विध्न विचारत भीरु जन, नहीं आरम्भे काम, विपति देख छोड़े तुरंत मध्यम मन कर श्याम।
पुरुष सिंह संकल्प कर, सहते विपति अनेक, 'बना' न छोड़े ध्येय को, रघुबर राखे टेक।।

रचितः मानव धर्म प्रणेता
सद्‌गुरु श्री रणछोड़दासजी महाराज

STUDY PACKAGE

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7. 34 Yrs. Que. from IIT-JEE
8. 10 Yrs. Que. from AIEEE

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KEY CONCEPTS

1. CATHODE RAYS :

(a) Generated in a discharge tube in which a high vaccum is maintained .

(b) They are electrons accelerated by high p.d. (10 to 15 K.V.)

(c) K.E. of C.R. particle accelerated by a p.d. V is $\frac{1}{2}mv^2 = \frac{P^2}{2m} = eV$.

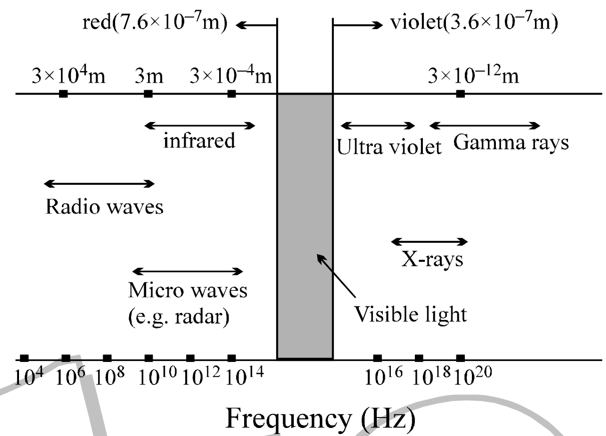
(d) Can be deflected by Electric & magnetic fields .

2. ELECTROMAGNETIC SPECTRUM :

Ordered arrangement of the big family of electro magnetic waves (EMW) either in ascending order of frequencies or of wave lengths

Speed of E.M.W. in vacuum

$C = 3 \times 10^8$ m/s $= \nu \lambda$



3. PLANK'S QUANTUM THEORY :

A beam of EMW is a stream of discrete packets of energy called **PHOTONS** , each photon having a frequency ν and energy $= E = h\nu$.

h = plank 's constant $= 6.63 \times 10^{-34}$ Js .

4. PHOTO ELECTRIC EFFECT :

The phenomenon of the emission of electrons , when metals are exposed to light (of a certain minimum frequency) is called photo electric effect.

Results :

(i) Can be explained only on the basis of the quantum theory (concept of photon) .

(ii) Electrons are emitted if the incident light has frequency $\nu \geq \nu_0$ (threshold frequency) emission of electrons is independent of intensity . The wave length corresponding to ν_0 is called threshold wave length λ_0 .

(iii) ν_0 is different for different metals .

(iv) Number of electrons emitted per second depends on the intensity of the incident light .

(v) **EINSTEINS PHOTO ELECTRIC EQUATION :**

Photon energy = K. E. of electron + work function .

$$h\nu = \frac{1}{2}mv^2 + \phi$$

ϕ = **Work function = energy needed by the electron in freeing itself from the atoms of the metal .**

$$\phi = h\nu_0$$

(vi) **STOPPING POTENTIAL OR CUT OFF POTENTIAL :**

The minimum value of the retarding potential to prevent electron emission is :

$$eV_{cut\ off} = (KE)_{max}$$

Note : The number of photons incident on a surface per unit time is called photon flux.

5. WAVE NATURE OF MATTER :

Beams of electrons and other forms of matter exhibit wave properties including interference and diffraction with a de Broglie wave length given by $\lambda = \frac{h}{p}$

(wave length of a praticle) .

6. ATOMIC MODELS :

(a) THOMSON MODEL : (PLUM PUDDING MODEL)

(i) Most of the mass and all the positive charge of an atom is uniformly distributed over the full size of atom (10^{-10} m).

(ii) Electrons are studded in this uniform distribution .

(iii) Failed to explain the large angle scattering α - particle scattered by thin foils of matter .

(b) RUTHERFORD MODEL : (Nuclear Model)

(i) The most of the mass and all the positive charge is concentrated within a size of 10^{-14} m inside the atom . This concentration is called the atomic nucleus .

(ii) The electron revolves around the nucleus under electric interaction between them in circular orbits. An accelerating charge radiates the nucleus spiralling inward and finally fall into the nucleus , which does not happen in an atom. This could not be explained by this model .

(c) BOHR ATOMIC MODEL :

Bohr adopted Rutherford model of the atom & added some arbitrary conditions. These conditions are known as his postulates :

(i) The electron in a stable orbit does not radiate energy . i.e. $\frac{mv^2}{r} = \frac{kze^2}{r^2}$

(ii) A stable orbit is that in which the angular momentum of the electron about nucleus is an integral (n) multiple of $\frac{h}{2\pi}$. i.e. $mvr = n\frac{h}{2\pi}$; $n = 1, 2, 3, ...(n \neq 0)$.

(iii) The electron can absorb or radiate energy only if the electron jumps from a lower to a higher orbit or falls from a higher to a lower orbit .

(iv) The energy emitted or absorbed is a light photon of frequency ν and of energy . $\mathbf{E = h\nu}$.

FOR HYDROGEN ATOM : (Z = atomic number = 1)

(i) L_n = angular momentum in the n^{th} orbit $= n\frac{h}{2\pi}$.

(ii) r_n = radius of n^{th} circular orbit $= (0.529\ A^o)\ n^2$; $(1A^o = 10^{-10}\ m)$; $r_n \propto n^2$.

(iii) E_n Energy of the electron in the n^{th} orbit $= \frac{-13.6\ ev}{n^2}$ i.e. $E_n \propto \frac{1}{n^2}$.

Note : Total energy of the electron in an atom is negative , indicating that it is bound .

$$\text{Binding Energy } (BE)_n = -E_n = \frac{13.6\ ev}{n^2}$$

(iv) $E_{n2} - E_{n1}$ = Energy emitted when an electron jumps from n_2^{th} orbit to n_1^{th} orbit $(n_2 > n_1)$.

$$\Delta E = (13.6\ ev)\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$\Delta E = h\nu$; ν = frequency of spectral line emitted .

$\frac{1}{\lambda} = \nu$ = wave no. [no. of waves in unit length (1m)] $= R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$.

Where R = Rydberg's constant for hydrogen $= 1.097 \times 10^7\ m^{-1}$.

(v) For hydrogen like atom/spicies of atomic number Z :

$$r_{nz} = \frac{\text{Bohr radius}}{Z}\ n^2 = (0.529\ A^o)\ \frac{n^2}{Z} \quad ; \quad E_{nz} = (-13.6)\ \frac{Z^2}{n^2}\ ev$$

$R_z = RZ^2$ – Rydberg's constant for element of atomic no. Z .

Note : If motion of the nucleus is also considered , then m is replaced by μ .

Where μ = reduced mass of electron - nucleus system = mM/(m+M) .

In this case $E_n = (-13.6\text{ ev})\ \dfrac{Z^2}{n^2}\cdot\dfrac{\mu}{m_e}$

7. SPECTRAL SERIES :

(i) Lyman Series : (Landing orbit n = 1) .

Ultraviolet region $\bar{\nu} = R\left[\dfrac{1}{1^2} - \dfrac{1}{n_2^{\,2}}\right]$; $n_2 > 1$

(ii) Balmer Series : (Landing orbit n = 2)

Visible region $\bar{\nu} = R\left[\dfrac{1}{2^2} - \dfrac{1}{n_2^{\,2}}\right]$; $n_2 > 2$

(iii) Paschan Series : (Landing orbit n = 3)

In the near infrared region $\bar{\nu} = R\left[\dfrac{1}{3^2} - \dfrac{1}{n_2^{\,2}}\right]$; $n_2 > 3$

(iv) Bracket Series : (Landing orbit n = 4)

In the mid infrared region $\bar{\nu} = R\left[\dfrac{1}{4^2} - \dfrac{1}{n_2^{\,2}}\right]$; $n_2 > 4$

(v) Pfund Series : (Landing orbit n = 5)

In far infrared region $\bar{\nu} = R\left[\dfrac{1}{5^2} - \dfrac{1}{n_2^{\,2}}\right]$; $n_2 > 5$

In all these series n_2 = $n_1 + 1$ is the α line
= $n_1 + 2$ is the β line
= $n_1 + 3$ is the γ line .... etc . where n_1 = Landing orbit

8. EXCITATION POTENTIAL OF ATOM :

Excitation potential for quantum jump from $n_1 \longrightarrow n_2 = \dfrac{E_{n2} - E_{n1}}{\text{electron charge}}$.

