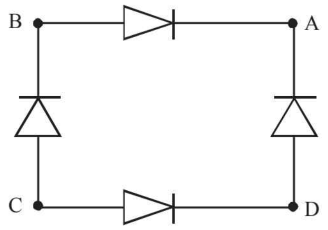
CHAPTER 17

Modern Physics

Section-A JEE Advanced/ IIT-JEE

A Fill in the Blanks

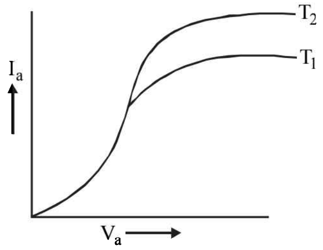
1. To produce characteristic X-rays using a Tungsten target in an X-ray generator, the accelerating voltage should be greater than ___________ volts and the energy of the characteristic radiation is _____eV.
(The binding energy of the innermost electron in Tungsten is 40 keV). *(1983 - 2 Marks)*
2. The radioactive decay rate of a radioactive element is found to be 10^3 disintegration/second at a certain time. If the half life of the element is one second , the decay rate after one second is _______ and after three seconds is _______. *(1983 - 2 Marks)*
3. The maximum kinetic energy of electrons emitted in the photoelectric effect is linearly dependent on the ...... of the incident radiation. *(1984- 2 Marks)*
4. In the Uranium radioactive series the initial nucleus is $^{238}_{92}U$ and the final nucleus is $^{206}_{82}Pb$. When the Uranium nucleus decays to lead, the number of α-particles emitted is ......and the number of β-particles emitted is ..... *(1985 - 2 Marks)*
5. When the number of electrons striking the anode of an X-ray tube is increased, the .... of the emitted X-rays increases, while when the speeds of the electrons striking the anode are increased, the cut-off wavelength of the emitted X-rays......... *(1986 - 2 Marks)*
6. When Boron nucleus $\left(^{10}_{5}B\right)$ is bombarded by neutrons, α-particles are emitted. The resulting nucleus is of the element .... and has the mass number ......*(1986 - 2 Marks)*
7. Atoms having the same .... but different .... are called isotopes. *(1986 - 2 Marks)*
8. 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 .... *(1988 - 2 Marks)*
9. In the forward bias arrangement of a *p-n* junction rectifier, the *p* end is connected to the ....terminal of the battery and the direction of the current is from ....to ....in the rectifier. *(1988 - 2 Marks)*
10. .... biasing of *p-n* junction offers high resistance to current flow across the junction. The biasing is obtained by connecting the *p*- side to the .... terminal of the battery. *(1990 - 2 Marks)*
11. The wavelength of the characteristic X-ray K_α line emitted by a hydrogen like element is 0.32 Å. The wavelength of the K_β line emitted by the same element will be .... *(1990 - 2 Marks)*
12. The Bohr radius of the fifth electron of phosphorous atom (atomic number = 15) acting as a dopant in silicon (relative dielectric constant = 12) is .... Å *(1991 - 1 Mark)*
13. For the given circuit shown in fig. to act as full wave rectifier, the a.c. input should be connected across .... and .... and the d.c. output would appear across .... and .... *(1991 - 1 Mark)*



14. 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-ray inside the tube is .... m/s *(1992 - 1 Mark)*
15. In the Bohr model of the hydrogen atom, the ratio of the kinetic energy to the total energy of the electron in a quantum state *n* is .... *(1992 - 1 Mark)*
16. In the nuclear process, $_6C^{11} \longrightarrow {_5B^{11}} + \beta^+ + X$, X stands for .... *(1992 - 1 Mark)*
17. In a ..... biased p-n junction, the net flow of holes is from the *n* region to the *p* region. *(1993 - 1 Mark)*
18. A potential difference of 20 kV is applied across an X-ray tube. The minimum wavelength of X-rays generated is...........Å. *(1996 - 2 Marks)*
19. The wavelength of K_α X-rays produced by an X-ray tube is 0.76Å. The atomic number of the anode material of the tube is..... *(1996 - 2 Marks)*
20. Consider the following reaction :
$^2_1H + ^2_1H = ^4_2He + Q$
Mass of the deuterium atom = 2.0141 *u*
Mass of helium atom = 4.0024 *u*
This is a nuclear .... reaction in which the energy *Q* released is .... MeV. *(1996 - 2 Marks)*

B True/False

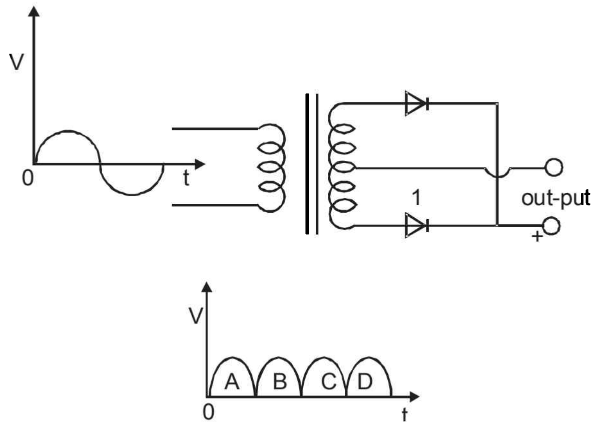
1. The kinetic energy of photoelectrons emitted by a photosensitive surface depends on the intensity of the incident radiation. *(1981- 2 Marks)*
2. In a photoelectric emission process the maximum energy of the photo-electrons increases with increasing intensity of the incident light. *(1986 - 3 Marks)*
3. For a diode the variation of its anode current I_a with the anode voltage V_a at two different cathode temperatures T_1 and T_2 is shown in the figure. The temperature T_2 is greater than T_1. *(1986 - 3 Marks)*



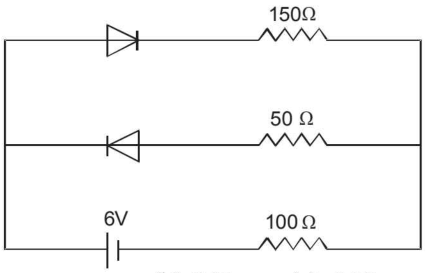
4. The order of magnitude of the density of nuclear matter is 10^4 kg m^{-2}. *(1989 - 2 Marks)*

C MCQs with One Correct Answer

1. The plate resistance of a triode is 3×10^3 ohms and its mutual conductance is 1.5×10^{-3} amp/volt. The amplification factor of the triode is *(1981- 2 - 3 Marks)*
   (a) 5×10^{-5} (b) 4.5 (c) 45 (d) 2×10^5
2. The half life of radioactive Radon is 3.8 days. The time at the end of which $\frac{1}{20}$th of the radon sample will remain undecayed is (given $\log_{10} e = 0.4343$) *(1981- 2 Marks)*
   (a) 3.8 days (b) 16.5 days
   (c) 33 days (d) 76 days.
3. An alpha particle of energy 5 MeV is scattered through 180° by a fixed uranium nucleus. The distance of closest approach is of the order of *(1981- 2 Marks)*
   (a) 1 Å (b) 10^{-10} cm
   (c) 10^{-12}cm (d) 10^{-15} cm
4. Beta rays emitted by a radioactive material are *(1983 - 1 Mark)*
   (a) electromagnetic radiations
   (b) the electrons orbiting around the nucleus
   (c) charged particles emitted by the nucleus
   (d) neutral particles
5. If elements with principal quantum number $n > 4$ were not allowed in nature, the number of possible elements would be *(1983 - 1 Mark)*
   (a) 60 (b) 32 (c) 4 (d) 64
6. Consider the spectral line resulting from the transition $n = 2 \rightarrow n = 1$ in the atoms and ions given below. The shortest wavelength is produced by *(1983 - 1 Mark)*
   (a) Hydrogen atom (b) Deuterium atom
   (c) Singly ionized Helium (d) Doubly ionised Lithium
7. The equation
   $4\,{}^1_1H^+ \longrightarrow {}^4_2He^{2+} + 2e^- + 26\,MeV$ represents *(1983 - 1 Mark)*
   (a) β-decay (b) γ-decay
   (c) fusion (d) fission
8. Fast neutrons can easily be slowed down by *(1994 - 1 Mark)*
   (a) the use of lead shielding
   (b) passing them through water
   (c) elastic collisions with heavy nuclei
   (d) applying a strong electric field.
9. Consider α particles, β particles and γ - rays, each having an energy of 0.5 MeV. In increasing order of penetrating powers, the radiations are: *(1994 - 1 Mark)*
   (a) α, β, γ (b) α, γ, β (c) β, γ, α (d) γ, β, α
10. 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 from a neutral helium atom is *(1995S)*
    (a) 38.2 (b) 49.2 (c) 51.8 (d) 79.0
11. A radioactive material decays by simultaneous emission of two particles with respective half-lives 1620 and 810 years. The time, in years, after which one-fourth of the material remains is *(1995S)*
    (a) 1080 (b) 2430 (c) 3240 (d) 4860
12. The probability of electrons to be found in the conduction band of an intrinsic semiconductor at a finite temperature *(1995S)*
    (a) increases exponentially with increasing band gap
    (b) decreases exponentially with increasing band gap
    (c) decreases with increasing temperature
    (d) is independent of the temperature and the band gap
13. A full-wave rectifier circuit along with the out-put is shown in Figure. The contribution (s) from the diode 1 is (are) *(1996 - 2 Marks)*



    (a) C (b) A,C (c) B, D (d) A,B,C, D.
14. 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 *(1997 - 1 Mark)*
    (a) 1.51 (b) 13.6 (c) 40.8 (d) 122.4
15. The circuit shown in the figure contains two diodes each with a forward resistance of 50 ohms and with infinite backward resistance. If the battery voltage is 6V, the current through the 100 ohm resistance (in amperes) is *(1997 - 1 Mark)*



(a) zero (b) 0.02 (c) 0.03 (d) 0.036.

