can be concluded that:



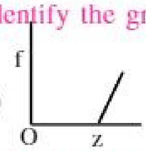
a) $V_Q > V_P; Z_Q > Z_P$ b) $V_Q = V_P; Z_Q < Z_P$
c) $V_Q < V_P; Z_Q > Z_P$ d) $V_Q > V_P; Z_Q = Z_P$

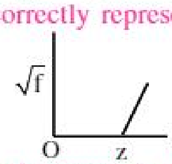
5. The following figure represents the observed in X-rays emitted by two different tubes A and B as of wavelength λ. For tube A, the potential between the filament and target is V_A and atomic target is Z_A. For the tube B, the corresponding difference is V_B and the atomic number is Z_B curve is for the tube A and the dotted curve for B. Then

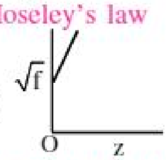


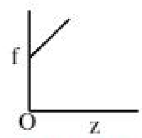
a) $Z_A > Z_B$ b) $Z_A = Z_B$ c) $Z_A < Z_B$ d) $Z_A \gtrless Z_B$

6. Identify the graph which correctly represents the Moseley's law

a) 

b) 

c) 

d) 

7. Which one of the following statements is wrong in the context of X-rays generated from a X-ray tube?
a) Wavelength of characteristic X-rays decreases when the atomic number of the target increases
b) Cut-off wavelength of the continuous X-rays depends on the atomic number of the target
c) Intensity of the characteristic X-rays depends on the electrical power given to the X-rays tube
d) Cut-off wavelength of the continuous X-rays depends on the energy of the electrons in the X-ray tube

8. In an X-ray tube, a potential difference of several thousand volts accelerates electrons which then hits the target and X-rays are emitted. Why are the X-rays emitted?
a) Because of electron transistions in an atom b) Because of removal of an electron from an atom
c) Because electrons get decelerated d) Because of the heat produced in the collision

9. K_α and K_β X-rays are emitted when there is a transition of electron between the levels:
a) n = 2 to n = 1 and n = 3 to n = 1 respectively b) n = 2 to n = 1 and n = 3 to n = 2 respectively
c) n = 3 to n = 2 and n = 4 to n = 2 respectively d) n = 3 to n = 2 and n = 4 to n = 3 respectively

More than One correct answer Type Questions

10. For a given material, the energy and wavelength of characteristic X-rays obey:
    a) $E(K_\alpha) > E(K_\beta) > E(K_\gamma)$
    b) $E(M_\alpha) > E(L_\alpha) > E(K_\alpha)$
    c) $\lambda(K_\alpha) > \lambda(K_\beta) > \lambda(K_\gamma)$
    d) $\lambda(M_\alpha) > \lambda(L_\beta) > \lambda(K_\alpha)$

11. An X-ray tube is operating at 50kV and 20mA. The target material of the tube has a mass of 1.0 kg and specific heat 495 $Jkg^{-1}\ {}^\circ C^{-1}$. One percent of the supplied electric power is converted into X-rays and entire remaining energy goes into heating the target. Then:
    a) the average rate of rise of temperature of the target would be 2°C/sec
    b) the minimum wavelength of the X-rays emitted is about 0.25×10^{-10} m
    c) a suitable target material must have a high melting temperature
    d) a suitable target material must have low thermal conductivity

12. An X-ray tube has three main controls
    a) the target material (its atomic number Z)
    b) the filament current (I_f)
    c) the accelerating voltage
    d) none of the above

13. The shortest wavelength produced in an X-ray tube operated at 0.5 million volt is:
    a) dependent on the target material
    b) 0.025 $\overset{o}{A}$ approximately
    c) half of the shortest wavelength produced by the tube operating at 1 million volts
    d) dependent only on the target material and not on the operating voltage

14. The wavelength of K_α X-rays for lead isotopes Pb^{208}, Pb^{206}, Pb^{204} are λ_1, λ_2 and λ_3 respectively. Then:
    a) $\lambda_1 = \lambda_2 = \lambda_3$
    b) $\lambda_1 > \lambda_2 > \lambda_3$
    c) $\lambda_1 < \lambda_2 < \lambda_3$
    d) $\lambda_2 = \sqrt{\lambda_1\lambda_3}$

15. Let $\lambda_\alpha, \lambda_\beta$ and λ_α' denote the wavelengths of the X-rays of the K_α, K_β and L_α lines in the characteristic X-rays for a metal:
    a) $\lambda_\alpha' > \lambda_\alpha > \lambda_\beta$
    b) $\lambda_\alpha' > \lambda_\beta > \lambda_\alpha$
    c) $\frac{1}{\lambda_\beta} = \frac{1}{\lambda_\alpha} + \frac{1}{\lambda_\alpha'}$
    d) $\frac{1}{\lambda_\alpha} + \frac{1}{\lambda_\beta} + \frac{1}{\lambda_\alpha'}$

16. When an electron moving at a high speed strikes a metal surface, which of the following are possible
    a) The entire energy of the electron may be converted into an X-ray photon
    b) Any fraction of the energy of the electron may be converted into X-ray photon
    c) The entire energy of the electron may get converted to heat
    d) The electron may undergo elastic collision within the metal surface

17. Which of the following statements are correct for an X-ray tube?
    a) On increasing potential difference between filament and target, photon flux of X-rays increases
    b) On increasing potential difference between filament and target, frequency of X-rays increases
    c) On increasing filament current, cut-off wavelength increases
    d) On increasing filament current, intensity of X-rays increases

18. Which of the following statements are true?
    a) The shortest wavelength of X-rays emitted from an X-ray tube depends on the current in the tube
    b) Characteristic X-ray spectra is simple as compared to optical spectra
    c) X-rays cannot be diffracted by means of the ordinary grating
    d) There exists a sharp limit on the short wavelength side for each continuous X-ray spectrum

19. An X-ray tube is operated at 6.6 kV. In the continuous spectrum of the emitted X-rays which of the following frequencies will be missing?

a) 10^{18} Hz b) 1.5×10^{18} Hz c) 2×10^{18}Hz d) 2.5×10^{18}Hz

Linked Comprehension Type Questions

Passage :

A continuous spectrum is produced by Bremsstrahlung, the electromagnetic radiation produced when free electrons are accelerated during collisions with ions. A line spectrum results when an electron having sufficient energy collides with a heavy atom, and an electron in an inner energy level is ejected from the atom. An electron from an outer energy level then fills the vacant inner energy level, resulting in emission of an X-ray photon. For example if an electron in the n = 1 energy level is ejected from an atom, an electron in the n = 2 level of the atom can fill the vacancy created in the n = 1 level, and a photon with an energy equal to the energy difference between the two levels will be emitted. A scientist produced both types of spectra using the X-ray tube shown in the Fig.1. The tube contains a heated filament cathode (C), which emits electrons. A power supply (LV) regulates the filament temperature, the electrical current in the tube, and the number of X-rays produced at the anode (A). Another power supply (HV) regulates electron acceleration. The scientist used an X-ray tube to determine the relationship between X-ray wavelength, λ and X-ray intensity I, which is proportional to the number of X-ray photons emitted at λ. The scientist then graphed the results of the experiment, as shown in Fig. 2.

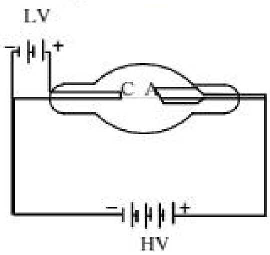


Fig. 1

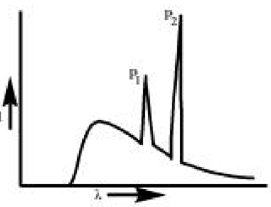


Fig. 2

20. In figure 2 which of the following represents the source of emission peaks P_1 and P_2?

a) Bremsstrahlung

b) Absorption of X-ray photons resulting in electronic excitations in atom

c) Emission of X-ray photons as a result of electronic transitions in atom

d) Acceleration of electrons in a magnetic field

21. Based on the tube in Figure1, to maintain an electron current of 0.005 A and a potential drop of 10^5V between the anode and the cathode, approximately how much power must the tube consume ?

a) 5×10^2 W b) 1×10^3 W c) 2×10^5 W d) 2×10^7 W

22. The ionization potentials for electrons in the n = 1,2 and 3 energy levels of Lead are 1400×10^{-17}J, 240×10^{-17}J and 4.8×10^{-17} respectively. When an electron in the n = 2 level fills a vacancy in the n = 1 level, what is the energy of the X-ray that is emitted ?

a) 1.92×10^{-15} J b) 2.40×10^{-15}J c) 1.16×10^{-14}J d) 1.40×10^{-14}J

23. According to the passage, Bremsstrahlung will not be produced by collisions between electrons and

a) He b) He^{2+} c) Li^{1+} d) protons

KEY SHEET (LECTURE SHEET)

EXERCISE-I

LEVEL-I

1) 4	2) 4	3) 3	4) 3	5) 2	6) 1	7) 4	8) 4
9) 2	10) 3	11) 3	12) 1	13) 3	14) 3	15) 3	16) 1
17) 3	18) 3	19) 1.5	20) 95	21) 63.75	22) 12.1		