9. IONIZATION ENERGY :

The energy required to remove an electron from an atom . The energy required to ionize hydrogen atom is = 0 - (- 13.6) = 13.6 ev .

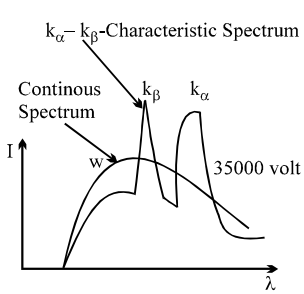
10. IONIZATION POTENTIAL :

Potential difference through which an electron is moved to gain ionization energy = $\dfrac{-E_n}{\text{electronic charge}}$

11. X - RAYS :

(i) Short wavelength (0.1 A° to 1 A°) electromagnetic radiation .

(ii) Are produced when a metal anode is bombarded by very high energy electrons .



(iii) Are not affected by electric and magnetic field .

(iv) They cause photoelectric emission .

Characteristics equation $eV = h\nu_m$

e = electron charge ;

V = accelerating potential

ν_m = maximum frequency of X - radiation

(v) Intensity of X - rays depends on number of electrons hitting the target .

(vi) Cut off wavelength or minimum wavelength, where v (in volts) is the p.d. applied to the tube

$$\lambda_{min} \cong \frac{12400}{V} \text{ A}^{o} .$$

(vii) Continuous spectrum due to retardation of electrons .

(viii) Characteristic Spectrum due to transition of electron from higher to lower
$\nu \ \alpha \ (z - b)^2$; $\upsilon = a\,(z - b)^2$ [MOSELEY'S LAW]
b = 1 for K series ; b = 7.4 for L series
Where b is Shielding factor (different for different series) .

Note : **(i)** Binding energy = - [Total Mechanical Energy]

(ii) Vel. of electron in nth orbit for hydrogen atom $\cong \frac{c}{137\,n}$; c = speed of light .

(iii) For x - rays $\frac{1}{\lambda} = R(z-b)^2\left(\frac{1}{n_1^{\,2}} - \frac{1}{n_2^{\,2}}\right)$

(iv) Series limit of series means minimum wave length of that series.

12. NUCLEAR DIMENSIONS :

$R = R_o A^{1/3}$ Where R_o = empirical constant = 1.1×10^{-15} m ; A = Mass number of the atom

13. RADIOACTIVITY :

The phenomenon of self emission of radiation is called radioactivity and the substances which emit these radiations are called **radioactive substances** . It can be natural or artificial (induced) .

14. α , β , γ RADIATION :

(i) α − particle :
(a) Helium nucleus ($_2He^4$) ; **(b)** energy varies from 4 Mev to 9 Mev ;
(c) Velocity $10^6 - 10^7$ m/s ; **(d)** low penetration

(ii) β − particle :
(a) Have much less energy ; **(b)** more penetration ; **(c)** higher velocities than α particles

(iii) γ − radiation : Electromagnetic waves of very high energy .

15. LAWS OF RADIOACTIVE DISINTEGRATION :

(A) DISPLACEMENT LAW : In all radioactive transformation either an α or β particle (never both or more than one of each simultaneously) is emitted by the nucleus of the atom.

(i) α − emission : $_zX^A \longrightarrow {}_{z-2}Y^{A-4} + {}_2\alpha^4$ + Energy

(ii) β − emission : $_zX^A \longrightarrow \beta + {}_{z+1}Y^A + \bar{\nu}$ (antinuetrino)

(iii) γ − emission : emission does not affect either the charge number or the mass number .

(B) STASTISTICAL LAW : The disintegration is a random phenomenon . Whcih atom disintegrates first is purely a matter of chance .
Number of nuclei disintegrating per second is given ;
(disintegration /s /gm is called specific activity) .

(i) $\frac{dN}{dt} \alpha N \rightarrow \frac{dN}{dt} = -\lambda N$ = activity .

Where N = No. of nuclei present at time t ; λ = decay constant

(ii) $N = N_o e^{-\lambda t}$ N_o = number of nuclei present in the beginning .

(iii) Half life of the population $T_{1/2} = \dfrac{0.693}{\lambda}$;

at the end of n half–life periods the number of nuclei left $N = \dfrac{N_o}{2^n}$.

(iv) Mean life of an atom $= \dfrac{\Sigma \text{lifetime of all atoms}}{\text{total number of atoms}}$; $T_{av} = \dfrac{1}{\lambda}$

(v) **Curie :** The unit of activity of any radioactive substance in which the number of disintegration per second is 3.7×10^{10} .

16. ATOMIC MASS UNIT (a.m.u. OR U) :

$$1 \text{ amu} = \frac{1}{12} \times (\text{mass of carbon} - 12 \text{ atom}) = 1.6603 \times 10^{-27} \text{ kg}$$

17. MASS AND ENERGY :

The mass m of a particle is equivalent to an energy given by $E = mc^2$;
c = speed of light . 1 amu = 931 Mev

18. MASS DEFECT AND BINDING ENERGY OF A NUCLEUS :

The nucleus is less massive than its constituents . The difference of masses is called mass defect .
ΔM = mass defect $= [\, Z_{mp} + (A - Z)\, m_n] - M_{zA}$.

Total energy required to be given to the nucleus to tear apart the individual nucleons composing the nucleus, away from each other and beyond the range of interaction forces is called the Binding Energy of a nucleus .

B.E. $= (\Delta M)C^2$.

B.E. per nucleon $= \dfrac{(\Delta M)C^2}{A}$.

Greater the B.E. , greater is the stability of the nucleus .

19. NUCLEAR FISSION :

(i) Heavy nuclei of A, above 200, break up onto two or more fragments of comparable masses.
(ii) The total B.E. increases and excess energy is released .
(iii) The man point of the fission energy is leberated in the form of the K.E. of the fission fragments . eg. ${}^{235}_{92}U + {}_o n^1 \rightarrow {}^{236}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}_o n^1$ + energy

20. NUCLEAR FUSION (Thermo nuclear reaction) :

(i) Light nuclei of A below 20, fuse together, the B.E. per nucleon increases and hence the excess energy is released .
(ii) These reactions take place at ultra high temperature ($\cong 10^7$ to 10^9)
(iii) Energy released exceeds the energy liberated in the fission of heavy nuclei .

eg . $4\,{}^1_1P \rightarrow {}^4_1He + {}^{0}_{+1}e$. (Positron)

(iv) The energy released in fusion is specified by specifying Q value .
i.e. Q value of reaction = energy released in a reaction .

Note : **(i)** In emission of β^-, z increases by 1 .
(ii) In emission of β^+, z decreases by 1 .

EXERCISE # I

Q.1 A parallel beam of uniform, monochromatic light of wavelength 2640 A has an intensity of $200 W/m^2$. The number of photons in $1 mm^3$ of this radiation are ....

Q.2 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 4.7eV is $T_b = (T_a - 1.5)$ eV. If the De Broglie wavelength of these photoelectrons is $\lambda_b = 2\lambda_a$, then find

(a) The work function of a (b) The work function of b is (c) T_a and T_b

Q.3 When a monochromatic point source of light is at a distance of 0.2 m from a 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 0.6 m away from the photoelectric cell, then find

(a) the stopping potential (b) the saturation current

Q.4 An isolated metal body is illuminated with monochromatic light and is observed to become charged to a steady positive potential 1.0 V with respect to the surrounding. The work function of the metal is 3.0 eV. The frequency of the incident light is ______________.

Q.5 663 mW of light from a 540 nm source is incident on the surface of a metal. If only 1 of each 5×10^9 incident photons is absorbed and causes an electron to be ejected from the surface, the total photocurrent in the circuit is ________.