16. Which of the following statements is not true? ***(1997 - 1 Mark)***
(a) The resistance of intrinsic semiconductors decrease with increase of temperature
(b) Doping pure Si with trivalent impurities give *p*-type semiconductors
(c) The majority carriers in *n*-type semiconductors are holes
(d) A *p-n* junction can act as a semiconductor diode

17. 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 volt, is ***(1997 - 1 Mark)***
(a) 2 (b) 4 (c) 6 (d) 10

18. In hydrogen spectrum the wavelength of H_α line is 656 nm, whereas in the spectrum of a distant galaxy, H_α line wavelength is 706 nm. Estimated speed of the galaxy with respect to earth is, ***(1999S - 2 Marks)***
(a) 2×10^8 m/s (b) 2×10^7 m/s
(c) 2×10^6 m/s (d) 2×10^5 m/s

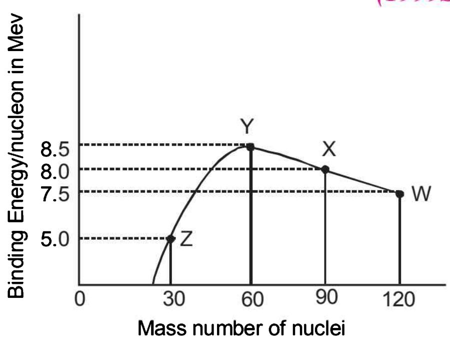
19. A particle of mass M at rest decays into two particles of masses m_1 and m_2, having non-zero velocities. The ratio of the de Broglie wavelengths of the particles, λ_1/λ_2, is ***(1999S - 2 Marks)***
(a) m_1/m_2 (b) m_2/m_1 (c) 1.0 (d) $\sqrt{m_2}/\sqrt{m_1}$

20. Which of the following is a correct statement? ***(1999S - 2 Marks)***
(a) Beta rays are same as cathode rays
(b) Gamma rays are high energy neutrons
(c) Alpha particles are singly ionised helium atoms
(d) Protons and neutrons have exactly the same mass

21. Order of magnitude of density of uranium nucleus is, [$m_p = 1.67 \times 10^{-27}$kg] ***(1999S - 2 Marks)***
(a) 10^{20}kg/m^3 (b) 10^{17}kg/m^3
(c) 10^{14}kg/m^3 (d) 10^{11}kg/m^3

22. ^{22}Ne nucleus, after absorbing energy, decays into two α-particles and an unknown nucleus. The unknown nucleus is ***(1999S - 2 Marks)***
(a) nitrogen (b) carbon (c) boron (d) oxygen

23. 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 ***(1999S - 2 Marks)***



(a) $Y \rightarrow 2Z$ (b) $W \rightarrow X + Z$
(c) $W \rightarrow 2Y$ (d) $X \rightarrow Y + Z$

24. 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 ***(2000S)***
(a) $9/(5R)$ (b) $36/(5R)$ (c) $18/(5R)$ (d) $4/R$

25. The electron in a hydrogen atom makes a transition from an excited state to the ground state. Which of the following statements is true ? ***(2000S)***
(a) Its kinetic energy increases and its potential and total energies decreases.
(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.

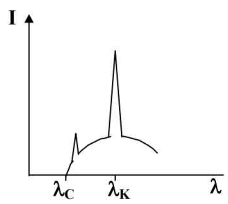
26. Two radioactive materials X_1 and X_2 have decay constants 10λ and λ respectively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of X_1 to that of X_2 will be $1/e$ after a time ***(2000S)***
(a) $\frac{1}{10\lambda}$ (b) $\frac{1}{11\lambda}$ (c) $\frac{11}{10\lambda}$ (d) $\frac{1}{9\lambda}$

27. Electrons with energy 80 keV are incident on the tungsten target of an X-ray tube. K-shell electrons of tungsten have 72.5 keV energy. X-rays emitted by the tube contain only
(a) a continuous X-ray spectrum (Bremsstrahlung) with a minimum wavelength of 0.155Å ***(2000S)***
(b) a continuous X-ray spectrum (Bremsstrahlung) with all wavelengths
(c) the characteristic X-ray spectrum of tungsten
(d) a continuous X-ray spectrum (Bremsstrahlung) with a minimum wavelength of 0.155Å and the characteristic X-ray spectrum of tungsten.

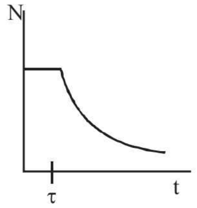
28. The electron emitted in beta radiation originates from
(a) inner orbits of atoms ***(2001S)***
(b) free electrons existing in nuclei
(c) decay of a neutron in a nucleus
(d) photon escaping from the nucleus

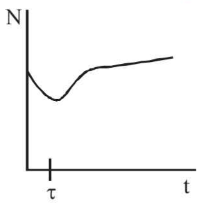
29. The transition from the state $n = 4$ to $n = 3$ in a hydrogen-like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition ***(2001S)***
(a) $2 \rightarrow 1$ (b) $3 \rightarrow 2$ (c) $4 \rightarrow 2$ (d) $5 \rightarrow 4$

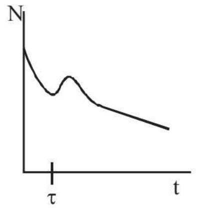
30. The intensity of X-rays from a Coolidge tube is plotted against wavelength λ as shown in the figure. The minimum wavelength found is λ_C and the wavelength of the K_α line is λ_K. As the accelerating voltage is increased ***(2001S)***
(a) $\lambda_K - \lambda_C$ increases
(b) $\lambda_K - \lambda_C$ decreases
(c) λ_K increases
(d) λ_K decreases

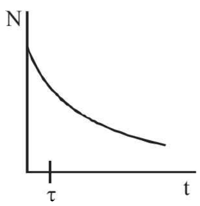


31. A radioactive sample consists of two distinct species having equal number of atoms initially. The mean life time of one species is τ and that of the other is 5τ. The decay products in both cases are stable. A plot is made of the total number of radioactive nuclei as a function of time. Which of the following figures best represent the form of this plot? ***(2001S)***

(a) 

(b) 

(c) 

(d) 

32. The potential difference applied to an X-ray tube is 5kV and the current through it is 3.2*mA*. Then the number of electrons striking the target per second is ***(2002S)***

(a) 2×10^{16} (b) 5×10^{6} (c) 1×10^{17} (d) 4×10^{15}

33. A Hydrogen atom and a 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 ***(2002S)***

(a) $\ell_H > \ell_{Li}$ and $|E_H| > |E_{Li}|$ (b) $\ell_H = \ell_{Li}$ and $|E_H| < |E_{Li}|$

(c) $\ell_H = \ell_{Li}$ and $|E_H| > |E_{Li}|$ (d) $\ell_H < \ell_{Li}$ and $|E_H| < |E_{Li}|$

34. 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 ***(2002S)***

(a) 400 μs (b) 6.3 μs (c) 40 μs (d) 300 μs

35. Which of the following processes represents a γ-decay? ***(2002S)***

(a) $^AX_z + \gamma \longrightarrow {}^AX_{Z-1} + a + b$

(b) $^AX_z + {}^1n_o \longrightarrow {}^{A-3}X_{Z-2} + c$

(c) $^AX_z \longrightarrow {}^AX_Z + f$

(d) $^AX_z + e_{-1} \longrightarrow {}^AX_{Z-1} + g$

36. The electric potential between a proton and an electron is given by $V = V_0 \ln \dfrac{r}{r_0}$, where r_0 is a constant. Assuming Bohr's model to be applicable, write variation of r_n with n, n being the principal quantum number? ***(2003S)***

(a) $r_n \propto n$ (b) $r_n \propto 1/n$

(c) $r_n \propto n^2$ (d) $r_n \propto 1/n^2$

37. If the atom $_{100}Fm^{257}$ follows the Bohr model and the radius of $_{100}Fm^{257}$ is n times the Bohr radius, then find n. ***(2003S)***

(a) 100 (b) 200 (c) 4 (d) 1/4

38. For uranium nucleus how does its mass vary with volume? ***(2003S)***

(a) $m \propto V$ (b) $m \propto 1/V$

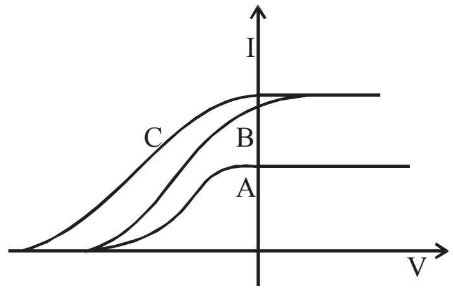
(c) $m \propto \sqrt{V}$ (d) $m \propto V^2$

39. A nucleus with mass number 220 initially at rest emits an α-particle. If the Q value of the reaction is 5.5 MeV, calculate the kinetic energy of the α-particle ***(2003S)***

(a) 4.4 MeV (b) 5.4 MeV

(c) 5.6 MeV (d) 6.5 MeV

40. In a photoelectric experiment anode potential is plotted against plate current. ***(2004S)***



(a) *A* and *B* will have different intensities while *B* and *C* will have different frequencies

(b) *B* and *C* will have different intensities while *A* and *C* will have different frequencies

(c) *A* and *B* will have different intensities while *A* and *C* will have equal frequencies

(d) *B* and *C* will have equal intensities while *A* and *B* will have same frequencies

41. A 280 days old radioactive substance shows an activity of 6000 dps, 140 days later its activity becomes 3000 dps. What was its initial activity? ***(2004S)***

(a) 20000 dps (b) 24000 dps

(d) 12000 dps (d) 6000 dps

42. A proton has kinetic energy $E = 100$ keV which is equal to that of a photon. The wavelength of photon is λ_2 and that of proton is λ_1. The ration of λ_2/λ_1 is proportional to ***(2004S)***

(a) E^2 (b) $E^{1/2}$

(c) E^{-1} (d) $E^{-1/2}$

43. K_α wavelength emitted by an atom of atomic number $Z = 11$ is λ. Find the atomic number for an atom that emits K_α radiation with wavelength 4λ. ***(2005S)***

(a) $Z = 6$ (b) $Z = 4$ (c) $Z = 11$ (d) $Z = 44$

44. A photon collides with a stationary hydrogen atom in ground state inelastically. Energy of the colliding photon is 10.2 eV. After a time interval of the order of micro second another photon collides with same hydrogen atom inelastically with an energy of 15 eV. What will be observed by the detector? ***(2005S)***

(a) One photon of energy 10.2 eV and an electron of energy 1.4 eV

(b) 2 photon of energy of 1.4 eV

(c) 2 photon of energy 10.2 eV

(d) One photon of energy 10.2 eV and another photon of 1.4 eV

45. A beam of electron is used in an YDSE experiment. The slit width is d. When the velocity of electron is increased, then *(2005S)*
(a) no interference is observed
(b) fringe width increases
(c) fringe width decreases
(d) fringe width remains same

46. If a star can convert all the He nuclei completely into oxygen nuclei, the energy released per oxygen nuclei is [Mass of He nucleus is 4.0026 amu and mass of Oxygen nucleus is 15.9994 amu] *(2005S)*
(a) 7.6 MeV (b) 56.12 MeV
(c) 10.24 MeV (d) 23.9 MeV

47. ${}^{221}_{87}Ra$ is a radioactive substance having half life of 4 days. Find the probability that a nucleus undergoes decay after two half lives *(2006 - 3M, –1)*
(a) 1 (b) $\frac{1}{2}$ (c) $\frac{3}{4}$ (d) $\frac{1}{4}$