LEVEL-II

1) a	2) a	3) c	4) a	5) b	6) c	7) a	8) d
9) b	10) b	11) d	12) a	13) d	14) ab	15) abc	16) acd
17) ac	18) bd	19) b	20) a	21) d	22) A-r; B-p; C-s; D-q		
23) A-qr; B-pqr; C-pr; D-qs				24) 2	25) 2		

EXERCISE-II

LEVEL-I

1) 4	2) 3	3) 4	4) 1	5) 1	6) 2	7) 4	8) 1
9) 4	10) 4	11) 2	12) 3	13) 2	14) 4	15) 1	16) 3
17) 0.58	18) 0.5	19) 1.5	20) 3.27	21) 3.93	22) 1.5		

LEVEL-II

1) c	2) c	3) a	4) a	5) b	6) b	7) a	8) c
9) b	10) a	11) d	12) c	13) c	14) acd	15) abd	16) cd
17) bd	18) bd	19) c	20) a	21) d	22) c	23) c	24) d
25) A-pr; B-prt; C-q; D-s			26) A-p; B-q; C-r; D-s				

EXERCISE-III

LEVEL-I

1) 2	2) 3	3) 2	4) 1	5) 4	6) 4	7) 1	8) 3
9) 3	10) 3	11) 2	12) 2	13) 0.27	14) 5.41	15) 0.18	16) 69.5

LEVEL-II

1) b	2) b	3) b	4) a	5) c	6) c	7) b	8) a
9) a	10) cd	11) ab	12) abc	13) bc	14) ad	15) ac	16) abc
17) bd	18) bcd	19) cd	20) c	21) a	22) c	23) bd	

PRACTICE SHEET

EXERCISE-I

(Bohr's Model of an atom)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. Check the correctness of the following statements about Bohr model of hydrogen atom:
   i) The acceleration of the electron in $n = 2$ orbit is more that in $n = 1$ orbit
   ii) The angular momentum of the electron in $n = 2$ orbit is more than in $n = 1$ orbit
   iii) The KE of the electron in $n = 2$ orbit is less than in $n = 1$ orbit
   1) all the statements are correct
   2) only (i) and (ii) are correct
   3) only (ii) and (iii) are correct
   4) only (iii) and (i) are correct

2. In the Bohr model of the hydrogen atom, let R, υ and E represent radius of the orbit, speed of electron and total energy of the electron respectively. Which of the following quantities is proportional to the quantum number n?

   1) R/E 2) E/υ 3) RE 4) υR

3. The potential energy of the orbital electron in the ground state of hydrogen atom is –E. What is the kinetic energy?

   1) 4E 2) 2E 3) E/2 4) E/4

4. In hydrogen atom, the electron is moving round the nucleus with velocity 2.18×10^6 m/s in an orbit of radius of radius $0.528\,\overset{o}{A}$. The acceleration of the electron is:

   1) 9×10^{18} m/s^2 2) 9×10^{22} m/s^2 3) 9×10^{-22} m/s^2 4) 9×10^{12} m/s^2

5. Using the Bohr's model calculate the speed of the electron in a hydrogen atom in the n = 1, 2 and 3 levels

   1) 4.2×10^4 m/s, 3.2×10^4 m/s and 7.2×10^6 m/s 2) 2×10^9 m/s, 3.2×10^5 m/s and 7×10^5 m/s
   3) 2.19×10^6 m/s, 1.01×10^6 m/s and 7.3×10^5 m/s 4) 2.2×10^6 m/s, 1.9×10^6 m/s and 7.5×10^4 m/s

6. If the electron in H-atom radiates a photon of wavelength $4860\,\overset{o}{A}$, the KE of the electron:

   1) decreases by 2.0×10^{-19} J 2) increases by 4.1×10^{-19} J
   3) decreases by 4.1×10^{-19} J 4) increases by 8.2×10^{-19} J

7. In a hypothetical Bohr hydrogen atom, the mass of the electron is doubled. The energy E_0 and radius r_0 of the first orbit will be: (a_0 is the Bohr radius)

   1) $E_0 = -27.2$ eV; $r_0 = a_0$ 2) $E_0 = -13.6$eV; $r_0 = a_0/2$
   3) $E_0 = -27.2$ eV; $r_0 = a_0/2$ 4) $E_0 = -13.6$eV; $r_0 = a_0$

8. The emission spectrum of hydrogen atoms has two lines from the Balmer series with wavelengths $4102\,\overset{o}{A}$ and $4861\,\overset{o}{A}$. The wave number of another emission line is equal to the difference between the wave numbers of these two lines. Find the λ of this line and series to which it belongs:

   1) Lyman, $78644\,\overset{o}{A}$ 2) Balmer $52400\,\overset{o}{A}$ 3) Paschen, $39300\,\overset{o}{A}$ 4) Brackett, $26253\,\overset{o}{A}$

9. When white light is passed through the hydrogen gas at room temperature, absorption lines will be observed in:

   1) Lyman series 2) Balmer series
   3) both Lyman and Balmer series 4) neither in Lyman series nor in Balmer series

10. In hydrogen spectrum, the shortest wavelength in Balmer series is λ. The shortest wavelength in Brackett series will be:

    1) 2λ 2) 4λ 3) 9λ 4) 16λ

LEVEL-II (ADVANCED)

Straight Objective Type Questions

1. The wavelength involved in the spectrum of deuterium ($_1D^2$) are slightly different from that of hydrogen spectrum, because:

   a) size of the two nuclei are different b) masses of the two nuclei are different
   c) nuclear forces are different in the two cases
   d) attraction between the electrons and the nucleus is different in two cases

2. A photon of energy 10.2 eV collides inelastically with hydrogen atom in ground state. After few microseconds another photon of energy 15 eV collides inelastically with same hydrogen atom. Finally by a suitable detector, we find:
   a) photon of energy 3.4 eV and electron of energy 1.7 eV
   b) photon of energy 10.2 eV and electron of energy 1.4 eV
   c) two photons of energy 3.4 eV
   d) two photons of energy 10.2 eV

3. n = 2 is chosen as reference of electrostatic potential energy in an He^+ ion. Assuming Bohr's model to be valid, choose the incorrect alternative
   a) Ionisation energy for the ion in its ground state is 27.2 eV
   b) Total energy associated with the ion in its first excited state is 13.6 eV
   c) Kinetic energy associated with electron's orbital motion in n = 2, the ion is 27.2 eV
   d) Kinetic energy associated with electron's orbital motion in ground state = 54.4 eV

4. In a hydrogen like atom of atomic no.Z, ionisation energy of an electron in ground state, orbital angular momentum of electron in nth orbit and time period of revolution or electron in nth orbit are I,L and T respectively. Which of these expressions does not depend on orbit of electron and Z?
   a) ILT
   b) $\frac{1}{LT}$
   c) I^2TL
   d) $\frac{IT}{L}$

More than One correct answer Type Questions

5. A beam of ultraviolet light of all wavelengths passes through hydrogen gas at room temperature, in he x-direction. Assume that all photons emitted due to electron transitions inside the gas emerge in the y-direction. Let A and B denote the lights emerging from the gas in the x and y-directions respectively:
   a) some of the incident wavelengths will be absent in A
   b) only those wavelengths will be present in B which are absent in A
   c) B will contain some visible light
   d) B will contain some infrared light

6. The general state and first excited state energies of hydrogen atom are –13.6eV and –3.4 eV respectively. If the potential energy in the ground state is taken to be zero then which of the following is (are) correct
   a) Potential energy in the first excited state would be 20.4 eV
   b) Total energy in the first excited state would be 23.8 eV
   c) Kinetic energy in the first excited state would be 3.4 eV
   d) Total energy in the ground state would be 13.6 eV

7. An electron make s a transition from n = 2 to n = 1 state in a hydrogen like atom
   a) magnetic field at the site of nucleus becomes 1/16 times
   b) magnetic field at the site of nucleus becomes 32 times
   c) frequency of revolution of electron in the final orbit is more that the frequency of photon emitted
   d) frequency of revolution of electron in the initial orbit is less than the frequency of photon emitted

8. If the ground state of hydrogen atom is chooses as zero potential energy level,
   a) then the value of the total energy in the second excited state is 25.69 eV
   b) then the value of the potential energy in the first excited state is 20.4 eV
   c) then the value of the total energy in the first energy state is 13.6eV
   d) then the value of the total energy in the second excited state is 10.2 eV

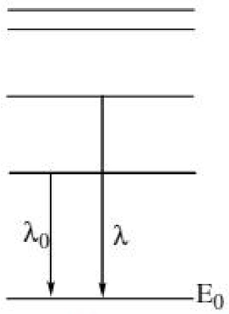
9. When a hydrogen atom is excited from ground state to first excited state then,
   a) its kinetic energy increases by 10.2 ev
   b) its kinetic energy decreases by 10.2 ev
   c) its potential energy increases by 20.4 ev
   d) its angular momentum increases by 1.05×10^{-34} J–S

10. Whenever a hydrogen atom emits a photon in the Balmer series:
   a) it may emit another photon in the Balmer series
   b) it must emit another photon in the Lyman series
   c) the second photon, if emitted, will have a wavelength of about 122 nm
   d) it may emit a second photon, but the wavelength of this photon cannot ve predicted

Linked Comprehension Type Questions

Passage :

Some energy levels are shown for a hypothetical one electron atom.