Q.6 Light of wavelength 330 nm falling on a piece of metal ejects electrons with sufficient energy which requires voltage V_0 to prevent a collector. In the same setup, light of wavelength 220 nm, ejects electrons which require twice the voltage V_0 to stop them in reaching a collector. Find the numerical value of voltage V_0.(Take plank's constant, $h = 6.6 \times 10^{-34}$ Js and $1 eV = 1.6 \times 10^{-19}$ J)

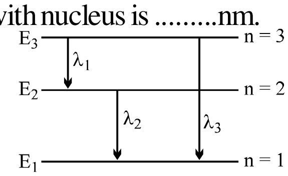
Q.7 A hydrogen atom in a state having a binding energy 0.85eV makes a transition to a state of excitation energy 10.2eV. The wave length of emitted photon is ....nm.

Q.8 A hydrogen atom is in 5^{th} excited state. When the electron jumps to ground state the velocity of recoiling hydrogen atom is .... m/s and the energy of the photon is ....eV.

Q.9 The ratio of series limit wavlength of Balmer series to wavelength of first line of paschen series is ....

Q.10 An electron joins a helium nucleus to form a He+ ion. The wavelength of the photon emitted in this process if the electron is assumed to have had no kinetic energy when it combines with nucleus is ....nm.

Q.11 Three energy levels of an atom are shown in the figure. The wavelength corresponding to three possible transition are λ_1, λ_2 and λ_3. The value of λ_3 in terms of λ_1 and λ_2 is given by ______.



Q.12 Imagine an atom made up of a proton and a hypothetical particle of double the mass of an electron but having the same charge as the electron. Apply the Bohr atom model and consider a possible transitions of this hypothetical particle to the first excited level. Find the longest wavelngth photon that will be emitted λ (in terms of the Rydberg constant R.)

Q.13 In a hydrogen atom, the electron moves in an orbit of radius 0.5 Å making 10^{16} revolution per second. The magnetic moment associated with the orbital motion of the electron is _______.

Q.14 The positron is a fundamental particle with the same mass as that of the electron and with a charge equal to that of an electron but of opposite sign. When a positron and an electron collide, they may annihilate each other. The energy corresponding to their mass appears in two photons of equal energy. Find the wavelength of the radiation emitted.

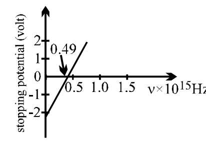
[Take : mass of electron = $(0.5/C^2)$MeV and $hC = 1.2 \times 10^{-12}$ MeV.m where h is the Plank's constant and C is the velocity of light in air]

Q.15 A small 10W source of ultraviolet light of wavelength 99 nm is held at a distance 0.1 m from a metal surface. The radius of an atom of the metal is approximately 0.05 nm. Find

(i) the average number of photons striking an atom per second.

(ii) the number of photoelectrons emitted per unit area per second if the efficiency of liberation of photoelectrons is 1%.

Q.16 The surface of cesium is illuminated with monochromatic light of various wavelengths and the stopping potentials for the wavelengths are measured. The results of this experiment is plotted as shown in the figure. Estimate the value of work function of the cesium and Planck's constant.



Q.17 A hydrogen like atom has its single electron orbiting around its stationary nucleus. The energy to excite the electron from the second Bohr orbit to the third Bohr orbit is 47.2 eV. The atomic number of this nucleus is ______________.

Q.18 A single electron orbits a stationary nucleus of charge Ze where Z is a constant and e is the electronic charge. It requires 47.2eV to excite the electron from the 2nd Bohr orbit to 3rd Bohr orbit. Find

(i) the value of Z,

(ii) energy required to excite the electron from the third to the fourth orbit

(iii) the wavelength of radiation required to remove the electron from the first orbit to infinity

(iv) the kinetic energy, potential energy and angular momentum in the first Bohr orbit

(v) the radius of the first Bohr orbit.

Q.19 A hydrogen like atom (atomic number Z) is in higher excited state of quantum number n. This excited atom can make a transition to the first excited state by successively emitting two photons of energy 22.95eV and 5.15eV respectively. Alternatively, the atom from the same excited state can make transition to the second excited state by successively emitting two photons of energies 2.4eV and 8.7eV respectively. Find the values of n and Z.

Q.20 Find the binding energy of an electron in the ground state of a hydrogen like atom in whose spectrum the third of the corresponding Balmer series is equal to 108.5nm.

Q.21 Which level of the doubly ionized lithium has the same energy as the ground state energy of the hydrogen atom. Find the ratio of the two radii of corresponding orbits.

Q.22 The binding energies per nucleon for deuteron ($_1H^2$) and helium ($_2He^4$) are 1.1 MeV and 7.0 MeV respectively. The energy released when two deuterons fuse to form a helium nucleus ($_2He^4$) is ________.

Q.23 A radioactive decay counter is switched on at t = 0. A β - active sample is present near the counter. The counter registers the number of β - particles emitted by the sample. The counter registers 1×10^5 β - particles at t = 36 s and 1.11×10^5 β - particles at t = 108 s. Find $T_{1/2}$ of this sample

Q.24 An isotopes of Potassium $^{40}_{19}K$ has a half life of 1.4×10^9 year and decays to Argon $^{40}_{18}Ar$ which is stable.

(i) Write down the nuclear reaction representing this decay.

(ii) A sample of rock taken from the moon contains both potassium and argon in the ratio 1/7. Find age of rock

Q.25 At t = 0, a sample is placed in a reactor. An unstable nuclide is produced at a constant rate R in the sample by neutron absorption. This nuclide β^- decays with half life τ. Find the time required to produce 80% of the equilibrium quantity of this unstable nuclide.

Q.26 Suppose that the Sun consists entirely of hydrogen atom and releases the energy by the nuclear reaction, $4\,^1_1H \longrightarrow \,^4_2He$ with 26 MeV of energy released. If the total output power of the Sun is assumed to remain constant at 3.9×10^{26} W, find the time it will take to burn all the hydrogen. Take the mass of the Sun as 1.7×10^{30} kg.

Q.27 Assuming that the source of the energy of solar radiation is the energy of the formation of helium from hydrogen according to the following cyclic reaction :

$${}_{6}C^{12} + {}_{1}H^{1} \rightarrow {}_{7}N^{13} \rightarrow {}_{6}C^{13} + {}_{+1}e^{0}$$

$${}_{6}C^{13} + {}_{1}H^{1} \rightarrow {}_{7}N^{14}$$

$${}_{7}N^{14} + {}_{1}H^{1} \rightarrow {}_{8}O^{15} \rightarrow {}_{7}N^{15} + {}_{+1}e^{0}$$

$${}_{7}N^{15} + {}_{1}H^{1} \rightarrow {}_{6}C^{12} + {}_{2}He^{4}$$

Find how many tons of hydrogen must be converted every second into helium . The solar constant is 8 J/cm^2 min. Assume that hydrogen forms 35% of the sun's mass . Calculate in how many years this hydrogen will be used up if the radiation of the sun is constant . $m_e = 5.49 \times 10^{-4}$ amu, atomic masses m_H=1.00814 amu, m_{He}=4.00388 amu, mass of the sun=2×10^{30} kg, distance between the sun and the earth= 1.5×10^{11}m. 1 amu = 931 MeV.

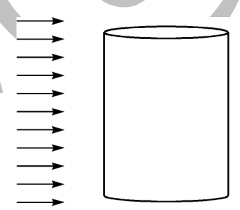
Q.28 An electron of mass "m" and charge "e" initially at rest gets accelerated by a constant electric field E. The rate of change of DeBroglie wavelength of this electron at time t is ....

<u>List of recommended questions from I.E. Irodov.</u>

5.247, 5.249, 5.260, 5.262, 5.263, 5.264, 5.265, 5.266, 5.270, 5.273, 5.277
6.21, 6.22, 6.27, 6.28, 6.30, 6.31, 6.32, 6.33, 6.35, 6.37, 6.38, 6.39, 6.40,
6.41, 6.42, 6.43, 6.49, 6.50, 6.51, 6.52, 6.53, 6.133, 6.134, 6.135, 6.136,
6.137, 6.138, 6.141, 6.214, 6.233, 6.249, 6.264, 6.289

EXERCISE # II

Q.1 Find the force exerted by a light beam of intensity I, incident on a cylinder (height h and base radius R) placed on a smooth surface as shown in figure if:



(a) surface of cylinder is perfectly reflecting
(b) surface of cylinder is having reflection coefficient 0.8. (assume no transmission)

Q.2 A small plate of a metal (work function = 1.17 eV) is placed at a distance of 2m from a monochromatic light source of wave length 4.8×10^{-7} m and power 1.0 watt. The light falls normally on the plate. Find the number of photons striking the metal plate per square meter per sec. If a constant uniform magnetic field of strength 10^{-4} tesla is applied parallel to the metal surface. Find the radius of the largest circular path followed by the emitted photoelectrons.