48. In the options given below, let E denote the rest mass energy of a nucleus and n a neutron. The correct option is *(2007)*
(a) $E\left({}^{236}_{92}U\right) > E\left({}^{137}_{53}I\right) + E\left({}^{97}_{39}Y\right) + 2E(n)$
(b) $E\left({}^{236}_{92}U\right) < E\left({}^{137}_{53}I\right) + E\left({}^{97}_{39}Y\right) + 2E(n)$
(c) $E\left({}^{236}_{92}U\right) < E\left({}^{140}_{56}Ba\right) + E\left({}^{94}_{36}Kr\right) + 2E(n)$
(d) $E\left({}^{236}_{92}U\right) = E\left({}^{140}_{56}Ba\right) + E\left({}^{94}_{36}Kr\right) + 2E(n)$

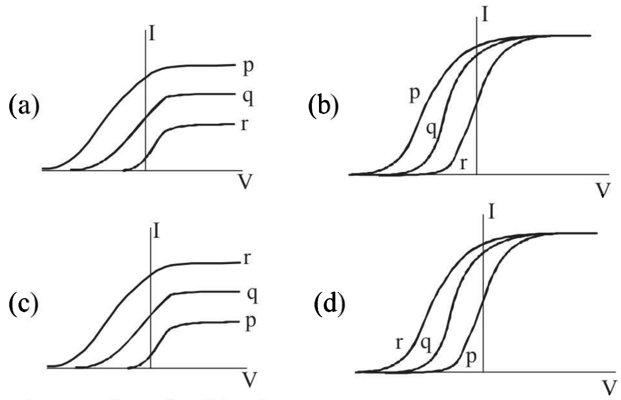
49. The largest wavelength in the ultraviolet region of the hydrogen spectrum is 122 nm. The smallest wavelength in the infrared region of the hydrogen spectrum (to the nearest integer) is *(2007)*
(a) 802 nm (b) 823 nm
(c) 1882 nm (d) 1648 nm

50. Electrons with de-Broglie wavelength λ fall on the target in an X-ray tube. The cut-off wavelength of the emitted X-rays is *(2007)*
(a) $\lambda_0 = \frac{2mc\lambda^2}{h}$ (b) $\lambda_0 = \frac{2h}{mc}$
(c) $\lambda_0 = \frac{2m^2c^2\lambda^3}{h^2}$ (d) $\lambda_0 = \lambda$

51. Which one of the following statements is WRONG in the context of X-rays generated from a X-ray tube? *(2008)*
(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-ray tube
(d) Cut-off wavelength of the continuous X-rays depends on the energy of the electrons in the X-ray tube

52. A radioactive sample S_1 having an activity 5μCi has twice the number of nuclei as another sample S_2 which has an activity of 10 μCi. The half lives of S_1 and S_2 can be *(2008)*
(a) 20 years and 5 years, respectively
(b) 20 years and 10 years, respectively
(c) 10 years each
(d) 5 years each

53. Photoelectric effect experiments are performed using three different metal plates p, q and r having work functions ϕ_p = 2.0 eV, ϕ_q = 2.5 eV and ϕ_r = 3.0 eV, respectively. A light beam containing wavelengths of 550 nm, 450 nm 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] *(2009)*



54. The wavelength of the first spectral line in the Balmer series of hydrogen atom is 6561 A°. The wavelength of the second spectral line in the Balmer series of singly-ionized helium atom is *(2011)*
(a) 1215 A° (b) 1640 A° (c) 2430 A° (d) 4687 A°

55. A pulse of light of duration 100 ns is absorbed completely by a small object initially at rest. Power of the pulse is 30 mW and the speed of light is 3×10^8 ms^{-1}. The final momentum of the object is *(JEE Adv. 2013)*
(a) 0.3×10^{-17} kg ms^{-1} (c) 3.0×10^{-17} kg ms^{-1}
(b) 1.0×10^{-17} kg ms^{-1} (d) 9.0×10^{-17} kg ms^{-1}

56. If λ_{Cu} is the wavelength of K_α X-ray line of copper (atomic number 29) and λ_{Mo} is the wavelength of the K_α X-ray line of molybdenum (atomic number 42), then the ratio $\lambda_{Cu}/\lambda_{Mo}$ is close to *(JEE Adv. 2014)*
(a) 1.99 (b) 2.14 (c) 0.50 (d) 0.48

57. A metal surface is illuminated by light of two different wavelengths 248 nm and 310 nm. The maximum speeds of the photoelectrons corresponding to these wavelengths are u_1 and u_2, respectively. If the ratio $u_1 : u_2 = 2 : 1$ and hc = 1240 eV nm, the work function of the metal is nearly *(JEE Adv. 2014)*
(a) 3.7 eV (b) 3.2 eV (c) 2.8 eV (d) 2.5 eV

58. In a historical experiment to determine Planck's constant, a metal surface was irradiated with light of different wavelengths. The emitted photoelectron energies were measured by applying a stopping potential. The relevant data for the wavelength (λ) of incident light and the corresponding stopping potential (V_0) are given below :

λ (μm)	V_0 (Volt)
0.3	2.0
0.4	1.0
0.5	0.4

Given that $c = 3 \times 10^8 m s^{-1}$ and $e = 1.6 \times 10^{-19} C$, Planck's constant (in units of J s) found from such an experiment is *(JEE Adv. 2016)*

(a) 6.0×10^{-34} (b) 6.4×10^{-34}
(c) 6.6×10^{-34} (d) 6.8×10^{-34}

59. The electrostatic energy of Z protons uniformly distributed throughout a spherical nucleus of radius R is given by

$$E = \frac{3}{5}\frac{Z(Z-1)e^2}{4\pi\varepsilon_0 R}$$

The measured masses of the neutron ^1_1H, $^{15}_7N$ and $^{15}_8O$ are 1.008665 u, 1.007825 u, 15.000109 u and 15.003065 u, respectively. Given that the radii of both the $^{15}_7N$ and $^{15}_8O$ nuclei are same, 1 u = 931.5 Me V/c^2 (c is the speed of light) and $e^2/(4\pi\varepsilon_0) = 1.44$ MeV fm. Assuming that the difference between the binding energies of $^{15}_7N$ and $^{15}_8O$ is purely due to the electrostatic energy, the radius of either of the nuclei is
(1 fm = 10^{-15} m) *(JEE Adv. 2016)*

(a) 2.85 fm (b) 3.03 fm
(c) 3.42 fm (d) 3.80 fm

60. An accident in a nuclear laboratory resulted in deposition of a certain amount of radioactive material of half-life 18 days inside the laboratory. Tests revealed that the radiation was 64 times more than the permissible level required for safe operation of the laboratory. What is the minimum number of days after which the laboratory can be considered safe for use? *(JEE Adv. 2016)*

(a) 64 (b) 90
(c) 108 (d) 120

D MCQs with One or More than One Correct

1. The shortest wavelength of X-rays emitted from an X-ray tube depends on *(1982 - 3 Marks)*
(a) the current in the tube
(b) the voltage applied to the tube
(c) the nature of the gas in tube
(d) the atomic number of the target material

2. The threshold wavelength for photoelectric emission from a material is 5200 Å. Photoelectrons will be emitted when this material is illuminated with monochromatic radiation from a *(1982 - 3 Marks)*
(a) 50 watt infrared lamp (b) 1-watt infra-red lamp
(c) 50 watt ultraviolet lamp (d) 1-watt ultraviolet lamp

3. From the following equations pick out the possible nuclear fusion reactions *(1984- 2 Marks)*
(a) ${}_6C^{13} + {}_1H^1 \rightarrow {}_6C^{14} + 4.3MeV$
(b) ${}_6C^{12} + {}_1H^1 \rightarrow {}_7N^{13} + 2MeV$
(c) ${}_7N^{14} + {}_1H^1 \rightarrow {}_8O^{15} + 7.3MeV$
(d) ${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{54}Xe^{140} + {}_{38}Sr^{94} + {}_0n^1 + {}_0n^1 + \gamma + 200MeV$

4. In Bohr's model of the hydrogen atom *(1984- 2 Marks)*
(a) the radius of the nth orbit is proportional to n^2
(b) the total energy of the electron in nth orbit is inversely proportional to n
(c) the angular momentum of the electron in an orbit is an integral multiple of $\frac{h}{2\pi}$
(d) the magnitude of potential energy of the electron in any orbit is greater than its K.E.

5. Select the correct statement from the following *(1984- 2 Marks)*
(a) A diode can be used as a rectifier
(b) A triode cannot be used as a rectifier
(c) The current in a diode is always proportional to the applied voltage
(d) The linear portion of the I–V characteristic of a triode is used for amplification without distortion

6. For a given plate voltage, the plate current in a triode valve is maximum when the potential of *(1985 - 2 Marks)*
(a) the grid is positive and plate is negative
(b) the grid is zero and plate is positive
(c) the grid is negative and plate is positive
(d) the grid is positive and plate is positive

7. The X-ray beam coming from an X-ray tube will be *(1985 - 2 Marks)*
(a) monochromatic
(b) having all wavelengths smaller than a certain maximum wavelength
(c) having all wavelengths larger than a certain minimum wavelength
(d) having all wavelengths lying between a minimum and a maximum wavelength

8. The mass number of a nucleus is *(1986 - 2 Marks)*
(a) always less than its atomic number
(b) always more than its atomic number
(c) sometimes equal to its atomic number
(d) sometimes more than and sometimes equal to its atomic number

9. Four physical quantities are listed in Column I. Their values are listed in Column II in a random order: *(1987 - 2 Marks)*

Column I	Column II
(a) Thermal energy of air molecules at room temp	(e) 0.02 eV
(b) Binding energy of heavy nuclei per nucleon	(f) 2 eV
(c) X-ray photon energy	(g) 1k eV
(d) Photon energy of visible light	(h) 7 MeV

The correct matching of Columns I and II is given by
(a) $a-e, b-h, c-g, d-f$
(b) $a-e, b-g, c-f, d-h$
(c) $a-f, b-e, c-g, d-h$
(d) $a-f, b-h, c-e, d-g$.