11. If the lowest energy state has energy E_0, the value of E_0 in terms of λ_0 is :
   a) $\frac{4hc}{3\lambda_0}$ b) $\frac{hc}{3\lambda_0}$ c) $\frac{3hc}{4\lambda_0}$ d) $\frac{hc}{2\lambda_0}$

12. The value of λ is
   a) $\frac{27}{16}\lambda_0$ b) $\frac{9}{16}\lambda_0$ c) $\frac{9}{32}\lambda_0$ d) $\frac{27}{32}\lambda_0$

13. If a radiation which carries an energy equal to ionisation energy of the atom fall on a photocathode of threshold wave length λ_0 the kinetic energy of fastest photoelectron is:
   a) $\frac{3hc}{4\lambda_0}$ b) $\frac{hc}{3\lambda_0}$ c) $\frac{hc}{2\lambda_0}$ d) $\frac{3hc}{2\lambda_0}$

Matrix Matching Type Questions

14. A neutron moving with kinetic energy K collides with a hydrogen atom at rest in ground state. Assume mass of neutron to be equal to that of hydrogen atom. Match the kinetic energy of neutron with possible collisions mentioned in Column-I energy of hydrogen in ground state is –13.6 eV.

Column-I	Column-II
A) K = 10.2eV	p) Elastic collision may take place
B) K = 13.6 eV	q) Inelastic collision may take place
C) K = 20.4eV	r) perfectly inelastic collision may take place
D) K = 22.0eV	s) hydrogen atom may get ionised

15. In Bohr's atomic model for hydrogen like atoms match the following table:

Column-I	Column-II
A) If electron jumps from n=2 to n=1	p) speed of electron will becomes 2times.
B) If electron jumps from n=1 to n=4	q) kinetic energy of electron will become 4times.
C) If electron jumps from n=4 to n=1	r) angular momentum of electron will become 2 times
	s) angular velocity of electron will become 4 times
	t) None

Integer Type Questions

16. Consider a hydrogen atom with its electron in the n^{th} orbital. An electromagnetic radiation of wavelength 90nm is used to ionize the atom. If the kinetic energy of the ejected electron is 10.4eV then the value of n is

17. A neutron is scattered through (=deviation from its old direction) θ degree in an elastic collision with an initially stationary deuteron. If the neutron loses $\frac{2}{3}$ of its initial K.E to the deuteron then find the value of $\frac{\theta^0}{10}$(In atomic mass unit U, the mass of a neutron is 1u and mass of a deuteron is 2u)

18. A stationary He^+ in emits a (K_a) photon corresponding to the first line of the Lyman series. The photon liberates electron from a stationary hydrogen atom in the ground state. The velocity of the liberated electron is 3.1×10^x unit. Find x (You can make necessary approximations).

EXERCISE-II

(Photoelectric effect)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. Photons of wavelength 660 nm are emitted from a 60 watt lamp. What is the number of photons emitted per second ?
   1) 2×10^{16} 2) 2×10^{18} 3) 2×10^{20} 4) 2×10^{22}

2. The threshold wavelength for photo electric emission from a material is 5,200A°, photo electrons will be emitted when this material is illuminated with monochromatic radiation from a
   1) 50 watt infrared lamp 2) 1 watt infrared lamp
   3) 1 watt ultraviolet lamp 4) 50 watt sodium vapour lamp

3. In a photo-electric cell, current stops when a negative potential of 0.5V is given to the collector w.r.t. emitter. The maximum K.E. of emitted electron is
   1) 0.8×10^{-19} joule 2) 0.8×10^{-19} erg 3) 0.5 joule 4) 0.5 erg

4. When radiation of wavelength λ is incident on a metallic surface, the stopping potential is 4.8Volt. If the same surface is illuminated with radiation of double the wavelength, then the stopping potential becomes 1.6V. Then the threshold wave length for the surface is
   1) 2λ 2) 4λ 3) 6λ 4) 8λ

5. The maximum wavelength of a beam of light can be used to produce photo electric effect on a metal is 250 nm. The energy of the electrons in Joule emitted from the surface of the metal when a beam of light of wavelength 200 nm is used [$h = 6.62\times10^{-34}$ Js, $C = 3\times10^8$ ms^{-1}]
   1) 89.61×10^{-22} 2) 69.81×10^{-22} 3) 18.96×10^{-20} 4) 19.86×10^{-20}

6. When light of wavelength $\lambda/2$ falls on a metal plate electrons are liberated with maximum K.E. of E. When light of wave length $\lambda/3$ falls on the same plate the maximum K.E. of the electron is found to be doubled. What is the threshold wave length

1) 2λ 2) 3λ 3) 1.5λ 4) λ

Numerical Value Type Questions

7. The K.E. of photo electron ejected from a metal surface by light of wavelength 2000 A° range from zero to 3.2×10^{-19}J. The stopping potential will be equal to (in volts)

8. The work function of potassium is 2.0 eV. When it is illuminated by light of wavelength 3300A^0 photo electrons are emitted. The stopping potential of photo electrons is (in volts)
[Plank's constant $h = 6.6 \times 10^{-34}$Js, $1eV = 1.6 \times 10^{-19}$J, $C = 3 \times 10^8$ ms^{-1}]

9. The work function of a certain metal is 3.31×10^{-19} J. Then the maximum kinetic energy of photoelectrons emitted by incident radiation of wavelength 5000 A^0 is (given $h = 6.62 \times 10^{-34}$ J-s, $C = 3 \times 10^8$ ms^{-1}, $e = 1.6 \times 10^{-19}$ coul.) in eV.

10. The surface of a metal is illuminated with the light of 400nm. 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) in eV.

LEVEL-II (ADVANCED)

Straight Objective Type Questions

1. Let n_r and n_b be respectively the number of photons emitted by a red bulb and a blue bulb of equal power in a given time.

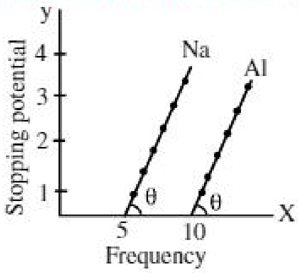
a) $n_r = n_b$ b) $n_r < n_b$ c) $n_r > n_b$ d) data insufficient

2. Mark the incorrect statement:

I) Bound electrons absorb whole energy of incident photon
II) Isolated free electron can't absorb whole energy of photon.
III) Classical mechanics permits massless particle to carry energy and momentum.
IV) Energy (E) and momentum of electrons (p) are related as E = pc where c is speed of light

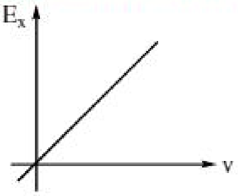
a) II and III b) III and IV c) All d) I and II

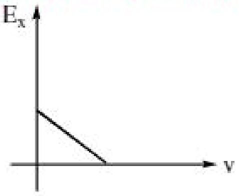
3. From the figure describing photoelectric effect we may infer correctly that:

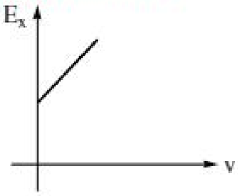


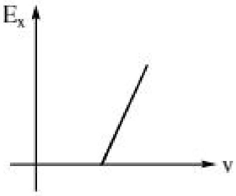
a) Na and Al both have the same thereshold frequency
b) maximum kinetic energy for both the metals depend linearly on frequency
c) the stopping potential are different for Na and Al for the same change in frequency
d) Al is a better photosensitive material than Na

4. Which one of the following graphs represents the variation of maximum kinetic energy (E_K) of the emitted electrons with frequency v in photoelectric effect correctly

a) 

b) 

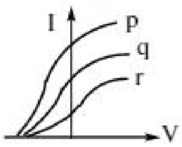
c) 

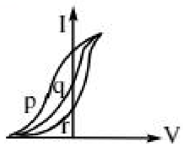
d) 

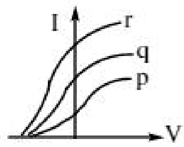
5. A photo-sensitive material would emit electrons, if excited by photons beyond a threshold. To overcome the threshold, one would increase:

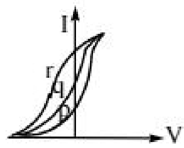
a) the voltage applied to the light source
b) the intensity of light
c) the wavelength of light
d) the frequency of light

6. Photoelectric effect experiments are performed using three different metal plates p,q and r having work function $\phi_p = 2.0\text{eV}$, $\phi_q = 2.5\text{eV}$ and $\phi_r = 3.0\text{eV}$, respectively. A light beam containing wavelength of 550 nm, 450nm and 350 nm with equal intensities illuminates each of the plates. The correct I-V graph for the experiment is [Take hc = 1240 eV nm]

a) 

b) 

c) 

d) 

7. Statement-I: When ultraviolet light is incident on photocell its stopping potential is V_0 and the maximum kinetic energy of the photoelectrons is K_{max}. When the ultraviolet light is replaced by X-rays both V_0 and K_{max} increase.