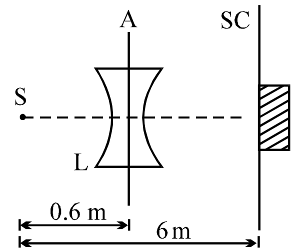
Q.3 Electrons in hydrogen like atoms (Z = 3) make transitions from the fifth to the fourth orbit & from the fourth to the third orbit. The resulting radiations are incident normally on a metal plate & eject photo electrons. The stopping potential for the photoelectrons ejected by the shorter wavelength is 3.95 volts. Calculate the work function of the metal, & the stopping potential for the photoelectrons ejected by the longer wavelength. (Rydberg constant = 1.094×10^7 m^{-1})

Q.4 A beam of light has three wavelengths 4144Å, 4972Å & 6216 Å 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 1.0 cm^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 energetically capable photon ejects one electron. Calculate the number of photoelectrons liberated in two seconds.

Q.5 Monochromatic radiation of wavelength $\lambda_1 = 3000$Å falls on a photocell operating in saturating mode. The corresponding spectral sensitivity of photocell is $J = 4.8 \times 10^{-3}$ A/w. When another monochromatic radiation of wavelength $\lambda_2 = 1650$Å and power $P = 5 \times 10^{-3}$ W is incident, it is found that maximum velocity of photoelectrons increases n = 2 times. Assuming efficiency of photoelectron generation per incident photon to be same for both the cases, calculate

(i) threshold wavelength for the cell. (ii) saturation current in second case.

Q.6 A monochromatic point source S radiating wavelength 6000 Å with power 2 watt, an aperture A of diameter 0.1 m & a large screen SC are placed as shown in figure . A photoemissive detector D of surface area 0.5 cm^2 is placed at the centre of the screen. The efficiency of the detector for the photoelectron generation per incident photon is 0.9.



(i) Calculate the photon flux density at the centre of the screen and the photocurrent in the detector .

(ii) If a concave lens L of focal length 0.6 m is inserted in the aperture as shown, find the new values of photon flux density & photocurrent Assume a uniform average transmission of 80% for the lens .

(iii) If the work-function of the photoemissive surface is 1 eV, calculate the values of the stopping potential in the two cases (without & with the lens in the aperture).

Q.7 A small 10 W source of ultraviolet light of wavelength 99 nm is held at a distance 0.1 m from a metal surface. The radius of an atom of the metal is approximaterly 0.05 nm. Find :

(i) the number of photons striking an atom per second.

(ii) the number of photoelectrons emitted per second if the efficiency of liberation of photoelectrons is 1%.

Q.8 A neutron with kinetic energy 25 eV strikes a stationary deuteron. Find the de Broglie wavelengths of both particles in the frame of their centre of mass.

Q.9 Two identical nonrelativistic particles move at right angles to each other, possessing De Broglie wavelengths, λ_1 & λ_2 . Find the De Broglie wavelength of each particle in the frame of their centre of mass.

Q.10 A stationary He^+ ion emitted a photon corresponding to the first line its Lyman series. That photon liberated a photoelectron from a stationary hydrogen atom in the ground state. Find the velocity of the photoelectron.

Q.11 A gas of identical hydrogen like atoms has some atoms in the lowest (ground) energy level A & some atoms in a particular upper (excited) energy level B & there are no atoms in any other energy level. The atoms of the gas make transition to a higher energy level by the absorbing monochromatic light of photon energy 2.7eV. Subsequently, the atoms emit radiation of only six different photon energies. Some of the emitted photons have energy 2.7 eV. Some have energy more and some have less than 2.7 eV.

(i) Find the principal quantum number of the initially excited level B.

(ii) Find the ionisation energy for the gas atoms.

(iii) Find the maximum and the minimum energies of the emitted photons.

Q.12 A hydrogen atom in ground state absorbs a photon of ultraviolet radiation of wavelength 50 nm. Assuming that the entire photon energy is taken up by the electron, with what kinetic energy will the electron be ejected ?

Q.13 A monochromatic light source of frequency ν illuminates a metallic surface and ejects photoelectrons. The photoelectrons having maximum energy are just able to ionize the hydrogen atoms in ground state. When the whole experiment is repeated with an incident radiation of frequency $(5/6)\nu$, the photoelectrons so emitted are able to excite the hydrogen atom beam which then emits a radiation of wavelength of 1215 Å. Find the work function of the metal and the frequency ν.

Q.14 An energy of 68.0 eV is required to excite a hydrogen like atom from its second Bohr orbit to the third. The nuclear charge Ze. Find the value of Z, the kinetic energy of the electron in the first Bohr orbit and the wavelength of the electro magnetic radiation required to eject the electron from the first Bohr orbit to infinity.

Q.15 A classical model for the hydrogen atom consists of a single electron of mass m_e in circular motion of radius r around the nucleus (proton). Since the electron is accelerated, the atom continuously radiates electromagnetic waves. The total power P radiated by the atom is given by $P = P_0/r^4$ where

$$P_0 = \frac{e^6}{96\pi^3\varepsilon_0{}^3C^3m_e{}^2} \quad (C = \text{velocity of light})$$

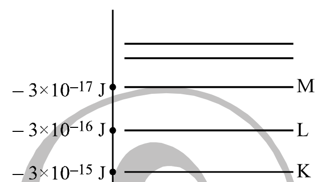
(i) Find the total energy of the atom.

(ii) Calculate an expression for the radius r (t) as a function of time. Assume that at t = 0, the radius is $r_0 = 10^{-10}$ m.

(iii) Hence or otherwise find the time t_0 when the atom collapses in a classical model of the hydrogen atom.

Take : $\left[\frac{2}{\sqrt{3}}\frac{e^2}{4\pi\varepsilon_0}\cdot\frac{1}{m_eC^2} = r_e \approx 3\times10^{-15}\,\text{m}\right]$

Q.16 Simplified picture of electron energy levels in a certain atom is shown in the figure. The atom is bombarded with high energy electrons. The impact of one of these electron has caused the complete removal of K-level is filled by an electron from the L-level with a certain amount of energy being released during the transition. This energy may appear as X-ray or may all be used to eject an M-level electron from the atom. Find :



(i) the minimum potential difference through which electron may be accelerated from rest to cause the ejectrion of K-level electron from the atom.

(ii) energy released when L-level electron moves to fill the vacancy in the K-level.

(iii) wavelength of the X-ray emitted. (iv) K.E. of the electron emitted from the M-level.

Q.17 U^{238} and U^{235} occur in nature in an atomic ratio 140 : 1. Assuming that at the time of earth's formation the two isotopes were present in equal amounts. Calculate the age of the earth.
(Half life of $u^{238} = 4.5\times10^9$ yrs & that of $U^{235} = 7.13\times10^8$ yrs)

Q.18 The kinetic energy of an $\alpha-$particle which flies out of the nucleus of a Ra^{226} atom in radioactive disintegration is 4.78 MeV. Find the total energy evolved during the escape of the $\alpha-$particle.

Q.19 A small bottle contains powdered beryllium Be & gaseous radon which is used as a source of α–particles. Neutrons are produced when α–particles of the radon react with beryllium. The yield of this reaction is (1/4000) i.e. only one α–particle out of 4000 induces the reaction. Find the amount of radon (Rn^{222}) originally introduced into the source, if it produces 1.2×10^6 neutrons per second after 7.6 days. [$T_{1/2}$ of R_n = 3.8 days]

Q.20 An experiment is done to determine the half – life of radioactive substance that emits one β–particle for each decay process. Measurement show that an average of 8.4 β are emitted each second by 2.5 mg of the substance. The atomic weight of the substance is 230. Find the half life of the substance.