10. Photoelectric effect supports quantum nature of light because *(1987 - 2 Marks)*
(a) there is a minimum frequency of light below which no photoelectrons are emitted
(b) the maximum kinetic energy of photo electrons 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 the photoelectrons is quantized

11. During a negative beta decay *(1987 - 2 Marks)*
(a) an atomic electron is ejected
(b) an electron which is already present within the nucleus is ejected
(c) a neutron in the nucleus decays emitting an electron
(d) a part of the binding energy of the nucleus is converted into an electron

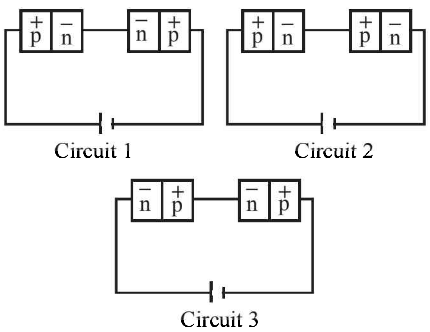
12. During a nuclear fusion reaction *(1987 - 2 Marks)*
(a) a heavy nucleus breaks into two fragments by itself
(b) a light nucleus bombarded by thermal neutrons breaks up
(c) a heavy nucleus bombarded by thermal neutrons breaks up
(d) two light nuclei combine to give a heavier nucleus and possibly other products

13. The potential difference applied to an X-ray tube is increased. As a result, in the emitted radiation
(a) the intensity increases *(1988 - 2 Marks)*
(b) the minimum wavelength increases
(c) the intensity remain unchanged
(d) the minimum wavelength decreases

14. A freshly prepared radioactive source of half life 2 hr emits radiation of intensity which is 64 times the permissibe safe level. The minimum time after which it would be possible to work safely with this source is *(1988 - 2 Marks)*
(a) 6 hr (b) 12 hr
(c) 24 hr (d) 128 hr

15. The impurity atoms with which pure silicon should be doped to make a *p*-type semiconductor are those of *(1988 - 2 Marks)*
(a) phosphorus (b) boron
(c) antimony (d) aluminium

16. Two identical *p-n* junctions may be connected in series with a battery in three ways, fig. The potential drops across the two $p-n$ junctions are equal in *(1989 - 2 Marks)*



(a) circuit 1 and circuit 2 (b) circuit 2 and circuit 3
(c) circuit 3 and circuit 1 (d) circuit 1 only

17. The decay constant of a radioactive sample is λ. The half-life and mean-life of the sample are respectively given by *(1989 - 2 Marks)*
(a) $1/\lambda$ and $(ln\,2)/\lambda$ (b) $(ln\,2)/\lambda$ and $1/\lambda$
(c) $\lambda\,(ln\,2)$ and $1/\lambda$ (d) $\lambda/(ln\,2)$ and $1/\lambda$

18. 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 V and 18.0 mA. If the same source is placed 0.6 m away from the photoelectric cell, then *(1992 - 2 Marks)*
(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

19. In an *n-p-n* transistor circuit, the collector current is 10 mA. If 90% of the electrons emitted reach the collector, *(1992 - 2 Marks)*
(a) the emitter current will be 9 mA
(b) the base current will be 1 mA
(c) the emitter current will be 11 mA
(d) the base current will be – 1 mA

20. A star initially has 10^{40} deuterons. It produces energy via the processes ${}_1H^2 + {}_1H^2 \rightarrow {}_1H^3 + p$, and ${}_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + n$. 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 *(1993-2 Marks)*
(a) $10^6 s$. (b) $10^8 s$.
(c) $10^{12} s$. (d) $10^{16} s$.
The masses of the nuclei are as follows :
$M(H^2) = 2.014$ amu;
$M(p) = 1.007$ amu; $M(n) = 1.008$ amu; $M(He^4) = 4.001$ amu.

21. When photons of energy 4.25 eV strike the surface of 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 *(1994 - 2 Marks)*
(a) The work function of *A* is 2.25 eV
(b) The work function of *B* is 4.20 eV
(c) $T_A = 2.00$ eV
(d) $T_B = 2.75$ eV

22. Which of the following statement(s) is (are) correct? *(1994 - 2 Marks)*
(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 fission, energy is released by fusing two nuclei of medium mass (approximately 100 amu)
(d) In nuclear fission, energy is released by fragmentation of a very heavy nucleus

23. Holes are charge carriers in *(1996 - 2 Marks)*
(a) intrinsic semiconductors (b) ionic solids
(c) *p*-type semiconductors (d) metals

24. A transistor is used in the common emitter mode as an amplifier. Then *(1998S - 2 Marks)*
(a) the base-emitter junction is forward-biased
(b) the base-emitter junction is reverse-biased
(c) the input signal is connected in series with the voltage applied to bias the base-emitter junction
(d) the input signal is connected in series with the voltage applied to bias the base-collector junction

25. 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 and M_2 the mass of a $^{40}_{20}Ca$ nucleus. Then *(1998S - 2 Marks)*

(a) $M_2 = 2M_1$ (b) $M_2 > 2M_1$

(c) $M_2 < 2M_1$ (d) $M_1 < 10(m_n + m_p)$

26. The electron in a hydrogen atom makes a transition $n_1 \to n_2$ where n_1 and 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 and n_2 are *(1998S - 2 Marks)*

(a) $n_1 = 4, n_2 = 2$ (b) $n_1 = 8, n_2 = 2$

(c) $n_1 = 8, n_2 = 1$ (d) $n_1 = 6, n_2 = 3$

27. The half-life of ^{131}I is 8 days. Given a sample of ^{131}I at time $t = 0$, we can assert that *(1998S - 2 Marks)*

(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 $t = 0$

28. In a *p-n* junction diode not connected to any circuit, *(1998S - 2 Marks)*

(a) the potential is the same everywhere

(b) the *p*-type side is at a higher potential than the *n*-type side

(c) there is an electric field at the junction directed from the *n*-type side to the *p*-type side

(d) there is an electric field at the junction directed from the *p*-type side to the *n*-type side

29. 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 *(1998S - 2 Marks)*

(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 $0 < \lambda_{min} < \lambda_{max} < \infty$

30. 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 *(1998S - 2 Marks)*

(a) 540 nm (b) 400 nm

(c) 310 nm (d) 220 nm

31. 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 *(1999S - 3 Marks)*

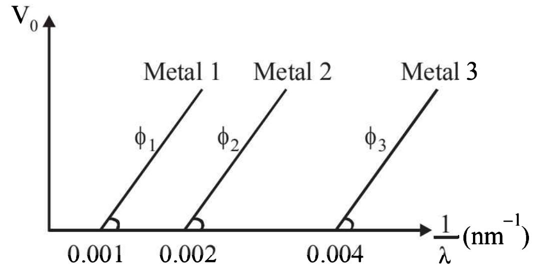
(a) *X* and *Y* have the same decay rate initially

(b) *X* and *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*

32. The graph between the stopping potential (V_0) and $\left(\frac{1}{\lambda}\right)$ is shown in the figure. ϕ_1, ϕ_2 and ϕ_3 are work functions, which of the following is/are correct **(2006 - 5M, –1)**



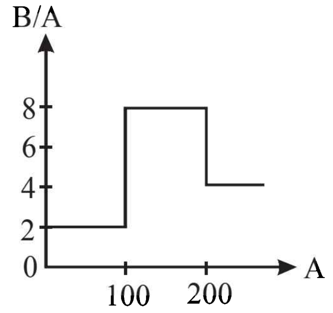
(a) $\phi_1 : \phi_2 : \phi_3 = 1 : 2 : 4$

(b) $\phi_1 : \phi_2 : \phi_3 = 4 : 2 : 1$

(c) $\tan\theta \propto \frac{hc}{e}$

(d) ultravioletlight can be used to emit photoelectrons from metal 2 and metal 3 only

33. Assume that the nuclear binding energy per nucleon (B/A) versus mass number (A) is as shown in the figure. Use this plot to choose the correct choice(s) given below. *(2008)*



(a) Fusion of two nuclei with mass numbers lying in the range of $1 < A < 50$ will release energy.

(b) Fusion of two nuclei with mass numbers lying in the range of $51 < A < 100$ will release energy

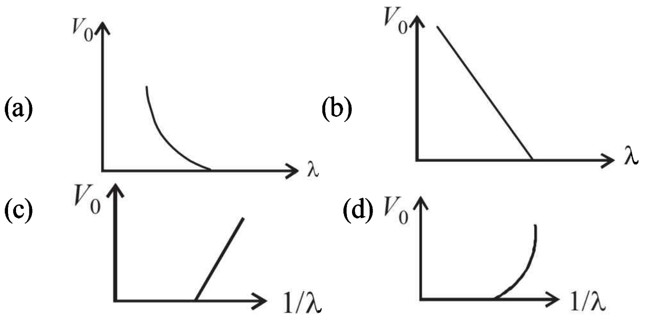
(c) Fission of a nucleus lying in the mass range of $100 < A < 200$ will release energy when broken into two equal fragments

(d) Fission of a nucleus lying in the mass range of $200 < A < 260$ will release energy when broken into two equal fragments

34. The radius of the orbit of an electron in a Hydrogen-like atom is 4.5 a_0, where a_0 is the Bohr radius. Its orbital angular momentum is $\frac{3h}{2\pi}$. It is given that h is Planck constant and R is Rydberg constant. The possible wavelength(s), when the atom de-excites, is (are) *(JEE Adv. 2013)*

(a) $\frac{9}{32R}$ (b) $\frac{9}{16R}$ (c) $\frac{9}{5R}$ (d) $\frac{4}{3R}$

35. For photo-electric effect with incident photon wavelength λ, the stopping potential is V_0. Identify the correct variation(s) of V_0 with λ and $1/\lambda$. *(JEE Adv. 2015)*



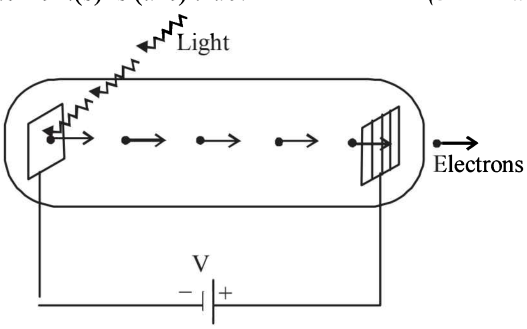
36. A fission reaction is given by ${}^{236}_{92}U \rightarrow {}^{140}_{54}Xe + {}^{94}_{38}Sr + x + y$, where x and y are two particles. Considering ${}^{236}_{92}U$ to be at rest, the kinetic energies of the products are denoted by K_{Xe}, K_{Sr}, K_x(2 MeV) and K_y(2 MeV), respectively. Let the binding energies per nucleon of ${}^{236}_{92}U$, ${}^{140}_{54}Xe$ and ${}^{94}_{38}Sr$ be 7.5 MeV, 8.5 MeV and 8.5 MeV, respectively. Considering different conservation laws, the correct option(s) is(are) *(JEE Adv. 2015)*

(a) $x = n, y = n, K_{Sr} = 129$ MeV, $K_{Xe} = 86$ MeV
(b) $x = p, y = e^-, K_{Sr} = 129$ MeV, $K_{Xe} = 86$ MeV
(c) $x = p, y = n, K_{Sr} = 129$ MeV, $K_{Xe} = 86$ MeV
(d) $x = n, y = n, K_{Sr} = 86$ MeV, $K_{Xe} = 129$ MeV