Statement-II: Photoelectrons are emitted with speeds ranging from zero to a maximum value because of the range of frequencies present in the incident light.

a) S-I is true, S-II is false
b) S-I is false, S-II is true.
c) S-II is true, S-II is true; S-II is the correct explanation of S-I
d) S-I is true, S-II, is true; S-II is not the correct explanation of S-I

8. This question has Statement-I and Statement-II. Of the four choice given after the statements, choose the one that best describes the two statements.

Statement-I: A metallic surface is irradiated by a monochromatic light of frequency $v > v_0$ (the threshold frequency). The maximum kinetic energy and th stopping potential are K_{max} and V_0 respectively. If the frequency incident on the surface is doubled, both the K_{max} and V_0 are also doubled.

Statement-II: The maximum kinetic energy and the stopping potential of photoelectrons emitted from a surface are linearly dependent on the frequency of incident light.

a) S-I is false, S-II is true
b) S-I is true, S-II is false
c) S-I is true, S-II is true, S-II is the correct explanation of S-I
d) S-I is true, S-II is true, S-II is not th correct explanation of S-I

9. Two identical photo cathodes receive lights of frequencies f_1 and f_2. If the velocity of the photoelectrons (of mass m) coming out are respectively υ_1 and υ_2 then:

a) $\upsilon_1^2 - \upsilon_2^2 = \frac{2h}{m}(f_1 - f_2)$
b) $\upsilon_1 + \upsilon_2 = \left[\frac{2h}{m}(f_1 - f_2)\right]^{1/2}$
c) $\upsilon_1^2 + \upsilon_2^2 = \frac{2h}{m}(f_1 - f_2)$
d) $\upsilon_1 - \upsilon_2 = \left[\frac{2h}{m}(f_1 - f_2)\right]^{1/2}$

10. Shining light of wavelength λ and intensity I on a surface S produces photoelectrons at rate R and with maximum kinetic energy E. Consider the following statements for the effect of changing one parameter at a time:

i) doubling I always doubles R

ii) doubling I does not change E at all

iii) making λ half always make E more than 2 fold

The statements true are:

a) (i) and (ii) only b) (ii) and (iii) only c) (i) and (iii) only d) all the three

More than One correct answer Type Questions

11. The frequency and intensity of a light source are both doubled. Which of the following statement (statements) is (are) true?

a) The saturation photocurrent gets doubled

b) The saturation photocurrent remains almost the same

c) The maximum KE of the photoelectrons is more than doubled

d) The maximum KE of the protoelectrons get doubled

12. When a monochromatic point source of light is at a distance of 0.2 m from photoelectric cell, the cut -off voltage and the saturation correct are respectively 0.6V and 18.0 mA. If the same source is placed 0.6 m away from the photoelectric cell, then:

a) the stopping potential will be 0.2V b) the stopping potential will be 0.6 V

c) the saturation current will be 6.0 mA d) the saturation current will be 2.0 mA

13. In a photoelectric experiment, the wavelength of the incident light is decreased from $6000\,\mathring{A}$ to $4000\,\mathring{A}$ while the intensity of radiation remains the same. Choose the correct statement(s).

a) The cut-off potential will increase

b) The cut-off potential will decrease

c) The photoelectric current will increase

d) The kinetic energy of the emitted photoelectrons will increase

14. In Millikan's experiment in photoelectric effect, the stopping potential (V) was measured for light of different wavelengths (λ) which of the following statement(s) is (are) true?

a) The V versus ($1/\lambda$) graph was a straight line

b) For different surfaces, the straight lines came out as parallel

c) The straight line always has a positive intercept on V-axis

d) The slope of the straight line gave (hc/e)

15. Radiations of monochromatic waves of wavelength 400nm are incident on the surfaces of metals Zn, Fe and Ni of work functions 3.4 eV, 4.8 eV and 5.9 eV respectively. (Take hc= 1242 V nm)

a) Maximum KE associated with photoelectrons from the surface of any metal is 0.3 eV

b) No photoelectrons are emitted from the surface of Ni

c) If the wavelength of the source of radiation is doubled, then KE of photoelectrons is also doubled

d) Photoelectrons will be emitted from the surface of all the three metals if the wavelength of the incident radiations is less than 200 nm

Linked Comprehension Type Questions

Passage-I :

A mercury arc lamp provides 0.10W of UV radiation at a wavelength of 253.7 nm, all other wavelengths having been absorbed by filters. This radiation falls of a photoelectric device (a photo-tube) at a distance of 1m. The cathode of photo-tube consists of potassium (work function, $\phi_0 = 2.22\,eV$) and has an effective area of 4cm^2. According to classical theory, the radiation from the arc lamp spreads out uniformly in space as a spherical wave. The radius of the potassium atom is 5%, which implies that each photon has a probability of 0.05 of ejecting an electron from the cathode. (You may take hc = 1242V nm).

16. Time of exposure of radiation required by the potassium atom to eject a photoelectron is
    a) 300s b) 200 s c) 355 s d) 980 s

17. The photoelectric current is
    a) 20 nA b) 10 mA c) 30 μA d) 32.5 nA

18. The cut-off potential is
    a) 3V b) 1.78 V c) 2.67 V d) 4.38 V

Passage-II :

In a photoelectric set-up, a point source of light (of power 3.2×10^{-3}W) emits monoenergetic photons of energy 5.0 eV. The source is located at a distance of 0.8m from the centre of a stationary metallic sphere of work function 3.0 eV and of radius 8.0×10^{-3} m. The efficiency of photoelectric emission by the metallic sphere is one for every 10^6 photons incident on it. Assume that the sphere is isolated and initially neutral and the photo electrons emitted by it are instantly swept away. As a result of it, the sphere gets positively charged and acquires a positive potential and after a certain time the photoelectron emission from it stops. Take the energy reaching the sphere from the source of light per second to be $E = \dfrac{Pr^2}{4R^2}$, where r is the radius of the sphere, R is the distance between the point source and the centre of the sphere and P is the power of the source.

19. The number of electrons emitted per second by the sphere is
    a) 10^4 b) 10^6 c) 10^5 d) 10^2

20. The ratio of the wavelength of incident light to the de Broglie wavelength of the fastest photoelectrons emitted is approximately:
    a) 200 b) 250 c) 280 d) 150

21. Time after which photoelectric emission stops is approximately:
    a) 110s b) 3 min c) 4 min d) 50s

Matrix Matching Type Questions

22. In perfoming photoelectric experiment to study photoelectric effect, intensity of radiation (I), frequency of radiation 9υ), work function (ϕ_0) of the photosensitive emitter, distance (d) between emitter and collector are changed or kept constant. Match the changes give in Column-I to their effects given in Column-II.

Column-I	Column-II
A) ϕ_0 is decreased, keeping υ and I constant	p) Saturation photoelectric current increase
B) d is increased, keeping I, υ, ϕ_0 constant	q) Stopping potential (V_0) increases
C) v is increased, keeping υ, ϕ_0 and d constant	r) Maximum K.E (K_{max}) of photoelectrons increases
D) I is increased keeping υ, ϕ_0 and d constant	s) Stopping potential remains the same

23. Wavelength associated with different particles are given in Column-I. Match these wavelengths with their values given in Column-II.

Column-I	Column-II
A) Wavelength associated with an electron accelerated through a pd of 1 volt	p) 10 nm
B) Wavelength associated with an α – particle accelerated through a pd of 1 volt	q) $0.10\,\overset{o}{A}$
C) Wavelength associated with a proton acceleration through a pd of 1 volt	r) $0.286\,\overset{o}{A}$
D) Wavelength associated with a photon of energy 124.2 eV	s) $12.27\,\overset{o}{A}$

EXERCISE-III

(X-rays)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. The characteristic X-rays radiation is emitted when:
   1) the electrons are accelerated to a fixed energy
   2) the source of electrons emits a monoenergetic beam
   3) the bombarding electrons knock out electrons from the inner shell of the target atoms, and the outer electrons falls into this vacancy
   4) the valence electrons in the target atoms are removed as a result of collision

2. The characteristic of the electrons striking the target in an X-ray tube that determines the intensity of X-rays is:
   1) energy 2) momentum
   3) number incident per second 4) mase

3. The target element in X-ray tube must have a high:
   1) atomic number only 2) mass number only
   3) melting point only 4) both atomic number and melting point

4. The characteristic of the electrons striking the target in a Coolidege tube, that determines the upper limit of frequency of continuous X-rays is
   1) energy 2) momentum
   3) number incident per second 4) mass

5. The characteristic of the target element that determines the frequency of characteristic X-rays is
   1) its mass number 2) its atomic number
   3) its melting point 4) its conductivity

