

## Modern Physics - Questions

### Q 1.

A single electron orbits around a stationary nucleus of charge  $+Ze$ . Where  $Z$  is a constant and  $e$  is the magnitude of the electronic charge. It requires 47.2 eV to excite the electron from the second Bohr orbit to the third Bohr orbit. **(IIT JEE 1981 – 10 MARKS)**

Find

The value of  $Z$ .

The energy required to excite the electron from the third to the fourth Bohr orbit.

The wavelength of the electromagnetic radiation required to remove the electron from the first Bohr orbit to infinity.

The kinetic energy, potential energy, potential energy and the angular momentum of the electron in the first Bohr orbit.

The radius of the first Bohr orbit.

(The ionization energy of hydrogen atom = 13.6 eV, Bohr radius =  $5.3 \times 10^{-11}$  metre, velocity of light =  $3 \times 10^8$  m / sec. Planck's constant =  $6.6 \times 10^{-34}$  joules – sec)

### Q 2.

Hydrogen atom in its ground is excited by means of monochromatic radiation of wavelength 975 Å. How many different lines are possible in the resulting spectrum ? Calculate the longest wavelength amongst them. You may assume the ionization energy for hydrogen atom as 13.6 eV.

**(IIT JEE 1982 – 5 Marks)**

### Q 3.

How many electron, protons and neutrons are there in a nucleus of atomic number 11 and mass number 24 ? **(IIT JEE1982 – 2 Marks)**

(i) number of electrons =

(ii) number of protons =

(iii) number of neutrons =

### Q 4.

A uranium nucleus (atomic number 92, mass number 238 ) emits an alpha particle and the resultant nucleus emits  $\beta$  – particle. What are the atomic number and mass number of the final nucleus.

**(IIT JEE 1982 – 2 Marks)**

(i) Atomic number =

(ii) Mass number =

**Q 5.**

Ultraviolet light of wavelengths  $800 \text{ \AA}$  when allowed to fall on hydrogen atoms in their ground state is found to liberate electrons with kinetic energy  $1.8 \text{ eV}$  and  $4.0 \text{ eV}$  respectively. Find the value of Planck's constant. **(IIT JEE1983 – 4 Marks)**

**Q 6.**

The ionization energy of a hydrogen like Bohr atoms is 4 Rydbergs. (i) What is the wavelength of the radiation emitted when the electrons jumps from the first excited state to the ground state ? (ii) What is the radius of the first orbit for this atom ? **(IIT JEE1984 – 4 Marks)**

**Q 7.**

A double ionized Lithium atom is hydrogen-like with atomic number 3.

**(IIT JEE1985 – 6 Marks)**

(i) Find the wavelength of the radiation required to excite the electron in  $\text{Li}^{++}$  from the first to the third Bohr orbit. (Ionization energy of the hydrogen atom equals  $13.6 \text{ eV}$ .)

(ii) How many spectral lines are observed in the emission spectrum of the above excited system ?

**Q 8.**

There is a stream of neutrons with a kinetic energy of  $0.0327 \text{ eV}$ . If the half life of neutrons is 700 seconds, what fraction of neutrons will decay before they travel a distance of 10 m ?

**(IIT JEE 1986 – 6 Marks)**

**Q 9.**

A triode has plate characteristics in the form of parallel lines in the region of our interest. At a grid voltage of  $-1$  volt the anode current  $-I$  (In milli amperes ) is given in terms of plate voltage  $V$  ( in volts) by the algebraic relation.

$$I = 0.125 V - 7.5$$

For grid voltage of  $-3$  volts, the current at anode voltage of 300 volts is 5 milliamperere. Determine the plate resistance ( $r_p$ ), transconductance ( $g_m$ ) and the amplification factor ( $\mu$ ) for the triode.

**(IIT JEE 1987 – 7 MARKS)**

**Q 10.**

A particle of charge equal to that of an electron,  $-e$ , and mass 208 times the mass of the electron (called a  $\mu$ -meson) moves in a circular orbit around a nucleus of charge  $+3e$ . (Take the mass of the nucleus to be infinite). Assuming that the Bohr model of the atom is applicable to this system.

Derive an expression for the radius of the nth Bohr orbit.

Find the value, of n for which the radius of the orbit is approximately the same as that of the first Bohr orbit for the hydrogen atom.

Find the wavelength of the radiation emitted when the mu-meson jumps from the third orbit of the first orbit.

**Q 11.**

A beam of light has three wavelengths 4144 Å, 4972 Å and 6216 Å with a total intensity of  $3.6 \times 10^{-3} \text{ W m}^{-2}$  equally distributed amongst the three wavelengths. The beam falls normally on an area  $1.0 \text{ cm}^2$  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 an electron. Calculate the number of photoelectrons liberated in two seconds.