Q.21 When thermal neutrons (negligible kinetic energy) are used to induce the reaction ;
${}^{10}_{5}B + {}^{1}_{0}n \longrightarrow {}^{7}_{3}Li + {}^{4}_{2}He$. $\alpha-$particles are emitted with an energy of 1.83 MeV.
Given the masses of boron neutron & He^4 as 10.01167, 1.00894 & 4.00386 u respectively. What is the mass of ${}^{7}_{3}Li$? Assume that particles are free to move after the collision.

Q.22 In a fusion reactor the reaction occurs in two stages :

(i) Two deuterium $\left({}_1^2D\right)$ nuclei fuse to form a tritium $\left({}_1^3T\right)$ nucleus with a proton as product. The reaction may be represented as D (D, p) T.

(ii) A tritium nucleus fuses with another deuterium nucleus to form a helium $\left({}_2^4He\right)$ nucleus with neutron as another product. The reaction is represented as T(D , n) α. Find :

(a) The energy release in each stage .

(b) The energy release in the combined reaction per deuterium &

(c) What % of the mass of the initial deuterium is released in the form of energy.

Given : $\left({}_1^2D\right) = 2.014102$ u ; $\left({}_1^3T\right) = 3.016049$ u ; $\left({}_2^4He\right) = 4.002603$ u ;
$\left({}_1^1P\right) = 1.00785$ u ; $\left({}_0^1n\right) = 1.008665$ u

Q.23 A wooden piece of great antiquity weighs 50 gm and shows C^{14} activity of 320 disintegrations per minute. Estimate the length of the time which has elapsed since this wood was part of living tree, assuming that living plants show a C^{14} activity of 12 disintegrations per minute per gm. The half life of C^{14} is 5730 yrs.

Q.24 Show that in a nuclear reaction where the outgoing particle is scattered at an angle of 90° with the direction of the bombarding particle, the Q-value is expressed as

$$Q = K_P\left(1+\frac{m_P}{M_O}\right) - K_I\left(1+\frac{m_I}{M_O}\right)$$

Where, I = incoming particle, P = product nucleus, T = target nucleus, O = outgoing particle.

Q.25 When Lithium is bombarded by 10 MeV deutrons, neutrons are observed to emerge at right angle to the direction of incident beam. Calculate the energy of these neutrons and energy and angle of recoil of the associated Beryllium atom. Given that : m $({}_0n^1)$ = 1.00893 amu ; m $({}_3Li^7)$ = 7.01784 amu ; m $({}_1H^2)$ = 2.01472 amu ; and m $({}_4Be^8)$ = 8.00776 amu.

Q.26 A body of mass m_0 is placed on a smooth horizontal surface. The mass of the body is decreasing exponentially with disintegration constant λ. Assuming that the mass is ejected backward with a relative velocity v. Initially the body was at rest. Find the velocity of body after time t.

Q.27 A radionuclide with disintegration constant λ is produced in a reactor at a constant rate α nuclei per sec. During each decay energy E_0 is released. 20% of this energy is utilised in increasing the temperature of water. Find the increase in temperature of m mass of water in time t. Specific heat of water is S. Assume that there is no loss of energy through water surface.

EXERCISE # III

Q.1 A neutron of kinetic energy 65 eV collides inelastically with a singly ionized helium atom at rest . It is scattered at an angle of 90º with respect of its original direction.

(i) Find the allowed values of the energy of the neutron & that of the atom after collision.

(ii) If the atom gets de-excited subsequently by emitting radiation, find the frequencies of the emitted radiation. (Given : Mass of he atom = 4×(mass of neutron), ionization energy of H atom =13.6 eV) [JEE '93]

Q.2 A hydrogen like atom (atomic number Z) is in a higher excited state of quantum number n. This excited atom can make a transition to the first excited state by successively emitting two photons of energies 10.20 eV & 17.00 eV respectively. Alternatively , the atom from the same excited state can make a transition to the second excited state by successively emitting two photons of energies 4.25 eV & 5.95 eV respectively. Determine the values of n & Z. (Ionisation energy of hydrogen atom = 13.6 eV) [JEE'94]

Q.3 Select the correct alternative(s) :

When photons of energy 4.25 eV strike the surface of a metal A, the ejected photo electrons have maximum kinetic energy T_AeV and de- Broglie wave length γ_A. The maximum kinetic energy of photo electrons liberated from another metal B by photons of energy 4.70 eV is $T_B = (T_A - 1.50)$ eV. If the de-Broglie wave length of these photo electrons is $\gamma_B = 2\gamma_A$, then :

(A) the work function of A is 2.225 eV (B) the work function of B is 4.20 eV

(C) $T_A = 2.00$ eV (D) $T_B = 2.75$ eV [JEE'94]

Q.4 In a photo electric effect set-up, a point source of light of power 3.2×10^{-3} W emits mono energetic photons of energy 5.0 eV. The source is located at a distance of 0.8 m from the centre of a stationary metallic sphere of work function 3.0 eV & of radius 8.0×10^{-3}m . The efficiency of photo electrons emission is one for every 10^6 incident photons. Assume that the sphere is isolated and initially neutral, and that photo electrons are instantly swept away after emission.

(a) Calculate the number of photo electrons emitted per second.

(b) Find the ratio of the wavelength of incident light to the De - Broglie wave length of the fastest photo electrons emitted.

(c) It is observed that the photo electron emission stops at a certain time t after the light source is switched on. Why ?

(d) Evaluate the time t. [JEE'95]

Q.5 An energy of 24.6 eV is required to remove one of the electrons from a neutral helium atom. The energy (In eV) required to remove both the electrons form a neutral helium atom is :

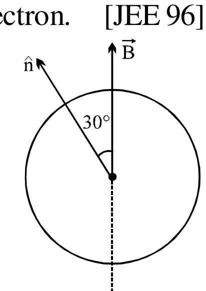
(A) 38.2 (B) 49.2 (C) 51.8 (D) 79.0 [JEE'95]

Q.6 An electron, in a hydrogen like atom , is in an excited state . It has a total energy of – 3.4 eV. Calculate: (i) The kinetic energy & (ii) The De - Broglie wave length of the electron. [JEE 96]

Q.7 An electron in the ground state of hydrogen atoms is revolving in anti-clockwise direction in a circular orbit of radius R.

(i) Obtain an expression for the orbital magnetic dipole moment of the electron.

(ii) The atom is placed in a uniform magnetic induction, such that the plane normal to the electron orbit make an angle of 30º with the magnetic induction. Find the torque experienced by the orbiting electron. [JEE'96]



Q.8 A potential difference of 20 KV is applied across an x-ray tube. The minimum wave length of X - rays generated is ________ . [JEE'96]

Q.9(i) As per Bohr model, the minimum energy (in eV) required to remove an electron from the ground state of doubly ionized Li atom (Z = 3) is

(A) 1.51 (B) 13.6 (C) 40.8 (D) 122.4

(ii) Assume that the de-Broglie wave associated with an electron can form a standing wave between the atoms arranged in a one dimensional array with nodes at each of the atomic sites. It is found that one such standing wave is formed if the distance 'd' between the atoms of the array is 2 Å. A similar standing wave is again formed if 'd' is increased to 2.5 Å but not for any intermediate value of d. Find the energy of the electrons in electron volts and the least value of d for which the standing wave of the type described above can form. [JEE' 97]

Q.10(i) The work function of a substance is 4.0 eV . The longest wavelength of light that can cause photoelectron emission from this substance is approximately :

(A) 540 nm (B) 400 nm (C) 310 nm (D) 220 nm

(ii) The electron in a hydrogen atom makes a transition $n_1 \longrightarrow n_2$, where n_1 & n_2 are the principal quantum numbers of the two states . Assume the Bohr model to be valid . The time period of the electron in the initial state is eight times that in the final state . The possible values of n_1 & n_2 are :

(A) $n_1 = 4, n_2 = 2$ (B) $n_1 = 8, n_2 = 2$
(C) $n_1 = 8, n_2 = 1$ (D) $n_1 = 6, n_2 = 3$ [JEE '98]

Q.11 A particle of mass M at rest decays into two particles of masses m_1 and m_2, having non-zero velocities. The ratio of the de-Broglie wavelengths of the particles, λ_1/λ_2, is

(A) m_1/m_2 (B) m_2/m_1 (C) 1.0 (D) $\sqrt{m_2}/\sqrt{m_1}$ [JEE '99]

Q.12 Photoelectrons are emitted when 400 nm radiation is incident on a surface of work function 1.9eV. These photoelectrons pass through a region containing α-particles. A maximum energy electron combines with an α-particle to form a He^+ ion, emitting a single photon in this process. He^+ ions thus formed are in their fourth excited state. Find the energies in eV of the photons, lying in the 2 to 4eV range, that are likely to be emitted during and after the combination. [Take , $h = 4.14 \times 10^{-15}$ eV−s] [JEE '99]

Q.13(a) Imagine an atom made up of a proton and a hypothetical particle of double the mass of the electron but having the same charge as the electron. Apply the Bohr atom model and consider all possible transitions of this hypothetical particle to the first excited level. The longest wavelength photon that will be emitted has wavelength λ (given in terms of the Rydberg constant R for the hydrogen atom) equal to

(A) 9/(5R) (B) 36/(5R) (C) 18/(5R) (D) 4/R [JEE' 2000 (Scr)]

(b) The electron in a hydrogen atom makes a transition from an excited state to the ground state. Which of the following statements is true?