6. Which of the given statements it true for both X-rays and α – particles?
   1) They cause ionisation of air when they pass through it
   2) They can be deflected in electric and magnetic fields
   3) They can be used to detect flaws in metal castings
   4) They travel with speed of light

7. X-rays and gamma rays are both electromagnetic waves. Which of the following statements is true?
   1) In general, X-rays have larger wavelength than that of gamma rays
   2) X-rays have smaller wavelength than that of gamma rays
   3) Gamma rays have shammler frequency than that of X-rays
   4) Wavelength and frequency of X-rays are both larger than those of gamma rays

8. To produce hard X-rays in Coolidge tube, abould increase:
   1) current in filament
   2) potential difference across the filament
   3) potential difference across cathode and anticathode
   4) none of the above

9. When high speed electrons hit a target of high atomic number, the efficiency for the production of X-rays is
   1) 100% 2) 99% 3) 50% 4) even less than 1%

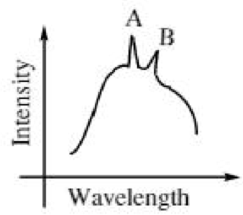
10. Hydrogen atom does not emit X-rays because
   1) it has single electron
   2) it i s very small in size
   3) its energy levels are too far apart
   4) its energy levels too close to each other

LEVEL-II (ADVANCED)

Straight Objective Type Questions

1. To produce characteristic X-rays using a tungsten target in an X-ray generator, the accelerating voltage should be greater then _____ volt. The binding energy of the innermost electron in tungsten is 40 keV:
   a) 2×10^4 b) 3×10^4 c) 4×10^4 d) 6×10^3

2. The given figure represents the observed intensity of X-rays emitted by an X-ray tube as a function of wavelength. The sharp peacks A and B denote:



   a) band spectrum
   b) continuous spectrum
   c) white radiation
   d) characteristic radiation

3. X-rays are produced in an X-ray tube operating at a given accelerating voltage. The wavelength of the continuous X-rays has values from:
   a) 0 to ∞
   b) λ_{min} to ∞ where $\lambda_{min} > 0$
   c) 0 to λ_{max}, where $\lambda_{max} < \infty$
   d) λ_{min} to λ_{max} where $0 < \lambda_{min} < \lambda_{max} < \infty$

4. If V_{K_α}, V_{K_β} and V_{L_α} represent the frequencies of K_α, K_β and L_α X-ray lines of a given material, then:
   a) $V_{K_\beta} = V_{K_\alpha} + V_{L_\alpha}$ b) $V_{K_\beta} = \sqrt{V_{K_\alpha} \times V_{L_\alpha}}$ c) $V_{L_\alpha} = V_{K_\alpha} + V_{K_\beta}$ d) $V_{K_\beta} = V_{K_\alpha} - V_{L_\alpha}$

5. Moseley's law for line X-rays is given by $\sqrt{v} = a(Z-b)$. Here:
   a) a is independent of target material while b is not
   b) b is independent of target material while a is not
   c) both a and b are independent of target material
   d) both a and b are dependent of target material

6. Wavelength of the K_α line for an element of atomic number 43 is λ. Then the wavelength of the K_α line for an element of atomic number 29 is:

a) $\left(\frac{43}{28}\right)\lambda$ b) $\left(\frac{42}{28}\right)\lambda$ c) $\left(\frac{9}{4}\right)\lambda$ d) $\left(\frac{4}{9}\right)\lambda$

7. In an X-ray tube, electrons accelerated through a potential difference of 15,000 volts strike a copper target. The speed of the emitted X-rays inside the tube is:

a) 28×10^8 m/s b) 1.5×10^8 m/s c) 2×10^8 m/s d) 3×10^8 m/s

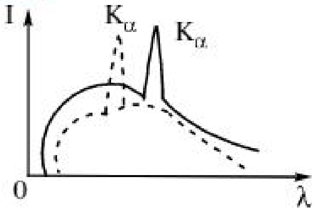
8. Which one of the following statements is incorrect in the context of X-rays generated from an X-ray tube ?

a) Wavelength of characteristic X-rays decreases when the atomic bnumber of the target increases
b) Cut-off wavelength of the continuous X-rays depends on the atomic number of the target
c) Intensity of the characteristic X-rays depends on the electrical power given to the X-ray tube
d) Cur-off wavelength of the continuous X-rays depends on the enegy of the electrons in the X-ray tube

9. Hard X-rays for the study of fractures in bones should have a minimum wavelength of 10^{-11} m. The accelerating voltage for electrons in X-ray machine should be

a) <124.2 kV b) >124.2 kV
c) between 60 kV and 70 kV d) = 100 kV

10. The following figure represents the observed in X-rays emitted by two different tubes A and B as of wavelength λ. For tube A, the potential between the filament and target is V_A and atomic target is Z_A. For the tube B, the corresponding difference is V_B and the atomic number is Z_B curve is for the tube A and the dotted curve for Then



a) $V_A > V_B$ b) $V_A = V_B$ c) $V_A < V_B$ d) $V_A \gtrless V_B$

More than One correct answer Type Questions

11. The potential difference applied to an X-ray tube is increased. As a result, in the emitted radiation:

a) the intensity increases b) the minimum wavelength increases
c) the intensity remains unchanged d) the minimum wavelength decreases

12. Which of the following statements are correct?

a) speed of X-rays is 3×10^8 m/s b) X-rays undergo diffraction
c) X-rays are deflected by electric and magnetic fields
d) X-rays undergo refraction in passing from one medium to other

13. Which of the following statements are correct?

a) Speed of X-rays is 3×10^8 m/s b) X-rays undergo diffraction
c) X-rays are deflected by electric and magnetic fields
d) X-rays undergo refraction inpassing from one medium to other

14. X-ray in cident on a material

a) exerts a force on it
b) transfers energy on it
c) transfers momentum to it
d) transfers impulse to it

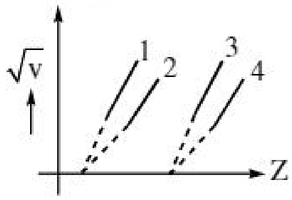
15. For harder X-rays:

a) the wavelength is higher
b) the intensity is higher
c) the frequency is higher
d) the photon energy is higher

Matrix Matching Type Questions

16. $\sqrt{v}$ versus Z graph for characteristic X-rays is as shown in the following figure. Match the entries of Column-I with the entries of Column-II.

Column-I	Column-II
A) Line -1	p) L_α
B) Line - 2	q) L_β
C) Line - 3	r) K_α
D) Line - 4	s) K_β



KEY SHEET (PRACTICE SHEET)

EXERCISE-I

LEVEL-I
1) **3** 2) **4** 3) **3** 4) **2** 5) **3** 6) **3** 7) **3** 8) **4** 9) **4** 10) **2**

LEVEL-II
1) **b** 2) **b** 3) **c** 4) **d** 5) **acd** 6) **abcd** 7) **bcd** 8) **abc** 9) **bcd** 10) **bc** 11) **a** 12) **b** 13) **b** 14) **A-p, B-p, C-pr or pqr, D-pq** 15) **A-pq; B-t; C-t** 16) **2** 17) **9** 18) **6**

EXERCISE-II

LEVEL-I
1) **3** 2) **3** 3) **1** 4) **2** 5) **4** 6) **4** 7) **2** 8) **1.75** 9) **0.41** 10) **1.41**

LEVEL-II
1) **c** 2) **b** 3) **b** 4) **d** 5) **d** 6) **a** 7) **a** 8) **a** 9) **a** 10) **d** 11) **ac** 12) **bd** 13) **ad** 14) **abd** 15) **bd** 16) **c** 17) **d** 18) **c** 19) **c** 20) **c** 21) **a** 22) **A-qr; B-s; C-qr; D-ps** 23) **A-s; B-q; C-r; D-p**

EXERCISE-III

LEVEL-I
1) **3** 2) **3** 3) **4** 4) **1** 5) **2** 6) **1** 7) **1** 8) **3** 9) **4** 10) **4**

LEVEL-II
1) **c** 2) **d** 3) **b** 4) **a** 5) **c** 6) **c** 7) **d** 8) **b** 9) **b** 10) **a** 11) **cd** 12) **abd** 13) **bc** 14) **abcd** 15) **cd** 16) **A-s; B-r; C-q; D-p**

ADDITIONAL PRACTICE EXERCISE

LEVEL-I (MAIN)

Straight Objective Type Questions

1. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. It will emit:
   1) 2 lines in the Lyman series and 1 line in the Balmer series
   2) 3 lines in the Lyman series
   3) 1 line in the Lyman series and 2 lines in the Balmer series
   4) 3 lines in the Balmer series

2. If the surface of a metal is successfully exposed to radiation of $\lambda_1 = 350$mm and $\lambda_2 = 450$nm, the maximum velocity of photoelectrons will differ by a factor of 2. The work function of this metal is
   1) 2.84×10^{-19} J 2) 1.6×10^{-19}J 3) 3.9×10^{-10}J 4) 2.4×10^{-10}J