(IIT JEE 1989 – 8 MARKS)

**Q 12.**

A gas of identical hydrogen-like atoms has some atoms in the lowest (ground) energy level A and some atoms in a particular upper (excited) energy level B and there are no atoms in any other energy level. The atoms of the gas make transition to a higher energy level absorbing monochromatic light of photon energy 2.7 eV. 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.

(IIT JEE 1989 – 8 MARKS)

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

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

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

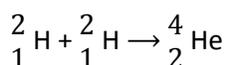
**Q 13.**

Electrons in hydrogen like atom ( $Z = 3$ ) make transitions from the fifth to the fourth orbit and from the fourth to the third orbit. The resulting radiations are incident normally on a metal plate and eject photoelectrons. The stopping potential for the photoelectrons ejected by the shorter wavelength is 3.95 volts. Calculate the work function of the metal and the stopping potential for the photoelectrons ejected by the longer wavelength.

(IIT JEE 1990 – 7 MARKS)

(Rydberg constant =  $1.094 \times 10^7 \text{ m}^{-1}$ )

**Q 14.** It is proposed to use the nuclear fusion reaction

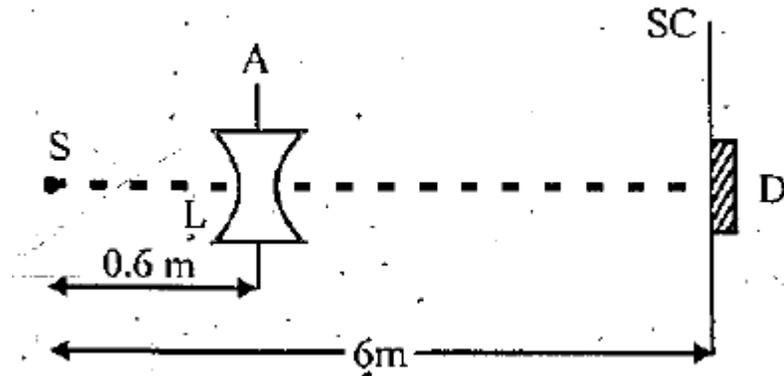


(IIT JEE 1990 – 8 MARKS)

in a nuclear reactor of 200 MW rating. If the energy from the above reaction is used with a 25 per cent efficiency in the reactor, how many grams of deuterium fuel will be needed per day. (The masses of  ${}^2_1\text{H}$  and  ${}^4_2\text{He}$  are 2.0141 atomic mass units and 4.0026 atomic mass units respectively)

**Q 15.**

A monochromatic point source radiating wavelength  $6000 \text{ \AA}$ , with power 2 watt, an aperture A of diameter 0.1 m and a large screen SC are placed as shown in fig. A photo emissive detector D of surface area  $0.5 \text{ cm}^2$  is placed at the centre of the screen. The efficiency of the detector for the photoelectron generation per incident photon is 0.9. **(IIT JEE 1991 – 2 + 4 + 2 MARKS)**



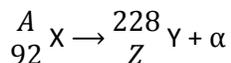
Calculate the photon flux at the centre of the screen and the photocurrent in the detector.

If the concave lens L of focal length 0.6 m is inserted in the aperture as shown, find the new values of photon flux and photocurrent. Assume a uniform average transmission of 80% from the lens.

If the work function of the photoemissive surface is 1 eV. Calculate the values of the stopping potential in the two cases (without and with the lens in the aperture).

**Q 16.**

A nucleus X, initially at rest, undergoes alpha decay according to the equation,



**(IIT JEE 1991 – 4 + 4 MARKS)**

Find the values of A and Z in the above process.

The alpha particle produced in the above process is found to move in a circular track of radius 0.11 m in a uniform magnetic field of 3 Tesla. Find the energy (In MeV) released during the process and the binding energy of the parent nucleus X.

Given that :  $m(\text{Y}) = 228.03 \text{ u}$ ;  $m({}^1_0\text{n}) = 1.009 \text{ u}$ .

$m({}^4_2\text{He}) = 4.003 \text{ u}$ ;  $m({}^1_1\text{H}) = 1.008 \text{ u}$

**Q 17.**

Light from a discharge tube containing hydrogen atoms falls on the surface of a piece of sodium. The kinetic energy of the fastest photoelectrons emitted from sodium is 0.73 eV. The work function for sodium is 1.82 eV. Find **(IIT JEE 1992 – 10 MARKS)**

- (a) the energy of the photons causing the photoelectric emission,
- (b) the quantum numbers of the two levels involved in the emission of these photons,
- (c) the change in the angular momentum of the electron in the above transition, and
- (d) the recoil speed of the emitting atom assuming it to be at rest before the transition.