37. Highly excited states for hydrogen–like atoms (also called Rydberg states) with nuclear charge Ze are defined by their principal quantum number n, where n>>1. Which of the following statement(s) is(are) true? *(JEE Adv. 2016)*

(a) Relative change in the radii of two consecutive orbitals does not depend on Z
(b) Relative change in the radii of two consecutive orbitals varies as 1/n
(c) Relative change in the energy of two consecutive orbitals varies as $1/n^3$
(d) Relative change in the angular momenta of two consecutive orbitals varies as 1/n

38. Light of wavelength λ_{ph} falls on a cathode plate inside a vacuum tube as shown in the figure. The work function of the cathode surface is ϕ and the anode is a wire mesh of conducting material kept at a distance d from the cathode. A potential difference V is maintained between the electrodes. If the minimum de Broglie wavelength of the electrons passing through the anode is λ_e, which of the following statement(s) is (are) true? *(JEE Adv. 2016)*



(a) λ_e decreases with increase in ϕ and λ_{ph}
(b) λ_e is approximately halved, if d is doubled
(c) For large potential difference ($V >> \phi/e$), λ_e is approximately halved if V is made four times
(d) λ_e increases at the same rate as λ_{ph} for $\lambda_{ph} < hc/\phi$

E Subjective Problems

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. Find *(1981- 10 Marks)*

(i) The value of Z.
(ii) The energy required to excite the electron from the third to the fourth Bohr orbit.
(iii) The wavelength of the electromagnetic radiation required to remove the electron from the first Bohr orbit to infinity.
(iv) The kinetic energy, potential energy, potential energy and the angular momentum of the electron in the first Bohr orbit.
(v) The radius of the first Bohr orbit.

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

2. Hydrogen atom in its ground state is excited by means of monochromatic radiation of wavelength 975Å. 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. *(1982 - 5 Marks)*

3. How many electron, protons and neutrons are there in a nucleus of atomic number 11 and mass number 24 ? *(1982 - 2 Marks)*

(i) number of electrons = (ii) number of protons =
(iii) number of neutrons =

4. The ionization energy of a hydrogen like Bohr atom is 4 Rydbergs. (i) What is the wavelength of the radiation emitted when the electron jumps from the first excited state to the ground state ? (ii) What is the radius of the first orbit for this atom? *(1984- 4 Marks)*

5. A double ionised Lithium atom is hydrogen-like with atomic number 3. *(1985 - 6 Marks)*

(i) Find the wavelength of the radiation required to excite the electron in Li^{++} from the first to the third Bohr orbit. (Ionisation energy of the hydrogen atom equals 13.6 eV.)
(ii) How many spectral lines are observed in the emission spectrum of the above excited system?

6. 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 :

$$I = 0.125V - 7.5$$

For grid voltage of – 3 volts, the current at anode voltage of 300 volts is 5 milliampere. Determine the plate resistance (r_p), transconductance (g_m) and the amplification factor (μ) for the triode. *(1987 - 7 Marks)*

7. 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. ***(1988 - 6 Marks)***

(i) Derive an expression for the radius of the nth Bohr orbit.

(ii) 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.

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

8. 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 by 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. ***(1989 - 8 Marks)***

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

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

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

9. 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. ***(1990 - 7 Marks)***

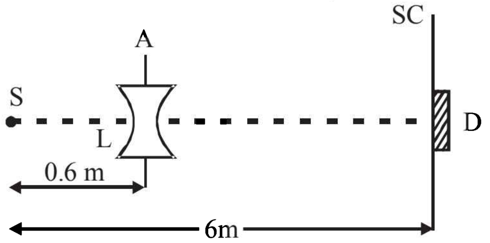
(Rydberg constant = $1.094 \times 10^7 \text{m}^{-1}$)

10. It is proposed to use the nuclear fusion reaction

$${}_1^2\text{H} + {}_1^2\text{H} \rightarrow {}_2^4\text{He} \qquad \textit{(1990 - 8 Marks)}$$

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 ${}_1^2\text{H}$ and ${}_2^4\text{He}$ are 2.0141 atomic mass units and 4.0026 atomic mass units respectively)

11. A monochromatic point source radiating wavelength 6000 Å, with power 2 watt, an aperture A of diameter 0.1 m and a large screen SC are placed as shown in fig. 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. ***(1991 - 2 + 4 + 2 Marks)***



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

(b) 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.

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

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

$${}_{92}^{A}X \rightarrow {}_{Z}^{228}Y + \alpha \qquad \textit{(1991 - 4 + 4 Marks)}$$

(a) Find the values of A and Z in the above process.

(b) 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 : $m(Y) = 228.03\,u$; $m\left({}_0^1n\right) = 1.009\,u$.

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

13. 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 ***(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 hydrogen atom 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)

14. A small quantity of solution containing 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 cm^3 taken after 5 hour show 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 = 3.7×10^{10} disintegrations per second) ***(1994 - 6 Marks)***

15. A hydrogen like atom (atomic number Z) is in a 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. ***(1994 - 6 Marks)***
Determine the values of n and Z. (Ionization energy of H-atom = 13.6 eV)

16. 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. *(1996 - 3 Marks)*

17. 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. *(1996 - 3 Marks)*

18. 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 2Å. 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. *(1997 - 5 Marks)*

19. The element Curium $^{248}_{96}$Cm has a mean life of 10^{13} seconds. Its pirmary 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* and $^{4}_{2}$He=4.002603 *u*. Calculate the power output from a sample of 10^{20} Cm atoms. (1 u = 931 MeV/c^2.) *(1997 - 5 Marks)*

20. 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. *(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 $t \to \infty$.

21. 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 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 4 eV range, that are likely to be emitted during and after the combination. [Take h = 4.14×10^{-15} eV.s.] *(1999 - 5 Marks)*

22. 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. *(2000 - 6 Marks)*

23. When a beam of 10.6 eV photons of intensity 2.0 W/m^2 falls on a platinum surface of area 1.0×10^{-4} m^2 and work function 5.6 eV, 0.53% of the incident photons eject photoelectrons. Find the number of photoelectrons emitted per second and their minimum and maximum energies (in eV). Take 1eV = 1.6×10^{-19} J. *(2000 - 4 Marks)*

24. In a nuclear reaction ^{235}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. *(2001 - 5 Marks)*

25. A nucleus at rest undergoes a decay emitting an α particle of de-Broglie wavelength $\lambda = 5.76 \times 10^{-15}$ m. If the mass of the daughter nucleus is 223.610 amu and that of the α 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 amu = 931.470 MeV/c^2) *(2001-5 Marks)*

26. A radioactive nucleus *X* decays to a nucleus *Y* with a decay constant $\lambda_x = 0.1$ s^{-1}. *Y* further decays to a stable nucleus *Z* with a decay constant $\lambda_Y = 1/30$ s^{-1}. Initially, there are only *X* nuclei and their number is $N_o = 10^{20}$. 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 $N_Y(t) = (N_o\lambda_X/(\lambda_X - \lambda_Y))\{\exp(-\lambda_Y t)-\exp(-\lambda_x t)\}$. Find the time at which N_Y is maximum and determine the populations *X* and *Z* at that instant. *(2001-5 Marks)*

27. 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 have energies between -0.85 eV and -0.544 eV (**including** both these values). *(2002 - 5 Marks)*
(a) Find the atomic number of the atom.
(b) Calculate the smallest wavelength emitted in these transitions.
(Take *hc* = 1240 eV-nm, ground state energy of hydrogen atom = –13.6 eV)

28. Two metallic plates *A* and *B*, each of area 5×10^{-4} m^2, are placed parallel to each other 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 2eV. Determine *(2002 - 5 Marks)*
(a) the number of photoelectrons emitted up to $t = 10$ s,
(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 the photoelectron to reach plate *B*. Take $\varepsilon_0 = 8.85 \times 10^{-12}$ C^2/N-m^2

29. Frequency of a photon emitted due to transition of electron of a certain element from *L* to *K* shell is found to be 4.2×10^{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}. *(2003 - 2 Marks)*

30. A radioactive sample emits *n* β-particles in 2 sec. In next 2 sec it emits 0.75 *n* β-particle, what is the mean life of the sample? *(2003 - 2 Marks)*

31. 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 $i_A = 4\mu A$ 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 2×10^{-5} W/m^2. *(2003 - 2 Marks)*

32. A radioactive sample of ^{238}U decays to Pb through a process for which the half-life is 4.5×10^9 years. Find the ratio of number of nuclei of Pb to ^{238}U after a time of 1.5×10^9 years. Given $(2)^{1/3} = 1.26$. *(2004 - 2 Marks)*

33. 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) *(2004 - 4 Marks)*

34. 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. *(2005 - 2 Marks)*

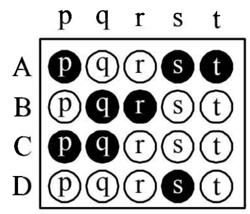
35. Highly energetic electrons are bombarded on a target of an element containing 30 neutrons. The ratio of radii of nucleus to that of Helium nucleus is $(14)^{1/3}$. Find (a) atomic number of the nucleus. (b) the frequency of K_α line of the X-ray produced. ($R = 1.1 \times 10^7 \text{ m}^{-1}$ and $c = 3 \times 10^8$ m/s) *(2005 - 4 Marks)*

36. In hydrogen-like atom ($z = 11$), nth line of Lyman series has wavelength λ. The de-Broglie's wavelength of electron in the level from which it originated is also λ. Find the value of n? *(2006 - 6M)*

F Match the Following

DIRECTIONS (Q. No. 1 to 4 & 6) : *Each question contains statements given in two columns, which have to be matched. The statements in Column-I are labelled A, B, C and D, while the statements in Column-II are labelled p, q, r and s. Any given statement in Column-I can have correct matching with ONE OR MORE statement(s) in Column-II. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following example :*

If the correct matches are A-p, s and t; B-q and r; C-p and q; and D-s then the correct darkening of bubbles will look like the given.