3. Ultraviolet light of wavelength 300 nm and intensity 1.0watt/m^2 falls on the surface of a photosensitive material. If one percent of the incident photons produce photoelectrons, then the number of photoelectrons emitted form an area of 1.0cm^2 of the surface is nearly
   1) 9.61×10^{14} per sec 2) 4.12×10^{13} per sec 3) 1.51×10^{12} per sec 4) 213×10^{11} sec

4. According to Einstein's photoelectric equation, the plot of the kinetic energy of the emitted photoelectrons from a metal versus frequency of the incident radiation gives a straight line whose slope:
   1) depends on the nature of metal used 2) depends on the intensity of metal used
   3) depends on both the intensity of radiation and the nature of metal used
   4) is the same for all metals and independent of the intensity of radiation

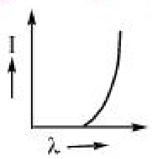
5. Two identical photocathodes receive light of frequencies v_1 and v_2. If the velocities of the photoelectrons (of mass m) coming out are υ_1 and υ_2 respectively, then

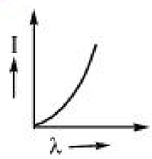
   1) $\upsilon_1 - \upsilon_2 = \left[\frac{2h}{m}(v_1 - v_2)\right]^{1/2}$ 2) $\upsilon_1^2 - \upsilon_2^2 = \frac{2h}{m}(v_1 - v_2)$

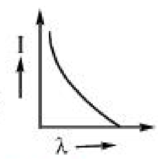
   3) $\upsilon_1 - \upsilon_2 = \left[\frac{2h}{m}(v_1 - v_2)\right]^{\frac{1}{2}}$ 4) $\upsilon_1^2 - \upsilon_2^2 = \frac{2h}{m}(v_1 - v_2)$

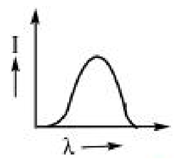
6. One milliwatt of light of wavelength 4560 $\overset{o}{A}$ is incident on a caesium surface of work function 1.9eV. Given that quantum efficiency of photoelectric emission is 0.5%, Plank's constant, $h = 6.62 \times 10^{-34}$ J sec, velocity of light, $c = 3 \times 10^8$ m/s, photoelectric current liberated is
   1) 1.856×10^{-6} amp 2) 1856×10^{7} amp 3) 1.856×10^{-5} amp 4) 1.856×10^{-1} amp

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. When a monochromatic point source of light is at a distance 0.2m from a photoelectric cell, the saturation current and cut-off voltage are 12.0 mA and 0.5V. If the same source is placed 0.4m away from the photoelectric cell, then the saturation current and the stopping potential respectively are
   1) 4 mA and 1V 2) 12mA and 1V 3) 3 mA and 1V 4) 3 mA and 0.5V

9. The voltage applied to an X-ray tube is 18kV. The maximum mass of photon emitted by the X-rays tube will be:
   1) 2×10^{-13} kg 2) 3.2×10^{-36} kg 3) 3.2×10^{-32}kg 4) 9.1×10^{-31}kg

10. A target element 'A' is bombarded with electrons and wave lengths of characteristic x-ray spectrum is also obtained because of impurity in the target. The wave lengths of K_α lines are 196pm (element A) and 169pm (for impurity). The atomic number of impurity is ________ (given atomic number of A is 27)
   1) 34 2) 31 3) 29 4) 46

11. A graph of $\sqrt{v}$ and Z is plotted. The intercept of the graph on the z-axis is 1 and the slope of the graph is $0.6\times10^3(\text{Hz})^{\frac{1}{2}}$. Find the wavelength of k_α line for an element of atomic number 51.
   1) 1/2 m 2) 1/3 m 3) 1/4 m 4) 1.5 m

Numerical Value Type Questions

12. A neutron moving with a speed 'υ' makes a head on collision with a stationary hydrogen atom in ground state. The minimum kinetic energy of the neutron for which inelastic collision will take place i eV.

13. Electrons in a hydrogen - like atom (Z=3) make transitions from 4^{th} excited state. The resulting radiations are incident on a metal plate to eject photoelectrons. The stopping potential for photoelectrons ejected by the shorter wavelength is 3.95 V. The stopping potential for the photoelectrons ejected by the longer wavelength, in volts.

14. The shortest K-line of tungsten is 0.015nm. The energy difference between the K and L level of the atom is closest to (in keV).

15. Given that a photon of light of wavelength 10000 angstrom has an energy equal to 1.23 eV. When light of wavelength 5000 angstrom and intensity I_0 falls on a photoelectric cell, the saturation current is 0.40×10^{-6} ampere and the stopping potential is 1.36 volt, then the work function in eV.

LEVEL-II

LECTURE SHEET (ADVANCED)

Straight Objective Type Questions

1. There are a number of hydrogen like atoms in free space. Initially all the atoms are stationary and in a particular excited level 'A'. They undergo transitions from the initial level 'A' to the ground state. The recoiling atom enters a region consisting of uniform magnetic field. If the radii of paths of recoiling atoms is observed to have only three different values then

   A – magnetic moment of atoms in initial state A is $\dfrac{5eh}{4\pi m}$

   B – Angular momentum of electrons in the initial state of emitting atoms is $\dfrac{3h}{2\pi}$

   C – Angular momentuma of electrons in the initial state of emitting atoms is $\dfrac{5h}{2\pi}$

   D – The principal quantum number of the level A is given by n = 3

   a) ABCD are true b) BD are only true c) CD are only true d) A is only true

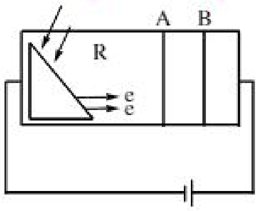
2. In hypothetical positronium atom (attraction between positron and electron binds them) if sum of magnitude linear momenta of atomic particle is quantized in the integral steps of $\frac{b_0 h}{2\pi}$ where 'b_0' is a positive constant, the energy of atom in the ground state is

a) $\frac{-b_0^2 h^2}{16\pi^2 m}$ b) $\frac{-b_0^2 h^2}{2\pi^2 m}$ c) $\frac{-b_0^2 h^2}{8\pi^2 m}$ d) $\frac{-b_0^2 h^2}{9\pi^2 m}$

3. Energy liberated in the de-excitation of hydrogen atoms from 3rd level to 1st level falls on a photo-cathode. Later when the same cathode is exposed to a spectrum of some unknown hydrogen like gas, excited to 2nd energy level it is found that the de-Broglie wave length of the fastest photo electrons now ejected has decreased by a factor of '3'. For this new gas, difference of energies of 2nd Lyman line and 1st Balmer line is found to be 3 time the ionization potential of hydrogen atom. Then

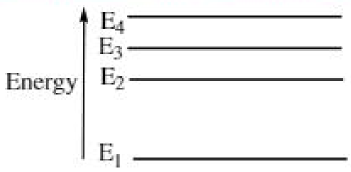
a) The gas is Helium b) Work function of photo cathode is 8.5 eV
c) Both a and b are true d) Both a and b are wrong

4. In a photoelectric experiment, under the condition of saturation current, if we consider different cross sections as shown, then ($i = neAV_d$, where V_d is average drift speed of photo-electrons)



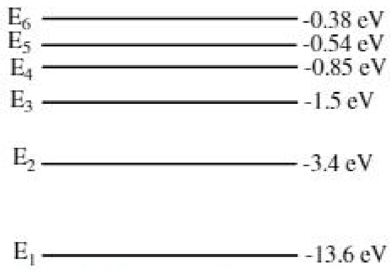
a) $i_A > i_B$ b) $V_{dA} = V_{dB}$ c) $i_A < i_B$ d) $V_{dA} < V_{dB}$

5. Figure represent in simplified form some of the lower energy levels of the hydrogen atom. If the transition of an electron from E_4 to E_2 were associated with the emission of blue light which one of the following transitions could be associated with the emission of red light?



a) E_4 to E_1 b) E_3 to E_1 c) E_3 to E_2 d) E_1 to E_3

6. In fig. E_1 to E_2 represent some of the energy levels of an electron in the hydrogen atom



Which one of the following transitions produces a photon of wavelength in the ultraviolet region of the electromagnetic spectrum $[1\text{eV} = 1.6 \times 10^{-19}]$

a) $E_2 - E_1$ b) $E_3 - E_2$ c) $E_4 - E_3$ d) $E_6 - E_4$

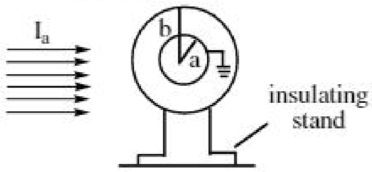
7. The work function of a certain metal is $\frac{hC}{\lambda_0}$. When a monochromatic light of wavelength $\lambda < \lambda_0$ is incident such that the plate gains a total power P. If the efficiency of photoelectric emission is $\eta\%$ and all the emitted photoelectrons are captured by a hollow conducting sphere of radius R. Already charged to potential V, then neglecting any interaction between plate and the sphere, expression potential of the sphere at time t is

a) $V+\frac{100_{\eta}\lambda P_{et}}{4\pi\varepsilon_0 RhC}$ b) $V-\frac{\eta\lambda P_{et}}{400\pi\varepsilon_0 RhC}$ c) $V-\frac{100_{\eta}\lambda P_{et}}{4\pi\varepsilon_0 RhC}$ d) $\frac{\lambda P_{et}}{400\pi\varepsilon_0 RhC}$