(A) Its kinetic energy increases and its potential and total energies decrease.
(B) Its kinetic energy decreases, potential energy increases and its total energy remains the same.
(C) Its kinetic and total energies decrease and its potential energy increases.
(D) Its kinetic, potential and total energies decrease. [JEE' 2000 (Scr)]

Q.14(a) A hydrogen - like atom of atomic number Z is in an excited state of quantum number 2 n. It can emit a maximum energy photon of 204 eV. If it makes a transition to quantum state n, a photon of energy 40.8 eV is emitted. Find n, Z and the ground state energy (in eV) for this atom. Also, calculate the minimum energy (in eV) that can be emitted by this atom during de-excitation. Ground state energy of hydrogen atom is – 13.6 eV. [JEE' 2000]

(b) When a beam of 10.6 eV photon of intensity 2 W/m^2 falls on a platinum surface of area 1×10^4 m^2 and work function 5.6 ev, 0.53% of the incident photons eject photoelectrons. Find the number of photoelectrons emitted per sec and their minimum and maximum energies in eV. [JEE' 2000]

Q.15 The potential difference applied to an X - ray tube is 5 kV and the current through it is 3.2 mA. Then the number of electrons striking the target per second is [JEE' 2002 (Scr.)]
(A) 2×10^{16} (B) 5×10^{16} (C) 1×10^{17} (D) 4×10^{15}

Q.16 A Hydrogen atom and Li^{++} ion are both in the second excited state. If l_H and l_{Li} are their respective electronic angular momenta, and E_H and E_{Li} their respective energies, then
(A) $l_H > l_{Li}$ and $|E_H| > |E_{Li}|$ (B) $l_H = l_{Li}$ and $|E_H| < |E_{Li}|$
(C) $l_H = l_{Li}$ and $|E_H| > |E_{Li}|$ (D) $l_H < l_{Li}$ and $|E_H| < |E_{Li}|$ [JEE 2002 (Scr)]

Q.17 A hydrogen like atom (described by the Bohr model) is observed to emit six wavelengths, originating from all possible transition between a group of levels. These levels have energies between – 0.85 eV and – 0.544 eV (including both these values)
(a) Find the atomic number of the atom.
(b) Calculate the smallest wavelength emitted in these transitions. [JEE' 2002]

Q.18 Two metallic plates A and B each of area 5×10^{-4} m^2, are placed at a separation of 1 cm. Plate B carries a positive charge of 33.7×10^{-12} C. A monochromatic beam of light, with photons of energy 5 eV each, starts falling on plate A at $t = 0$ so that 10^{16} photons fall on it per square meter per second. Assume that one photoelectron is emitted for every 10^6 incident photons. Also assume that all the emitted photoelectrons are collected by plate B and the work function of plate A remains constant at the value 2 eV. Determine
(a) the number of photoelectrons emitted up to $t = 10$ sec.
(b) the magnitude of the electric field between the plates A and B at $t = 10$ s and
(c) the kinetic energy of the most energetic photoelectron emitted at $t = 10$ s when it reaches plate B.
(Neglect the time taken by photoelectron to reach plate B) [JEE' 2002]

Q.19 The attractive potential for an atom is given by $v = v_0 \, ln(r/r_0)$, v_0 and r_0 are constant and r is the radius of the orbit. The radius r of the n^{th} Bohr's orbit depends upon principal quantum number n as :
(A) $r \propto n$ (B) $r \propto 1/n^2$ (C) $r \propto n^2$ (D) $r \propto 1/n$
[JEE' 2003 (Scr)]

Q.20 Frequency of a photon emitted due to transition of electron of a certain elemrnt from L to K shell is found to be 4.2×10^{18} Hz. Using Moseley's law, find the atomic number of the element, given that the Rydberg's constant $R = 1.1 \times 10^7$ m^{-1}. [JEE' 2003]

Q.21 In a photoelctric experiment set up, photons of energy 5 eV falls on the cathode having work function 3 eV.
(a) If the saturation current is $i_A = 4\mu A$ for intensity 10^{-5} W/m^2, then plot a graph between anode potential and current.
(b) Also draw a graph for intensity of incident radiation of 2×10^{-5} W/m^2 ? [JEE' 2003]

Q.22 A star initially has 10^{40} deutrons. It produces energy via, the processes ${}_1H^2 + {}_1H^2 \rightarrow {}_1H^3 + p$ & ${}_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + n$. If the average power radiated by the star is 10^{16} W, the deuteron supply of the star is exhausted in a time of the order of : [JEE '93]
(A) 10^6 sec (B) 10^8 sec (C) 10^{12} sec (D) 10^{16} sec

Q.23 A small quantity of solution containing ^{24}Na radionuclide (half life 15 hours) of activity 1.0 microcurie is injected into the blood of a person. A sample of the blood of volume 1 cm^3 taken after 5 hours shows an activity of 296 disintegrations per minute. Determine the total volume of blood in the body of the person. Assume that the radioactive solution mixes uniformly in the blood of the person. (1 Curie = 3.7×10^{10} disintegrations per second) [JEE'94]

Q.24(i) Fast neutrons can easily be slowed down by :
(A) the use of lead shielding (B) passing them through water
(C) elastic collisions with heavy nuclei (D) applying a strong electric field

(ii) Consider α – particles, β – particles & γ rays, each having an energy of 0.5 MeV. Increasing order of penetrating powers, the radiations are : [JEE'94]
(A) α, β, γ (B) α, γ, β (C) β, γ, α (D) γ, β, α

Q.25 Which of the following statement(s) is (are) correct ? [JEE'94]
(A) The rest mass of a stable nucleus is less than the sum of the rest masses of its separated nucleons.
(B) The rest mass of a stable nucleus is greater than the sum of the rest masses of its separated nucleons.
(C) In nuclear fusion, energy is released by fusion two nuclei of medium mass (approximately 100 amu).
(D) In nuclear fission, energy is released by fragmentation of a very heavy nucleus.

Q.26 The binding energy per nucleon of ^{16}O is 7.97 MeV & that of ^{17}O is 7.75 MeV. The energy in MeV required to remove a neutron from ^{17}O is : [JEE'95]
(A) 3.52 (B) 3.64 (C) 4.23 (D) 7.86

Q.27 At a given instant there are 25 % undecayed radio – active nuclei in a sample. After 10 sec the number of undecayed nuclei remains to 12.5 %. Calculate : [JEE 96]
(i) mean – life of the nuclei and
(ii) The time in which the number of undecayed nuclear will further reduce to 6.25 % of the reduced number.

Q.28 Consider the following reaction ; $^2H_1 + {}^2H_1 = {}^4He_2 + Q$. [JEE 96]
Mass of the deuterium atom = 2.0141 u ; Mass of the helium atom = 4.0024 u
This is a nuclear ______ reaction in which the energy Q is released is ______ MeV.

Q.29(a) The maximum kinetic energy of photoelectrons emitted from a surface when photons of energy 6 eV fall on it is 4 eV. The stopping potential in Volts is :
(A) 2 (B) 4 (C) 6 (D) 10

(b) In the following, **column I** lists some physical quantities & the **column II** gives approx. energy values associated with some of them. Choose the appropriate value of energy from **column II** for each of the physical quantities in **column I** and write the corresponding letter A, B, C etc. against the number (i), (ii), (iii), etc. of the physical quantity in the answer book. In your answer, the sequence of **column I** should be maintained.