1. In the following, column I lists some physical quantities and the column II gives approximate 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 p, q, r, etc. against the number (A), (B), (C), (D) etc. of the physical quantity in the answer book. In your answer, the sequence of column I should be maintained. *(1997 - 4 Marks)*

Column I	Column II
(A) Energy of thermal neutrons	(p) 0.025 eV
(B) Energy of X-rays	(q) 0.5 eV
(C) Binding energy per nucleon	(r) 3 eV
(D) Photoelectric threshold of a metal	(s) 20 eV
	(t) 10 k eV
	(u) 8 M eV

2. Given below are certain matching type questions, where two columns (each having 4 items) are given. Immediately after the columns the matching grid is given, where each item of Column I has to be matched with the items of Column II, by encircling the correct match(es). Note that an item of column I can match with more than one item of column II. All the items of column II must be matched. Match the following : *(2006 - 6M)*

Column I	Column II
(A) Nuclear fusion	(p) Converts some matter into energy
(B) Nuclear fission	(q) Generally possible for nuclei with low atomic number
(C) β-decay	(r) Generally possible for nuclei with higher atomic number
(D) Exothermic nuclear reaction	(s) Essentially proceeds by weak nuclear forces

3. Some laws / processes are given in **Column I**. Match these with the physical phenomena given in **Column II** and indicate your answer by darkening appropriate bubbles in the 4×4 matrix given in the ORS. *(2007)*

Column I	Column II
(A) Transition between two atomic energy levels	(p) Characteristic X-rays
(B) Electron emission from a material	(q) Photoelectric effect
(C) Mosley's law	(r) Hydrogen spectrum
(D) Change of photon energy into kinetic energy of electrons	(s) β-decay

4. **Column-II** gives certain systems undergoing a process. **Column-I** suggests changes in some of the parameters related to the system. Match the statements in **Column-I** to the approapriate process(es) from **Column-II**. *(2009)*

Column-I	**Column-II**
(A) The energy of the system is increased	(p) *System :* A capacitor, initially uncharged *Process :* It is connected to a battery
(B) Mechanical energy is provided to the system, which is converted into energy of random motion of its parts	(q) *System :* A gas in an adiabatic container fitted with an adiabatic piston *Process:* The gas is compressed by pushing the piston
(C) Internal energy of the system is converted into its mechanical energy	(r) *System:* A gas in a rigid container *Process:* The gas gets cooled due to colder atmosphere surrounding it
(D) Mass of the system is decreased	(s) *System:* A heavy nucleus, initially at rest *Process:* The nucleus fissions into two fragments of nearly equal masses and some neutrons are emitted
	(t) *System:* A resistive wire loop *Process:* The loop is placed in a time varying magnetic field perpendicular to its plane

DIRECTION (Q.No. 5) : *Following question has matching list I and II. The codes for the lists have choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

5. Match List I of the nuclear processes with List II containing parent nucleus and one of the end products of each process and then select the correct answer using the codes given below the lists: *(JEE Adv. 2013-II)*

List I	**List II**
P. Alpha decay	1. $^{15}_{8}O \rightarrow ^{15}_{7}O + ...$
Q. β+ decay	2. $^{138}_{92}U \rightarrow ^{234}_{90}Th + ...$
R. Fission	3. $^{185}_{83}Bi \rightarrow ^{184}_{82}Pb + ...$
S. Proton emission	4. $^{239}_{94}Pu \rightarrow ^{140}_{57}La + ...$

Codes:

	P	Q	R	S
(a)	4	2	1	3
(b)	1	3	2	4
(c)	2	1	4	3
(d)	4	3	2	1

6. Match the nuclear processes given in column I with the appropriate option(s) in column II. *(JEE Adv. 2015)*

Column I	**Column II**
(A) Nuclear fusion	(p) Absorption of thermal neutrons by $^{235}_{92}U$
(B) Fission in a nuclear reactor	(q) $^{60}_{27}Co$ nucleus
(C) β-decay	(r) Energy production in stars via hydrogen conversion to helium
(D) γ-ray emission	(s) Heavy water
	(t) Neutrino emission

G Comprehension Based Questions

PASSAGE-I

In a mixture of H-He^+ gas (He+ is singly ionized He atom), H atoms and He+ ions are excited to their respective first excited states. Subsequently, H atoms transfer their total excitation energy to He+ ions (by collisions). Assume that the Bohr model of atom is exactly valid. *(2008)*

1. The quantum number n of the state finally populated in He^+ ions is –
(a) 2 (b) 3
(c) 4 (d) 5

2. The wavelength of light emitted in the visible region by He+ ions after collisions with H atoms is –
(a) 6.5×10^{-7} m
(b) 5.6×10^{-7} m
(c) 4.8×10^{-7} m
(d) 4.0×10^{-7} m

3. The ratio of the kinetic energy of the n = 2 electron for the H atom to that of He^+ ion is –
(a) 1/4 (b) 1/2
(c) 1 (d) 2

PASSAGE-2

Scientists are working hard to develop nuclear fusion reactor. Nuclei of heavy hydrogen, ${}_1^2$H, known as deuteron and denoted by D, can be thought of as a candidate for fusion reactor. The D-D reaction is ${}_1^2\text{H} + {}_1^2\text{H} \rightarrow {}_2^3\text{He} + n +$ energy. In the core of fusion reactor, a gas of heavy hydrogen is fully ionized into deuteron nuclei and electrons. This collection of ${}_1^2H$ nuclei and electrons is known as plasma. The nuclei move randomly in the reactor core and occasionally come close enough for nuclear fusion to take place. Usually, the temperatures in the reactor core are too high and no material wall can be used to confine the plasma. Special techniques are used which confine the plasma for a time t_0 before the particles fly away form the core. If n is the density (number/volume) of deuterons, the product nt_0 is called Lawson number. In one of the criteria, a reactor is termed successful if Lawson number is greater than 5×10^{14} s/cm^3.

It may be helpful to use the following: Boltzmann constant

$$k = 8.6 \times 10^{-5}\,\text{eV/K}; \quad \frac{e^2}{4\pi\varepsilon_0} = 1.44 \times 10^{-9}\,\text{eVm}$$ *(2009)*

4. In the core of nuclear fusion reactor, the gas becomes plasma because of
(a) strong nuclear force acting between the deuterons
(b) coulomb force acting between the deuterons
(c) coulomb force acting between deuteron-electron pairs
(d) the high temperature maintained inside the reactor core

5. Assume that two deuteron nuclei in the core of fusion reactor at temperature T are moving towards each other, each with kinetic energy 1.5 kT, when the separation between them is large enough to neglect coulomb potential energy. Also neglect any interaction from other particles in the core. The minimum temperature T required for them to reach a separation of 4×10^{-15} m is in the range
(a) $1.0 \times 10^9\,\text{K} < T < 2.0 \times 10^9\,\text{K}$
(b) $2.0 \times 10^9\,\text{K} < T < 3.0 \times 10^9\,\text{K}$
(c) $3.0 \times 10^9\,\text{K} < T < 4.0 \times 10^9\,\text{K}$
(d) $4.0 \times 10^9\,\text{K} < T < 5.0 \times 10^9\,\text{K}$

6. Results of calculations for four different designs of a fusion reactor using D-D reaction are given below. Which of these is most promising based on Lawson criterion?
(a) deuteron density = 2.0×10^{12} cm^{-3}, confinement time = 5.0×10^{-3} s
(b) deuteron density = 8.0×10^{14} cm^{-3}, confinement time = 9.0×10^{-1} s
(c) deuteron density = 4.0×10^{23} cm^{-3}, confinement time = 1.0×10^{-11} s
(d) deuteron density = 1.0×10^{24} cm^{-3}, confinement time = 4.0×10^{-12} s

PASSAGE-3

When a particle is restricted to move along x - axis between $x = 0$ and $x = a$, where a is of nanometer dimension, its energy can take only certain specific values. The allowed energies of the particle moving in such a restricted region, correspond to the formation of standing waves with nodes at its ends $x = 0$ and $x = a$. The wavelength of this standing wave is related to the linear momentum p of the particle according to the de Broglie relation. The energy of the particle of mass m is related to its linear momentum as $E = \frac{p^2}{2m}$. Thus, the energy of the particle can be denoted by a quantum number 'n' taking values 1, 2, 3, ... (n = 1, called the ground state) corresponding to the number of loops in the standing wave. Use the model described above to answer the following three questions for a particle moving in the line $x = 0$ to $x = a$. Take $h = 6.6 \times 10^{-34}\,Js$ and $e = 1.6 \times 10^{-19}\,C$.

7. The allowed energy for the particle for a particular value of n is proportional to *(2009)*
(a) a^{-2} (b) $a^{-3/2}$
(c) a^{-1} (d) a^2

8. If the mass of the particle is $m = 1.0 \times 10^{-30}$ kg and $a = 6.6$ nm, the energy of the particle in its ground state is closest to *(2009)*
(a) 0.8 meV (b) 8 meV
(c) 80 meV (d) 800 meV

9. The speed of the particle, that can take discrete values, is proportional to *(2009)*
(a) $n^{-3/2}$ (b) n^{-1}
(c) $n^{1/2}$ (d) n

PASSAGE-4

The key feature of Bohr's theory of spectrum of hydrogen atom is the quantization of angular momentum when an electron is revolving around a proton. We will extend this to a general rotational motion to find quantized rotational energy of a diatomic molecule assuming it to be rigid. The rule to be applied is Bohr's quantization condition. *(2010)*

10. A diatomic molecule has moment of inertia I. By Bohr's quantization condition its rotational energy in the nth level (n = 0 is not allowed) is
(a) $\frac{1}{n^2}\left(\frac{h^2}{8\pi^2 I}\right)$ (b) $\frac{1}{n}\left(\frac{h^2}{8\pi^2 I}\right)$
(c) $n\left(\frac{h^2}{8\pi^2 I}\right)$ (d) $n^2\left(\frac{h^2}{8\pi^2 I}\right)$

11. It is found that the excitation frequency from ground to the first excited state of rotation for the CO molecule is close to $\frac{4}{\pi} \times 10^{11}$ Hz. Then the moment of inertia of CO molecule about its center of mass is close to

(Take $h = 2\pi \times 10^{-34}$ J s)

(a) 2.76×10^{-46} kg m^2 (b) 1.87×10^{-46} kg m^2

(c) 4.67×10^{-47} kg m^2 (d) 1.17×10^{-47} kg m^2

12. In a CO molecule, the distance between C (mass = 12 a.m.u.) and O (mass = 16 a.m.u.), where 1 a.m.u. $= \frac{5}{3} \times 10^{-27}$ kg, is close to

(a) 2.4×10^{-10} m (b) 1.9×10^{-10} m

(c) 1.3×10^{-10} m (d) 4.4×10^{-11} m

PASSAGE-5

The β -decay process, discovered around 1900, is basically the decay of a neutron (n). In the laboratory, a proton (p) and an electron (e^-) are observed as the decay products of the neutron. Therefore, considering the decay of a neutron as a two-body decay process, it was predicted theoretically that the kinetic energy of the electron should be a constant. But experimentally, it was observed that the electron kinetic energy has continuous spectrum. Considering a three-body decay process, i.e. $n \to p + e^- + \bar{\nu}_e$, around 1930, Pauli explained the observed electron energy spectrum. Assuming the anti-neutrino ($\bar{\nu}_e$) to be massless and possessing negligible energy, and the neutron to be at rest, momentum and energy conservation principles are applied. From this calculation, the maximum kinetic energy of the electron is 0.8×10^6 eV. The kinetic energy carried by the proton is only the recoil energy.