8. If light of wavelength of maximum intensity emitted from a surface of hot body at temperature T_1 is used to cause photoelectric emission from a metallic surface, then maximum kinetic energy of the emitted photo electron is 6eV, which is 3 times the work function of the metallic surface. If the light of wavelength of maximum intensity emitted from a surface of same body at temperature T_2 $(T_2 = 2T_1)$ is used, the maximum kinetic energy of photoelectrons emitted is

a) 2eV b) 4eV c) 14eV d) 18eV

9. A parallel beam of light of mono chromatic radiation of cross-section area 'A' $(<\pi b^2)$, intensity I and frequency 'ϑ' is incident on a solid perfectly absorbing conducting sphere of work function ϕ_0 $(h\vartheta > \phi_0)$ and radius 'b'. The inner sphere of radius 'a' is ground by a conducting wire. Assume that for each incident photon one photo electron is ejected. Current through the conducting wire just after the radiation incidents is



a) $\frac{IAe}{h\vartheta}\frac{b}{a}$ b) $\frac{IAe}{2h\vartheta}$ c) $\frac{2IAe}{h\vartheta}$ d) $\frac{IAe}{h\vartheta}\frac{a}{b}$

10. The frequency and the intensity of a beam of light falling on the surface of a photoelectric material are increased by a factor of two. This will:

a) increase the maximum kinetic energy of the photoelectrons, as well ad photoelectric current by a factor of two

b) increase the maximum kinetic energy of the photoelectrons and would increase the photoelectric current by a factor of two

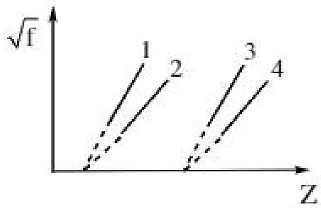
c) increase the maximum kinetic energy of the photoelectrons by a factor of two and will have no effect on the magnitude of the photoelectric current produced

d) not produce any effect on the kinetic energy of the emitted electrons but will increase the photoelectric current by a factor of two

11. When photons of wavelength λ_1 are incident on an isolated sphere, the corresponding stopping, potential is found to be V. When photons of wavelength λ_2 are used, the corresponding stopping potential was thrice that of the above value. If light of wavelength λ_3 is used then find the stopping potential for this case is

a) $\frac{hc}{e}\left[\frac{1}{\lambda_3}+\frac{1}{2\lambda_2}-\frac{1}{2\lambda_1}\right]$ b) $\frac{hc}{e}\left[\frac{1}{\lambda_3}+\frac{1}{2\lambda_2}-\frac{1}{\lambda_1}\right]$ c) $\frac{hc}{e}\left[\frac{1}{\lambda_3}-\frac{1}{\lambda_2}-\frac{1}{\lambda_1}\right]$ d) $\frac{hc}{e}\left[\frac{1}{\lambda_3}+\frac{1}{\lambda_2}-\frac{1}{\lambda_1}\right]$

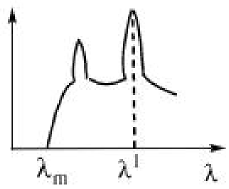
12. The given graph shows the variation of $\sqrt{f}$ vs Z for characteristic X-rays. Lines 1,2,3,4 shown in the graph corresponds to any one of $K_\alpha, K_\beta, L_\alpha, L_\beta$. Then L_β is represented by



a) line 1 b) line 2

c) line 3 d) line 4

13. The following diagram describes the intensity of x-ray photons versus their wavelength coming out of the tube, when the potential difference across the tube is 'V' and atomic number of target element is 'Z'. If V is changed to V_1 and Z to Z_1, choose the incorrect statement



a) for $V_1 > V$ and $Z = Z_1$, λ_m decreases and λ^1 remains same

b) for $V_1 > V$ and $Z_1 = Z$, λ_m and λ^1 both will decrease

c) for $V_1 = V$ and $Z_1 > Z$, λ_m will remain same and λ^1 will decrease

d) for $V_1 > V$ and $Z_1 > Z$, λ_m and λ^1 both with decrease

More than One correct answer Type Questions

14. In the Bohr's model of hydrogen – like atom the force between the nucleus and the electron is modified as $F = \frac{e^2}{4\pi \epsilon_0}\left(\frac{1}{r^2}+\frac{\beta}{r^3}\right)$. Where β is a constant. For this atom, the radius of the n^{th} orbit in terms of the Bohr radius $\left(a_0 = \frac{\epsilon_0 h^2}{m\pi e^2}\right)$ is :

a) $r_n = a_0 n - \beta$ b) $r_n = a_0 n^2 + \beta$ c) $r_n = a_0 n^2 - \beta$ d) $r_n = a_0 n + \beta$

15. When a point source of light of power W emitting monochromatic light of wavelength λ is kept at a distance "a" from a photosensitive surface of work function ϕ and area S, we will have

a) number of photons striking the surface per unit time as $W\lambda S / 4\pi hca^2$

b) the maximum energy of the emitted photoelectrons as $\frac{1}{2}(hc - \lambda\phi)$

c) the stopping potential needed to stop the most energetic emitted photoelectrons as $\frac{e}{\lambda}(hc - \lambda\phi)$

d) photo-emission only if λ lies in the range $0 \le \lambda \le (hc/\phi)$

16. Radiations of monochromatic waves of wavelength 400 nm are made incident on the surface of metals Zn, Fe and Ni of work functions 3.4eV, 4.8eV and 5.9eV respectively (take $h = 6.63\times10^{-34}$ J-s)

a) maximum KE associated with photoelectrons from the surface of any metal is 0.3 eV

b) no photoelectrons are emitted from the surface of Ni

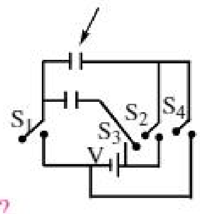
c) if the wavelength of source of radiation is doubled then KE of photoelectrons is also doubled

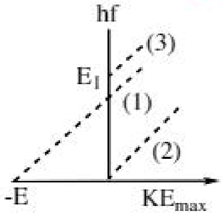
d) photoelectrons will be emitted from the surface of all the three metals if the wavelength of incident radiations is less than 200nm

Linked Comprehension Type Questions

Passage-I :

The circuit shown is placed in vacuum. Both the capacitors are identical and they have the same capacitance C. Light is incident on the left plate of the upper capacitor. When all the switches are open then hf versus KE_{max} is shown by the straight line (1). In all the cases, we are measuring the KE_{max} when the electron reaches the opposite plate. When only S_1 and S_2 are closed, the graph becomes (2). When only S_3 and S_4 are closed then the graph becomes (3)





17. What is the value of eV?

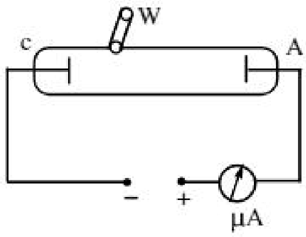
a) E b) E_1 c) $E + E_1$ d) None of these

18. What is the value of E_1?

a) 3E b) $\frac{3E}{2}$ c) $\frac{E}{2}$ d) None of these

Matrix Matching Type Questions

19. As shown in experimental setup to study photoelectric effect, two conducing electrodes are enclosed in a evacuated glass tube as shown. A parallel beam of monochromatic radiation falls on photosensitive electrode. Assume that for each photons incident, a photoelectron is ejected if it's energy is greater than work function of electrode. Match the statement in Column-I with corresponding graphs in Column-II



Column-I

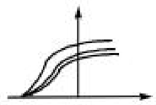
A) Saturation photocurrent versus intensity of radiation is represented by

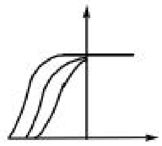
B) Maximum K.E of ejected photoelectrons versus frequency for electrodes of different work function is represented by

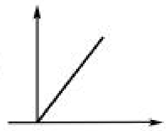
C) Photo current versus applied voltage for different intensity but same frequency of radiation is represented by

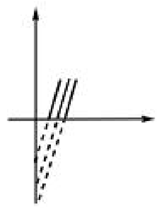
D) Photo current versus applied voltage at constant photon flux density and constant frequency of radiation for electrodes of different work functions

Column-II

p) 

q) 

r) 

s) 

PRACTICE SHEET (ADVANCED)

Straight Objective Type Questions

1. Radiation of wavelength $\frac{\lambda_0}{3}$ (λ_0 being the threshold wave length) is incident on a photo sensitive metallic sphere of radius R. The steady state charge developed on the sphere will be

a) $\frac{4\pi \in_0 Rch}{\lambda_0 e}$ b) $\frac{6\pi \in_0 Rch}{\lambda_0 e}$ c) $\frac{8\pi \in_0 Rch}{\lambda_0 e}$ d) $\frac{12\pi \in_0 Rch}{\lambda_0 e}$