	Column I	**Column II**
(i)	Energy of thermal neutrons	(A) 0.025 eV
(ii)	Energy of X–rays	(B) 0.5 eV
(iii)	Binding energy per nucleon	(C) 3 eV
(iv)	Photoelectric threshold of metal	(D) 20 eV
		(E) 10 keV
		(F) 8 MeV

(c) The element Curium $^{248}_{96}Cm$ has a mean life of 10^{13} seconds. Its primary decay modes are spontaneous fission and α decay, the former with a probability of 8% and the latter with a probability of 92%. Each fission releases 200 MeV of energy. The masses involved in α decay are as follows :
$^{248}_{96}Cm = 248.072220\,u$, $^{244}_{94}Pu = 244.064100\,u$ & $^{4}_{2}He = 4.002603\,u$.
Calculate the power output from a sample of 10^{20} Cm atoms. (1 u = 931 MeV/c^2) [JEE'97]

Q.30 Select the correct alternative(s). [JEE '98]
(i) Let m_p be the mass of a proton, m_n the mass of a neutron, M_1 the mass of a $^{20}_{10}Ne$ nucleus & M_2 the mass of a $^{40}_{20}Ca$ nucleus. Then :
(A) $M_2 = 2\,M_1$ (B) $M_2 > 2\,M_1$ (C) $M_2 < 2\,M_1$ (D) $M_1 < 10\,(m_n + m_p)$

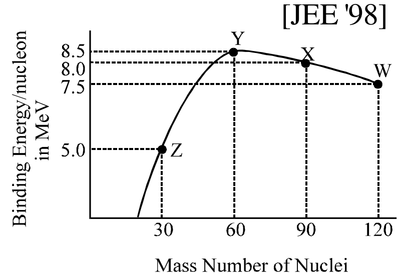
(ii) The half – life of ^{131}I is 8 days. Given a sample of ^{131}I at time t = 0, we can assert that :
(A) no nucleus will decay before t = 4 days (B) no nucleus will decay before t = 8 days
(C) all nuclei will decay before t = 16 days (D) a given nucleus may decay at any time after t = 0.

Q.31 Nuclei of a radioactive element A are being produced at a constant rate α. The element has a decay constant λ. At time $t = 0$, there are N_0 nuclei of the element.

(a) Calculate the number N of nuclei of A at time t .

(b) If $\alpha = 2N_0\lambda$, calculate the number of nuclei of A after one halflife of A & also the limiting value of N as $t \to \infty$. [JEE '98]

Q.32(a) Binding energy per nucleon vs. mass number curve for nuclei is shown in the figure. W, X, Y and Z are four nuclei indicated on the curve. The process that would release energy is



(A) $Y \to 2Z$ (B) $W \to X + Z$
(C) $W \to 2Y$ (D) $X \to Y + Z$

(b) Order of magnitude of density of Uranium nucleus is, [$m_P = 1.67 \times 10^{-27}$ kg]
(A) 10^{20} kg/m^3 (B) 10^{17}kg/m^3 (C) 10^{14}kg/m^3 (D) 10^{11}kg/m^3

(c) ^{22}Ne nucleus, after absorbing energy, decays into two α–particles and an unknown nucleus. The unknown nucleus is
(A) nitrogen (B) carbon (C) boron (D) oxygen

(d) Which of the following is a correct statement?
(A) Beta rays are same as cathode rays
(B) Gamma rays are high energy neutrons.
(C) Alpha particles are singly ionized helium atoms
(D) Protons and neutrons have exactly the same mass
(E) None

(e) The half–life period of a radioactive element X is same as the mean–life time of another radioactive element Y. Initially both of them have the same number of atoms. Then
(A) X & Y have the same decay rate initially (B) X & Y decay at the same rate always
(C) Y will decay at a faster rate than X (D) X will decay at a faster rate than Y [JEE '99]

Q.33 Two radioactive materials X_1 and X_2 have decay constants 10λ and λ respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of X_1 to that of X_2 will be 1/e after a time
(A) $1/(10\lambda)$ (B) $1/(11\lambda)$ (C) $11/(10\lambda)$ (D) $1/(9\lambda)$ [JEE ' 2000 (Scr)]

Q.34 The electron emitted in beta radiation originates from [JEE'2001(Scr)]
(A) inner orbits of atoms (B) free electrons existing in nuclei
(C) decay of a neutron in a nucleus (D) photon escaping from the nucleus

Q.35 The half - life of ^{215}At is 100 μs. The time taken for the radioactivity of a sample of ^{215}At to decay to 1/16th of its initial value is [JEE 2002 (Scr)]
(A) 400 μs (B) 6.3 μs (C) 40 μs (D) 300 μs

Q.36 Which of the following processes represents a gamma - decay? [JEE 2002 (Scr)]
(A) $^{A}X_Z + \gamma \longrightarrow {}^{A}X_{Z-1} + a + b$ (B) $^{A}X_Z + {}^{1}n_0 \longrightarrow {}^{A-3}X_{Z-2} + c$
(C) $^{A}X_Z \longrightarrow {}^{A}X_Z + f$ (D) $^{A}X_Z + e_{-1} \longrightarrow {}^{A}X_{Z-1} + g$

Q.37 The volume and mass of a nucleus are related as [JEE 2003 (Scr)]
(A) $v \propto m$ (B) $v \propto 1/m$ (C) $v \propto m^2$ (D) $v \propto 1/m^2$

Q.38 The nucleus of element X (A = 220) undergoes α-decay. If Q-value of the reaction is 5.5 MeV, then the kinetic energy of α-particle is : [JEE 2003 (Scr)]
(A) 5.4 MeV (B) 10.8 MeV (C) 2.7 MeV (D) None

Q.39 A radioactive sample emits n β-particles in 2 sec. In next 2 sec it emits 0.75 n β-particles, what is the mean life of the sample? [JEE 2003]

Q.40 The wavelength of K_α X-ray of an element having atomic number z = 11 is λ . The wavelength of K_α X-ray of another element of atomic number z' is 4λ. Then z' is
(A) 11 (B) 44 (C) 6 (D) 4 [JEE' 2005 (Scr)]

Q.41 A photon of 10.2 eV energy collides with a hydrogen atom in ground state inelastically. After few microseconds one more photon of energy 15 eV collides with the same hydrogen atom.Then what can be detected by a suitable detector.
(A) one photon of 10.2 eV and an electron of energy 1.4 eV
(B) 2 photons of energy 10.2 eV
(C) 2 photons of energy 3.4 eV
(D) 1 photon of 3.4 eV and one electron of 1.4 eV [JEE' 2005 (Scr)]

Q.42 Helium nuclie combines to form an oxygen nucleus. The binding energy per nucleon of oxygen nucleus is if m_0 = 15.834 amu and m_{He} = 4.0026 amu
(A) 10.24 MeV (B) 0 MeV (C) 5.24 MeV (D) 4 MeV
[JEE' 2005 (Scr)]

Q.43 The potential energy of a particle of mass m is given by

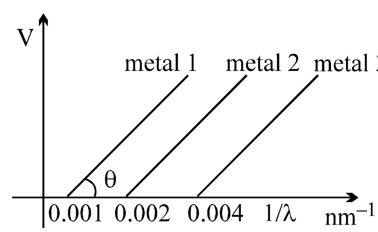
$$V(x) = \begin{Bmatrix} E_0 & 0 \le x \le 1 \\ 0 & x > 1 \end{Bmatrix}$$

λ_1 and λ_2 are the de-Broglie wavelengths of the particle, when $0 \le x \le 1$ and $x > 1$ respectively. If the total energy of particle is $2E_0$, find λ_1/λ_2. [JEE 2005]

Q.44 Highly energetic electrons are bombarded on a target of an element containing 30 neutrons. The ratio of radii of nucleus to that of helium nucleus is $(14)^{1/3}$. Find
(a) atomic number of the nucleus
(b) the frequency of K_α line of the X-ray produced. ($R = 1.1\times 10^7\ m^{-1}$ and $c = 3 \times 10^8$ m/s)
[JEE 2005]

Q.45 Given a sample of Radium-226 having half-life of 4 days. Find the probability, a nucleus disintegrates within 2 half lives.
(A) 1 (B) 1/2 (C) 3/4 (D) 1/4 [JEE 2006]

Q.46 The graph between $1/\lambda$ and stopping potential (V) of three metals having work functions ϕ_1, ϕ_2 and ϕ_3 in an experiment of photo-electric effect is plotted as shown in the figure. Which of the following statement(s) is/are correct? [Here λ is the wavelength of the incident ray].