13. If the anti-neutrino had a mass of 3 eV/c^2 (where c is the speed of light) instead of zero mass, what should be the range of the kinetic energy, K, of the electron? ***(2012)***

(a) $0 \le K \le 0.8 \times 10^6\, eV$

(b) $3.0\, eV \le K \le 0.8 \times 10^6\, eV$

(c) $3.0\, eV \le K < 0.8 \times 10^6\, eV$

(d) $0 \le K < 0.8 \times 10^6\, eV$

14. What is the maximum energy of the anti-neutrino? ***(2012)***

(a) Zero

(b) Much less than 0.8×10^6 eV.

(c) Nearly 0.8×10^6 eV

(d) Much larger than 0.8×10^6 eV

PASSAGE-6

The mass of a nucleus ${}^{A}_{Z}X$ is less than the sum of the masses of (A-Z) number of neutrons and Z number of protons in the nucleus. The energy equivalent to the corresponding mass difference is known as the binding energy of the nucleus. A heavy nucleus of mass M can break into two light nuclei of masses m_1 and m_2 only if $(m_1 + m_2) < M$. Also two light nuclei of masses m_3 and m_4 can undergo complete fusion and form a heavy nucleus of mass M' only if $(m_3 + m_4) > M'$. The masses of some neutral atoms are given in the table below:

${}^{1}_{1}H$	1.007825 u	${}^{2}_{1}H$	2.014102 u
${}^{3}_{1}H$	3.016050 u	${}^{4}_{2}He$	4.002603 u
${}^{6}_{3}Li$	6.015123 u	${}^{7}_{3}Li$	7.016004 u
${}^{70}_{30}Zn$	69.925325 u	${}^{82}_{34}Se$	81.916709 u
${}^{152}_{64}Gd$	151.919803 u	${}^{206}_{82}Pb$	205.974455 u
${}^{209}_{83}Bi$	208.980388 u	${}^{210}_{84}Po$	209.982876 u

(1u = 932 MeV/c^2)

(JEE Adv. 2013)

15. The kinetic energy (in keV) of the alpha particle, when the nucleus ${}^{210}_{84}Po$ at rest undergoes alpha decay, is

(a) 5319 (b) 5422

(c) 5707 (d) 5818

16. The correct statement is

(a) The nucleus ${}^{6}_{3}Li$ can emit an alpha particle

(b) The nucleus ${}^{210}_{84}Po$ can emit a proton

(c) Deuteron and alpha particle can undergo complete fusion

(d) The nuclei ${}^{70}_{30}Zn$ and ${}^{82}_{34}Se$ can undergo complete fusion

H Assertion & Reason Type Questions

1. **STATEMENT-1** ***(2007)***

If the accelerating potential in an X-ray tube is increased, the wavelengths of the characteristic X-rays do not change.

STATEMENT-2

When an electron beam strikes the target in an X-ray tube, part of the kinetic energy is converted into X-ray energy.

(a) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1

(b) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

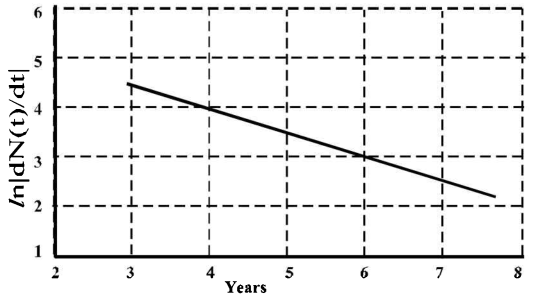
(c) Statement-1 is True, Statement-2 is False

(d) Statement-1 is False, Statement-2 is True

I Integer Value Correct Type

1. An α-particle and a proton are accelerated from rest by a potential difference of 100 V. After this, their de Broglie wavelengths are λ_α and λ_p respectively. The ratio $\frac{\lambda_p}{\lambda_\alpha}$, to the nearest integer, is ***(2010)***

2. To determine the half life of a radioactive element, a student plots a graph of $ln\left|\frac{dN(t)}{dt}\right|$ versus t. Here $\left|\frac{dN(t)}{dt}\right|$ is the rate of radioactive decay at time t. If the number of radioactive nuclei of this element decreases by a factor of p after 4.16 years, the value of p is *(2010)*



3. The activity of a freshly prepared radioactive sample is 10^{10} disintegrations per second, whose mean life is 10^9 s. The mass of an atom of this radioisotope is 10^{-25} kg. The mass (in mg) of the radioactive sample is *(2011)*
4. A silver sphere of radius 1 cm and work function 4.7 eV is suspended from an insulating thread in freespace. It is under continuous illumination of 200 nm wavelength light. As photoelectrons are emitted, the sphere gets charged and acquires a potential. The maximum number of photoelectrons emitted from the sphere is $A \times 10^z$ (where $1 < A < 10$). The value of 'z' is *(2011)*
5. A proton is fired from very far away towards a nucleus with charge $Q = 120\ e$, where e is the electronic charge. It makes a closest approach of 10 fm to the nucleus. The de Broglie wavelength (in units of fm) of the proton at its start is: (take the proton mass, $m_p = (5/3) \times 10^{-27}$ kg; $h/e = 4.2 \times 10^{-15}$ J.s / C;

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ m/F}; 1 \text{ fm} = 10^{-15} \text{ m}$$ *(2012- I)*

6. The work functions of Silver and Sodium are 4.6 and 2.3 eV, respectively. The ratio of the slope of the stopping potential versus frequency plot for Silver to that of Sodium is *(JEE Adv. 2013-I)*
7. A freshly prepared sample of a radioisotope of half-life 1386 s has activity 10^3 disintegrations per second. Given that $ln2 = 0.693$, the fraction of the initial number of nuclei (expressed in nearest integer percentage) that will decay in the first 80 s after preparation of the sample is *(JEE Adv. 2013-I)*
8. A nuclear power plant supplying electrical power to a village uses a radioactive material of half life T years as the fuel. The amount of fuel at the beginning is such that the total power requirement of the village is 12.5% of the electrical power available from the plant at that time. If the plant is able to meet the total power needs of the village for a maximum period of nT years, then the value of n is *(JEE Adv. 2015)*
9. Consider a hydrogen atom with its electron in the n^{th} orbital. An electromagnetic radiation of wavelength 90 nm is used to ionize the atom. If the kinetic energy of the ejected electron is 10.4 eV, then the value of n is ($hc = 1242$ eV nm) *(JEE Adv. 2015)*
10. For a radioactive material, its activity A and rate of change of its activity R are defined as $A = -\frac{dN}{dt}$ and $R = -\frac{dA}{dt}$, where N(t) is the number of nuclei at time t. Two radioactive sources P (mean life τ) and Q (mean life 2τ) have the same activity at $t = 0$. Their rates of change of activities at $t = 2\tau$ are R_P and R_Q, respectively. If $\frac{R_P}{R_Q} = \frac{n}{e}$, then the value of n is *(JEE Adv. 2015)*
11. An electron is an excited state of Li^{2+} ion has angular momentum $3h/2\pi$. The de Broglie wavelength of the electron in this state is $p\pi a_0$ (where a_0 is the Bohr radius). The value of p is *(JEE Adv. 2015)*
12. The isotope ${}^{12}_{5}B$ having a mass 12.014 u undergoes β–decay to ${}^{12}_{6}C$. ${}^{12}_{6}C$ has an excited state of the nucleus $\left({}^{12}_{6}C^*\right)$ at 4.041 MeV above its ground state. If ${}^{12}_{5}E$ decays to ${}^{12}_{6}C^*$, the maximum kinetic energy of the β–particle in units of MeV is (1 u = 931.5 MeV/c^2, where c is the speed of light in vacuum). *(JEE Adv. 2016)*
13. A hydrogen atom in its ground state is irradiated by light of wavelength 970 Å. Taking $hc/e = 1.237 \times 10^{-6}$ eV m and the ground state energy of hydrogen atom as –13.6 eV, the number of lines present in the emission spectrum is *(JEE Adv. 2016)*

Section-B JEE Main / AIEEE

1. If 13.6 eV energy is required to ionize the hydrogen atom, then the energy required to remove an electron from $n = 2$ is [2002]
   (a) 10.2 eV (b) 0 eV
   (c) 3.4 eV (d) 6.8 eV.
2. At absolute zero, Si acts as [2002]
   (a) non-metal (b) metal
   (c) insulator (d) none of these
3. At a specific instant emission of radioactive compound is deflected in a magnetic field. The compound can emit
   (i) electrons (ii) protons
   (iii) He^{2+} (iv) neutrons
   The emission at instant can be [2002]
   (a) i, ii, iii (b) i, ii, iii, iv (c) iv (d) ii, iii
4. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then the ratio of the wavelengths is nearest to [2002]
   (a) 1 : 2 (b) 4 : 1 (c) 2 : 1 (d) 1 : 4.
5. Formation of covalent bonds in compounds exhibits [2002]
   (a) wave nature of electron
   (b) particle nature of electron
   (c) both wave and particle nature of electron
   (d) none of these

6. If N_0 is the original mass of the substance of half-life period $t_{1/2}$ = 5 years, then the amount of substance left after 15 years is [2002]
(a) $N_0/8$ (b) $N_0/16$ (c) $N_0/2$ (d) $N_0/4$

7. By increasing the temperature, the specific resistance of a conductor and a semiconductor [2002]
(a) increases for both (b) decreases for both
(c) increases, decreases (d) decreases, increases

8. The energy band gap is maximum in [2002]
(a) metals (b) superconductors
(c) insulators (d) semiconductors.

9. The part of a transistor which is most heavily doped to produce large number of majority carriers is [2002]
(a) emmiter
(b) base
(c) collector
(d) can be any of the above three.