2. A metallic surface ejects n electrons per second, when exposed to green colour light of certain intensity I. The long wavelength limit for the surface being 560nm. If the surface is exposed to same intensity I of green, yellow and red light simultaneously then the number of electrons emitted will be

a) n b) 2n c) 3n d) 9n

3. Wavelength of K_α X-ray of an element A is λ_1 and wavelength of K_α X-rays element B is λ_2. $\frac{\lambda_1}{\lambda_2}$ is equal to $\frac{1}{4}$ and Z_1 and the atomic numbers of element A and B respectively. The relation between Z_1 and Z_2 are given by

a) $2Z_2 = Z_1 = 1$ b) $Z_2 - 2Z_1 = 1$ c) $\frac{Z_2}{Z_1} = 4$ d) $\frac{Z_1}{Z_2} = 4$

4. In a X-Ray tube, the operating voltage V is slightly changed by ΔV, then if λ_{min} is the original cut off wavelength, the spread between $\lambda_{k\alpha}$ and λ_{min} changes by

a) $\lambda_{min}\frac{\Delta V}{V}$ b) $-\lambda_{min}\frac{\Delta V}{V}$ c) $-\lambda_{min}\frac{\Delta V}{V^2}$ d) $(\lambda_{min})^2\frac{\Delta V}{V}$

5. If $V_{K_\alpha}, V_{K_\beta}$ and V_{L_α} represent the frequencies of K_α, K_β and L_α X-ray lines of a given material then

a) $V_{K\beta} = V_{K\alpha} + V_{L_\alpha}$ b) $V_{K\beta} = \sqrt{V_{K\alpha} \times V_{L_\alpha}}$

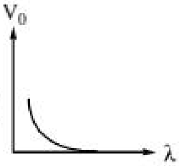
c) $V_{L\alpha} = V_{K\alpha} \times V_{K_\beta}$ d) $V_{K\beta} = V_{K\alpha} - V_{L_\alpha}$

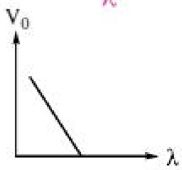
6. The binding energy of the innermost electron in tungsten is 40 keV. To produce the characteristic X-rays, using a tungsten target in an X-ray tube,the potential difference V between the cathode and the anticathode should be:

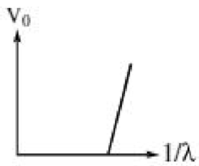
a) V< 40 kV b) $V \le 40\,kV$ c) V > 40 kV d) $V \gtrless 40kV$

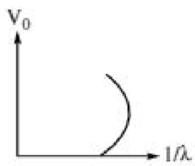
More than One correct answer Type Questions

7. For photo electric effect with incident photon wavelength λ the stopping potential is V identify the correct variation(s) of V with λ or $\frac{1}{\lambda}$

a) 

b) 

c) 

d) 

8. Photoelectric effect supports the quantum nature of light because:

a) there is a minimum frequency of light below which no photoelectrons are emitted

b) the maximum KE of photoelectrons depends only on the frequency of light and not on its intensity

c) even when the metal surface is faintly illuminated the photoelectrons leave the surface immediately

d) electric charge of photoelectrons is quantized

9. In a photoelectric experiment the wavelength of the incident light is decreased from $6000\,\mathring{A}$ to $4000\,\mathring{A}$, while the intensity of radiations remains the same:

a) the cut-off potential will decreases

b) the cut-off potential will increases

c) the photoelectric current will increase

d) the kinetic energy of emitted e^- will increase

10. When photons of energy 4.25eV strike the surface of a metal A, the ejected photoelectrons have maximum kinetic energy T_A eV and de Broglie wavelength λ_A. The maximum kinetic energy of photoelectrons liberated from another metal B by photons of energy 4.70 eV is $T_B = (T_A - 1.50)$eV. If the de Broglie wavelength of these photoelectrons is $\lambda_B = 2\lambda_A$, then:

a) the work function of A is 2.25 eV b) the work function of B is 4.20eV

c) T_A = 200eV d) T_B = 275 eV

11. Which of the following are not dependent on the intensity of the incident radiation in a photoelectric experiment?

a) Amount of photoelectric current

b) Stopping potential to reduce the photoelectric current to zero

c) Work function of the surface d) Maximum kinetic energy of photoelectrons

12. Which of the following statements about X-rays is correct?

a) $E_{K_\alpha} + E_{L_\beta} = E_{K_\beta} + E_{M_\alpha} = E_{K_\gamma}$ (E indicates the energy of photon)

b) For the harder X-rays, the intensity is always higher than soft X-rays

c) The continuous and characteristic X-rays differ only in the method of creation

d) The cut-off wavelength λ_{min}, depends only on the accelerating voltage applied between the target and the filament

Linked Comprehension Type Questions

Passage-I:

A beam of light has three wavelengths $4144\,\mathring{A}$, $4972\,\mathring{A}$ and $6216\,\mathring{A}$ with a total intensity of 3.6×10^{-3} W/m^2 equally distributed amongst the three wavelengths. The beam falls normally on an area 1.0cm^2 of a clean metallic surface of work function 2.3 eV. Assume that there is no loss of light by reflection and that each energically capable, photon ejects one electron. Give that h = 6.63×10^{-34} J-s and c = 3×10^8 m/s

13. The wavelength which are capable of ejecting photoelectrons, are

a) $4144\,\mathring{A}, 4972\,\mathring{A}$ and $6216\,\mathring{A}$ b) $4972\,\mathring{A}$, $6216\,\mathring{A}$

c) $4144\,\mathring{A}$, $4972\,\mathring{A}$ d) only $4144\,\mathring{A}$

14. Number of photons falling per sec per unit area of the surface corresponding to any wavelength λ is:

a) $\frac{I\lambda}{3hc}$ b) $\frac{I\lambda}{hc}$ c) $\frac{I\lambda}{2hc}$ d) $\frac{I\lambda}{4hc}$

15. Number of photoelectrons liberated in 2 second is:

a) 11×10^9 b) 11×10^{10} c) 11×10^{11} d) 11×10^{12}

Passage-II :

A sample of He^+ ions is excited by photons of energy 48.35eV. Photons are emitted when the He^+ ions returns to their ground state. Their radiation falls on a metallic plate of work function 6eV.

16. The maximum wavelength of photon emitted when the He^+ returns to their ground state is approximately

a) $1640A^0$ b) $256A^0$ c) $304A^0$ d) $293A^0$

17. The maximum kinetic energy of photoelectron due to the incidence of radiation on metal plate of work function 6eV is

a) 48.35 eV b) 42.35 eV c) 34.8 eV d) 1.56 eV

18. The wavelength of the photoelectron emitted having maximum possible kinetic energy is approximately

a) $1.9A^0$ b) $2.9A^0$ c) $3.9A^0$ d) $4.9A^0$

Integer Type Questions

19. 1.5m W of $4000A^0$ light is directed at a photoelectric cell. If 0.10% of the incident photons produce photoelectrons, the current in the cell is $B\times10^{-7}$ Amp. The value of B in nearest integer is

20. A light beam of wavelength 400nm is incident on a metal plate of work function 2.2eV. A particular electron absorbs a photon and makes two collisions before coming out of the metal. Assuming that 10% of the extra energy is lost to the metal in each collision, find the minimum number of collisions the electron can suffer before it is unable to come out of the metal

21. A silver sphere of radius 1cm and work function 4.7 eV is suspended fro an insulating thread in free space. It is under continuous illumination of 200nm wavelength light. As photoelectrons are emitted, the sphere gets charged and acquires a potential. The maximum number of photoelectrons emitted the sphere is $A\times10^z$ (Where $1< A<10$), the value of z is

KEY SHEET (ADDITIONAL PRACTICE EXERCISE)

LEVEL-I (MAIN)

1) **1** 2) **3** 3) **3** 4) **4** 5) **2** 6) **1** 7) **3** 8) **4** 9) **3** 10) **3**

11) **2** 12) **20.4** 13) **0.6** 14) **62.0** 15) **1.10**

LEVEL-II

LECTURE SHEET (ADVANCED)

1) **b** 2) **a** 3) **c** 4) **d** 5) **c** 6) **a** 7) **b** 8) **c** 9) **d** 10) **b**

11) **a** 12) **c** 13) **a** 14) **cd** 15) **abd** 16) **bd** 17) **a**

18) **b** 19) **A-r, B-s, C-q, D-pq**

PRACTICE SHEET (ADVANCED)

1) **c** 2) **a** 3) **a** 4) **b** 5) **a** 6) **c** 7) **ac** 8) **abc** 9) **bd** 10) **abc**

11) **bcd** 12) **acd** 13) **c** 14) **a** 15) **c** 16) **a** 17) **b** 18) **a** 19) **5** 20) **3**

21) **7**