(A) Ratio of work functions $\phi_1 : \phi_2 : \phi_3 = 1 : 2 : 4$
(B) Ratio of work functions $\phi_1 : \phi_2 : \phi_3 = 4 : 2 : 1$
(C) $\tan\theta$ is directly proportional to hc/e, where h is Planck's constant and c is the speed of light
(D) The violet colour light can eject photoelectrons from metals 2 and 3. [JEE 2006]

Q.47 In hydrogen-like atom (z = 11), n^{th} line of Lyman series has wavelength λ equal to the de-Broglie's wavelength of electron in the level from which it originated. What is the value of n? [JEE 2006]

Q.48 Match the following Columns [JEE 2006]

Column 1	Column 2
(A) Nuclear fusion	(P) Converts some matter into energy
(B) Nuclear fission	(Q) Generally occurs for nuclei with low atomic number
(C) β–decay	(R) Generally occurs for nuclei with higher atomic number
(D) Exothermic nuclear reaction	(S) Essentially proceeds by weak nuclear forces

ANSWER KEY

EXERCISE # I

Q.1 885 Q.2 (a) 2.25eV, (b) 4.2eV, (c) 2.0 eV, 0.5 eV Q.3 (a) 0.6 volt, (b) 2.0 mA

Q.4 when the potential is steady, photo electric emission just stop when $h\upsilon = (3 + 1)eV = 4.0$ eV

Q.5 5.76×10^{-11} A Q.6 15/8 V Q.7 487.06 nm Q.8 4.26 m/s, 13.2 eV

Q.9 7 : 36 Q.10 22.8 nm Q.11 $\dfrac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$ Q.12 18/(5R)

Q.13 1.257×10^{-23} Am^2 Q.14 2.48×10^{-12} m Q.15 $\dfrac{5}{16}, \dfrac{10^{20}}{80\pi}$ Q.16 2 eV, 6.53×10^{-34} J-s

Q.17 5 Q.18 (i) 5, 16.5 eV, 36.4 A, 340 eV, – 680 eV, $\dfrac{h}{2\pi}$ 1.06×10^{-11} m

Q.19 z = 3, n = 7 Q.20 54.4 eV Q.21 n = 3, 3 : 1 Q.22 23.6 MeV

Q.23 ($T_{1/2}$ = 10.8 sec) Q.24 (i) ${}^{40}_{19}K \longrightarrow {}^{40}_{18}Ar + {}_{+1}e^0 + \nu$ (ii) 4.2×10^9 years

Q.25 $t = \left(\dfrac{\ln 5}{\ln 2}\right)\tau$ Q.26 $8/3\times10^{18}$ sec Q.27 1.14×10^{18} sec Q.28 $-h/eEt^2$

EXERCISE # II

Q.1 8IhR/3C $\dfrac{38\,I\,R\,h}{15C}$ Q.2 4.8×10^{16}, 4.0 cm Q.3 1.99 eV, 0.760 V

Q.4 1.1×10^{12} Q.5 (i) 4125Å, (ii) 13.2 µA

Q.6 (i) 1.33×10^{16} photons/m^2–s ; 0.096 µÅ (ii) 2.956×10^{15} photons/m^{2}s ; 0.0213 µA (iii) 1.06 volt

Q.7 (i) 5/16 photon/sec, (ii) 5/1600 electrons/sec Q.8 $\lambda_{deutron} = \lambda_{neutron} = 8.6$ pm

Q.9 $\lambda = \dfrac{2\lambda_1\lambda_2}{\sqrt{\lambda_1^2+\lambda_2^2}}$ Q.10 3.1×10^6 m/s Q.11 (i) 2 ; (ii) 23.04×10^{-19} J ; (iii) $4 \to 1$, $4 \to 3$

Q.12 11.24 eV Q.13 6.8 eV, 5×10^{15} Hz Q.14 489.6 eV, 25.28 Å

Q.15 (i) $-\dfrac{1}{8\pi\varepsilon_0}\dfrac{e^2}{r}$, (ii) $r_0\left(1-\dfrac{3C\,r_e^{\,2}t}{r_0^{\,3}}\right)^{1/3}$, (iii) $10^{-10} \times \dfrac{100}{81}$ sec

Q.16 (i) 1.875×10^4 V, (ii) 2.7×10^{-15} J, (iii) 0.737 Å, (iv) 2.67×10^{-15} J

Q.17 6.04×10^9 yrs Q.18 4.87 MeV Q.19 3.3×10^{-6} g

Q.20 1.7×10^{10} years Q.21 7.01366 amu

Q.22 (a) 4 MeV , 17.6 (b) 7.2 MeV (c) 0.384 % Q.23 5196 yrs

Q.25 Energy of neutron = 19.768 MeV ; Energy of Beryllium = 5.0007 MeV;
Angle of recoil = $\tan^{-1}(1.034)$ or 46°

Q.26 $v = u\lambda t$ Q.27 $\Delta T = \dfrac{0.2E_0\left[\alpha t - \dfrac{\alpha}{\lambda}(1-e^{-\lambda t})\right]}{mS}$

EXERCISE # III

Q.1 (i) Allowed values of energy of neutron = 6.36 eV and 0.312 eV ; Allowed values of energy of He atom = 17.84 eV and 16.328 eV , (ii) 18.23×10^{15} Hz , 9.846×10^{15} Hz , 11.6×10^{15} Hz

Q.2 n = 6, Z = 3 Q.3 B, C Q.4 (a) $10^5\ s^{-1}$; (b) 286.18 ; (d) 111 s

Q.5 D Q.6 (i) KE = 3.4 eV, (ii) $\lambda = 6.66$ Å Q.7 (i) $\frac{he}{4\pi m}$ (ii) $\frac{ehB}{8\pi m}$

Q.8 0.61 Å Q.9 (i) D, (ii) KE $\cong$ 151 eV, $d_{least} = 0.5$ Å

Q.10 (i) C (ii) A, D Q.11 C

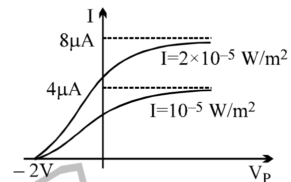
Q.12 during combination = 3.365 eV; after combination = 3.88 eV $(5 \rightarrow 3)$ & 2.63 eV $(4 \rightarrow 3)$

Q.13 (a) C, (b) A

Q.14 (a) n = 2, z = 4; G.S.E. – 217.6 eV; Min. energy = 10.58 eV; (b) 6.25×10^{19} per sec, 0, 5 eV

Q.15 A Q.16 B Q.17 3, 4052.3 nm Q.18 5×10^7, 2000N/C, 23 eV

Q.19 A Q.20 z = 42 Q.21



Q.22 C Q.23 6 litre Q.24 (i) B, (ii) A Q.25 A , D

Q.26 C Q.27 (i) $t_{1/2} = 10$ sec. , $t_{means} = 14.43$ s (ii) 40 seconds

Q.28 Fusion , 24 Q.29 (a) B, (b) (i) – A, (ii) – E, (iii) – F, (iv) – C, (c) $\cong$ 33.298 μW

Q.30 (i) C, D (ii) D Q.31 (a) $N = \frac{1}{\lambda}[\alpha(1 - e^{-\lambda t}) + \lambda N_0 e^{-\lambda t}]$ (b) $\frac{3N_0}{2}$, $2N_0$

Q.32 (a) C ; (b) B ; (c) B ; (d) E ; (e) C Q.33 D

Q.34 C Q.35 A Q.36 C Q.37 A

Q.38 A Q.39 $1.75n = N_0(1 - e^{-4\lambda})$, 6.95 sec, $\frac{2}{ln\left(\frac{4}{3}\right)}$ Q.40 C

Q.41 A Q.42 A Q.43 $\sqrt{2}$ Q.44 $\nu = 1.546 \times 10^{18}$ Hz

Q.45 C Q.46 A,C Q.47 n = 24

Q.48 (A) P, Q; (B) P, R; (C) S, P; (D) P, Q, R