(Ionization potential of hydrogen is 13.6 eV)

**Q 18.**

A neutron of kinetic energy 65eV collides inelastically with a singly ionized helium atom at rest. It is scattered at an angle of  $90^\circ$  with respect of its original direction **(IIT JEE 1993 – 9 + 1 MARKS)**

- (i) Find the allowed values of the energy of the neutron and that of the atom after the 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 x (mass of neutron), Ionization energy of H atom = 13.6 eV]

**Q 19.**

A small quantity of solution containing  $\text{Na}^{24}$  radio nuclide (half life = 15 hour) of activity 1.0 microcurie is injected into the blood of a person. A sample of the blood of volume  $1 \text{ cm}^3$  taken. After 5 hour shown an activity of 296 disintegrations per minute. Determine the total volume of the blood in the body of the person. Assume that radioactive solution mixes uniformly in the blood of the person. (1 curie =  $3.7 \times 10^{10}$  disintegrations per second) **(IIT JEE 1994 – 6 MARKS)**

**Q 20.**

A hydrogen like atom (atomic number Z) is in higher excited state of quantum number n. The excited atom can make a transition to the first excited state by successively emitting two photons of energy 10.2 and 17.0 eV respectively. Alternately, 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 and 5.95 eV respectively.

**(IIT JEE 1994 – 6 MARKS)**

Determine the values of n and Z. ( Ionization energy of H – atom = 13.6 eV)

**Q 21.**

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 and (ii) the de Broglie wavelength of the electron

**(IIT JEE 1996 – 3 MARKS)**

**Q 22.**

At a given instant there are 25% undecayed radio-active nuclei in a sample. After 10 seconds the number of undecayed nuclei reduces to 12.5% Calculate (i) mean-life of the nuclei, and (ii) the time in which the number of undecayed nuclei will further reduce to 6.25% of the reduced number

(IIT JEE 1996 – 3 MARKS)

**Q 23.**

In an ore containing Uranium, the ratio of  $U^{238}$  to  $Pb^{206}$  nuclei is 3. Calculate the age of the ore, assuming that all the lead present in the ore is the final stable product of  $U^{238}$ . Take the half-life of  $U^{238}$  to  $4.5 \times 10^9$  years.

(IIT JEE 1997 C – 5 MARKS)

**Q 24.**

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 that distance  $d$  between the atoms of the array is  $2\text{Å}$ . A similar standing wave is again formed if  $d$  is increased to  $2.5\text{Å}$  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.

(IIT JEE 1997 – 5 MARKS)

**Q 25.**

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

(IIT JEE 1997 – 5 MARKS)

**Q 26.**

Nuclei of a radioactive element A are being produced at a constant rate  $\alpha$ . The element has a decay constant  $\lambda$ . At time  $t = 0$ , there are  $N_0$  nuclei of the element

(IIT JEE 1998 – 8 MARKS)

(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 half-life of A, and also the limiting value of  $N$  as  $t \rightarrow \infty$ .

**Q 27.**

Photoelectrons are emitted when 40 nm radiation is incident on a surface of work function 1.9 eV. These photoelectrons pass through a region containing  $\alpha$  – particles. A maximum energy electron combines with an  $\alpha$ -particle to form a  $\text{He}^+$  ion, emitting a single photon in this process.  $\text{He}^+$  ions thus formed are in their fourth excited state. Find the energies in eV of the photons, lying in the 2 to 4 eV range, that are likely to be emitted during and after the combination [Take  $h = 4.14 \times 10^{-15}$  eV.s.]

(IIT JEE 1999 – 5 MARKS)

**Q 28.**

A hydrogen-like atom of atom number  $Z$  is in an excited state of quantum number  $2n$ . 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.

(IIT JEE 2000 – 6 MARKS)

**Q 29.**

When a beam of 106 eV photon of intensity  $2.0 \text{ W/m}^2$  falls on a platinum surface of area  $1.0 \times 10^{-4} \text{ m}^2$  and work function 5.6 eV, 0.53% of the incident photons eject photoelectrons. Find the number of photoelectrons emitted per second and their minimum and maximum energies

(IIT JEE 2000 – 4 MARKS)

**Q 30.**

In a nuclear reaction  $^{235}\text{U}$  undergoes fission liberating 200 MeV of energy. The reactor has a 10% efficiency and produces 1000 MW power. If the reactor is to function for 10 years, find the total mass of uranium required.

(IIT JEE 2001 – 5 MARKS)

**Q 31.**

A nucleus at rest undergoes a decay emitting an  $\alpha$  particle of de-Broglie wavelength  $\lambda = 5.76 \times 10^{-15} \text{ m}$ . If the mass of the daughter nucleus is 223.610 amu and that of the  $\alpha$  particles is 4.002 amu, determine the total kinetic energy in the final state. Hence, obtain the mass of the parent nucleus in amu. ( $1 \text{ amu} = 931.470 \text{ MeV} / c^2$ )

(IIT JEE 2001 – 5 MARKS)

**Q 32.**

A radioactive nucleus  $X$  decays to a nucleus  $Y$  with a decay constant  $\lambda_x = 0.1 \text{ s}^{-1}$ .  $Y$  further decays to a stable nucleus  $Z$  with a decay constant  $\lambda_y = 1/30 \text{ s}^{-1}$ . Initially, there are only  $X$  nuclei and their number is  $N_0 = 10^{20}$ . Set up the rate equations for the populations of  $X$ ,  $Y$  and  $Z$ . The population of  $Y$  nucleus as a function of time is given by  $N_Y(t) = (N_0 \lambda_x / (\lambda_x - \lambda_y)) \{ \exp(-\lambda_y t) - \exp(-\lambda_x t) \}$ . Find the time at which  $N_Y$  is maximum and determine the populations  $X$  and  $Z$  at that instant.

(IIT JEE 2001 – 5 MARKS)

**Q 33.**

A hydrogen – like atom (described by the Bohr model) is observed to emit six wavelengths, originating from all possible transitions between a group of levels. These levels both these values).

(IIT JEE 2002 – 5 MARKS)

(a) Find the atomic number of the atom.

(b) Calculate the smallest wavelength emitted in these transitions.

(Take  $hc = 1240 \text{ eV}\cdot\text{nm}$ , ground state energy of hydrogen atom =  $-13.6 \text{ eV}$ )

**Q 34.**

Two metallic plates A and B, each of area  $5 \times 10^{-4} \text{ m}^2$ , are placed parallel to each other at a separation of 1 cm. Plate B carries a positive charge of  $33.7 \times 10^{-12} \text{ C}$ . 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 2eV. Determine

(IIT JEE 2002 – 5 MARKS)

(a) the number of photoelectrons emitted up to  $t = 10 \text{ s}$ ,

(b) the magnitude of the electric field between the plates A and B at  $t = 10 \text{ s}$ , and

(c) the kinetic energy of the most energetic photoelectron emitted at  $t = 10 \text{ s}$  when it reaches plate B.

Neglect the time taken by the photoelectron to reach plate B. Take  $\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 / \text{N}\cdot\text{m}^2$

**Q 35.**

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

(IIT JEE 2003 – 2 MARKS)

**Q 36.**

A radioactive sample emits  $n$   $\beta$ -particles in 2 sec. In next 2 sec it emits  $0.75 n$   $\beta$ -particle, what is the mean life of the sample ?

(IIT JEE 2003 – 2 MARKS)

**Q 37.**

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

(IIT JEE 2003 – 2 MARKS)

**Q 38.**

A radioactive sample of  $^{238}\text{U}$  decays to Pb through a process for which the half-life is  $4.5 \times 10^9$  years. Find the ratio of number of nuclei of Pb to  $^{238}\text{U}$  after a time of  $1.5 \times 10^9$  years. Given  $(2)^{1/3} = 1.26$ .

(IIT JEE 2004 – 2 MARKS)

**Q 39.**

The photons from the Balmer series in Hydrogen spectrum having wavelength between 450 nm to 700 nm are incident on a metal surface of work function 2 eV. Find the maximum kinetic energy of ejected electron. (Given  $hc = 1242$  eV nm)

( IIT JEE 2004 – 4 MARKS)

**Q 40.**

The potential energy of a particle of mass  $m$  is given by

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

$\lambda_1$  and  $\lambda_2$  are the de-Broglie wavelengths of the particle, when  $0 \leq x \leq 1$  and  $x > 1$  respectively. If the total energy of particle is  $2E_0$ , find  $\lambda_1 / \lambda_2$ .

(IIT JEE 2005 – 2 MARKS)

**Q 41.**

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  $K_\alpha$  line of the X-ray produced. ( $R = 1.1 \times 10^7 \text{ m}^{-1}$  and  $c = 3 \times 10^8 \text{ m/s}$ )

(IIT JEE 2005 – 4 MARKS)

**Q 42.**

In hydrogen – like atom ( $z = 11$ ),  $n$ th line of Lyman series has wavelength  $\lambda$ . The de- Broglie's wavelength of electron in the level from which it originated is also  $\lambda$ . Find the value of  $n$ ?

(IIT JEE 2006 – 6 Marks)