10. Which of the following are not electromagnetic waves? [2002]
(a) cosmic rays (b) gamma rays
(c) β-rays (d) X-rays.

11. A strip of copper and another of germanium are cooled from room temperature to 80K. The resistance of [2003]
(a) each of these decreases
(b) copper strip increases and that of germanium decreases
(c) copper strip decreases and that of germanium increases
(d) each of these increases

12. Which of the following radiations has the least wavelength ? [2003]
(a) γ-rays (b) β-rays
(c) α-rays (d) X-rays

13. When a U^{238} nucleus originally at rest, decays by emitting an alpha particle having a speed 'u', the recoil speed of the residual nucleus is [2003]
(a) $\frac{4u}{238}$ (b) $-\frac{4u}{234}$ (c) $\frac{4u}{234}$ (d) $-\frac{4u}{238}$

14. The difference in the variation of resistance with temeperature in a metal and a semiconductor arises essentially due to the difference in the *[2003]*
(a) crystal sturcture
(b) variation of the number of charge carriers with temperature
(c) type of bonding
(d) variation of scattering mechanism with temperature

15. A radioactive sample at any instant has its disintegration rate 5000 disintegrations per minute. After 5 minutes, the rate is 1250 disintegrations per minute. Then, the decay constant (per minute) is [2003]
(a) 0.4 ln 2 (b) 0.2 ln 2 (c) 0.1 ln 2 (d) 0.8 ln 2

16. A nucleus with Z= 92 emits the following in a sequence:
$\alpha, \beta^-, \beta^- \alpha, \alpha, \alpha, \alpha, \alpha, \beta^-, \beta^-, \alpha, \beta^+, \beta^+, \alpha$
Then Z of the resulting nucleus is [2003]
(a) 76 (b) 78 (c) 82 (d) 74

17. Two identical photocathodes receive light of frequencies f_1 and f_2. If the velocites of the photo electrons (of mass m) coming out are respectively v_1 and v_2, then [2003]
(a) $v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$
(b) $v_1 + v_2 = \left[\frac{2h}{m}(f_1 + f_2)\right]^{1/2}$
(c) $v_1^2 + v_2^2 = \frac{2h}{m}(f_1 + f_2)$
(d) $v_1 - v_2 = \left[\frac{2h}{m}(f_1 - f_2)\right]^{1/2}$

18. Which of the following **cannot** be emitted by radioactive substances during their decay ? [2003]
(a) Protons (b) Neutrinoes
(c) Helium nuclei (d) Electrons

19. In the nuclear fusion reaction
$${}_1^2H + {}_1^3H \rightarrow {}_2^4He + n$$
given that the repulsive potential energy between the two nuclei is ~ 7.7×10^{-14} J , the temperature at which the gases must be heated to initiate the reaction is nearly
[Boltzmann's Constant $k = 1.38 \times 10^{-23}$ J/K] [2003]
(a) 10^7 K (b) 10^5 K (c) 10^3 K (d) 10^9 K

20. Which of the following atoms has the lowest ionization potential ? [2003]
(a) ${}_7^{14}N$ (b) ${}_{55}^{133}Cs$ (c) ${}_{18}^{40}Ar$ (d) ${}_8^{16}O$

21. The wavelengths involved in the spectrum of deuterium $\left({}_1^2D\right)$ are slightly different from that of hydrogen spectrum, because [2003]
(a) the size of the two nuclei are different
(b) the nuclear forces are different in the two cases
(c) the masses of the two nuclei are different
(d) the atraction between the electron and the nucleus is differernt in the two cases

22. In the middle of the depletion layer of a reverse- biased *p-n* junction, the [2003]
(a) electric field is zero
(b) potential is maximum
(c) electric field is maximum
(d) potential is zero

23. If the binding energy of the electron in a hydrogen atom is 13.6eV, the energy required to remove the electron from the first excited state of Li^{++} is [2003]
(a) 30.6 eV (b) 13.6 eV
(c) 3.4 eV (d) 122.4 eV

24. A radiation of energy E falls normally on a perfectly reflecting surface. The momentum transferred to the surface is [2004]
(a) Ec (b) $2E/c$ (c) E/c (d) E/c^2

25. According to Einstein's photoelectric equation, the plot of the kinetic energy of the emitted photo electrons from a metal **Vs** the frequency, of the incident radiation gives as straight the whose slope [2004]
(a) depends both on the intensity of the radiation and the metal used
(b) depends on the intensity of the radiation
(c) depends on the nature of the metal used
(d) is the same for the all metals and independent of the intensity of the radiation

26. 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. [2004]
(a) 310 nm (b) 400 nm (c) 540 nm (d) 220 nm

27. A nucleus disintegrated into two nuclear parts which have their velocities in the ratio of 2 : 1. The ratio of their nuclear sizes will be [2004]
(a) $3^{1/2}:1$ (b) $1:2^{1/3}$ (c) $2^{1/3}:1$ (d) $1:3^{1/2}$

28. The binding energy per nucleon of deuteron $\left({}_1^2\text{H}\right)$ and helium nucleus $\left({}_2^4\text{He}\right)$ is 1.1 MeV and 7 MeV respectively. If two deuteron nuclei react to form a single helium nucleus, then the energy released is [2004]
(a) 23.6 MeV (b) 26.9 MeV (c) 13.9 MeV (d) 19.2 MeV

29. An α-particle of energy 5 MeV is scattered through 180° by a fixed uranium nucleus. The distance of closest approach is of the order of [2004]
(a) 10^{-12} cm (b) 10^{-10} cm (c) 1A (d) 10^{-15} cm

30. When npn transistor is used as an amplifier [2004]
(a) electrons move from collector to base
(b) holes move from emitter to base
(c) electrons move from base to collector
(d) holes move from base to emitter

31. For a transistor amplifier in common emitter configuration for load impedance of 1kΩ $(h_{fe} = 50$ and $h_{oe} = 25)$ the current gain is [2004]
(a) −24.8 (b) −15.7 (c) −5.2 (d) −48.78

32. A piece of copper and another of germanium are cooled from room temperature to 77K, the resistance of [2004]
(a) copper increases and germanium decreases
(b) each of them decreases
(c) each of them increases
(d) copper decreases and germanium increases

33. The manifestation of band structure in solids is due to [2004]
(a) Bohr's correspondence principle
(b) Pauli's exclusion principle
(c) Heisenberg's uncertainty principle
(d) Boltzmann's law

34. When p-n junction diode is forward biased then [2004]
(a) both the depletion region and barrier height are reduced
(b) the depletion region is widened and barrier height is reduced
(c) the depletion region is reduced and barrier height is increased
(d) Both the depletion region and barrier height are increased

35. If radius of the ${}_{13}^{27}\text{Al}$ nucleus is estimated to be 3.6 fermi then the radius of ${}_{52}^{125}\text{Te}$ nucleus be nearly [2005]
(a) 8 fermi (b) 6 fermi (c) 5 fermi (d) 4 fermi

36. Starting with a sample of pure ${}^{66}\text{Cu}$, $\frac{7}{8}$ of it decays into Zn in 15 minutes. The corresponding half life is [2005]
(a) 15 minutes (b) 10 minutes
(c) $7\frac{1}{2}$ minutes (d) 5 minutes

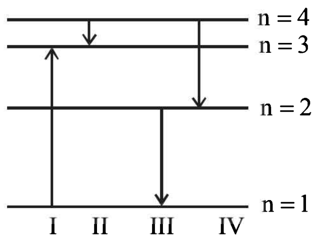
37. A photocell is illuminated by a small bright source placed 1 m away. When the same source of light is placed $\frac{1}{2}$ m away, the number of electrons emitted by photocathode would
(a) increase by a factor of 4 [2005]
(b) decrease by a factor of 4
(c) increase by a factor of 2
(d) decrease by a factor of 2

38. The electrical conductivity of a semiconductor increases when electromagnetic radiation of wavelength shorter than 2480 nm is incident on it. The band gap in (eV) for the semiconductor is [2005]
(a) 2.5 eV (b) 1.1 eV (c) 0.7 eV (d) 0.5 eV

39. The intensity of gamma radiation from a given source is I. On passing through 36 mm of lead, it is reduced to $\frac{I}{8}$. The thickness of lead which will reduce the intensity to $\frac{I}{2}$ will be
(a) 9mm (b) 6mm [2005]
(c) 12mm (d) 18mm

40. In a common base amplifier, the phase difference between the input signal voltage and output voltage is [2005]
(a) π (b) $\frac{\pi}{4}$ (c) $\frac{\pi}{2}$ (d) 0

41. The diagram shows the energy levels for an electron in a certain atom. Which transition shown represents the emission of a photon with the most energy? [2005]



(a) IV (b) III
(c) II (d) I

42. If the kinetic energy of a free electron doubles, it's deBroglie wavelength changes by the factor [2005]
(a) 2 (b) $\frac{1}{2}$ (c) $\sqrt{2}$ (d) $\frac{1}{\sqrt{2}}$

43. A nuclear transformation is denoted by $X(n, \alpha)\,{}_3^7\text{Li}$. Which of the following is the nucleus of element X?
(a) ${}_5^{10}\text{Be}$ (b) ${}^{12}\text{C}_6$ [2005]
(c) ${}_4^{11}\text{Be}$ (d) ${}_5^9\text{B}$

44. In a full wave rectifier circuit operating from 50 Hz mains frequency, the fundamental frequency in the ripple would be
(a) 25 Hz (b) 50 Hz [2005]
(c) 70.7 Hz (d) 100 Hz

45. In a common base mode of a transistor, the collector current is 5.488 mA for an emitter current of 5.60 mA. The value of the base current amplification factor (β) will be [2006]
(a) 49 (b) 50 (c) 51 (d) 48

46. The threshold frequency for a metallic surface corresponds to an energy of 6.2 eV and the stopping potential for a radiation incident on this surface is 5 V. The incident radiation lies in [2006]

(a) ultra-violet region (b) infra-red region
(c) visible region (d) *X*-ray region

47. An alpha nucleus of energy $\frac{1}{2}mv^2$ bombards a heavy nuclear target of charge Ze. Then the distance of closest approach for the alpha nucleus will be proportional to [2006]

(a) v^2 (b) $\frac{1}{m}$
(c) $\frac{1}{v^2}$ (d) $\frac{1}{Ze}$

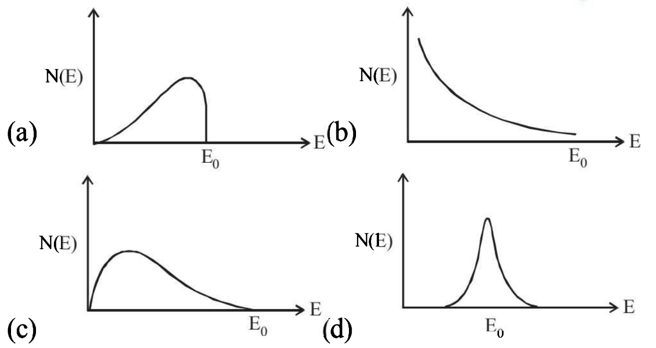
48. The time taken by a photoelectron to come out after the photon strikes is approximately [2006]

(a) 10^{-4} s (b) 10^{-10} s
(c) 10^{-16} s (d) 10^{-1} s

49. When $_3Li^7$ nuclei are bombarded by protons, and the resultant nuclei are $_4Be^8$, the emitted particles will be [2006]

(a) alpha particles (b) beta particles
(c) gamma photons (d) neutrons

50. The energy spectrum of β-particles [number N(E) as a function of β-energy E] emitted from a radioactive source is [2006]



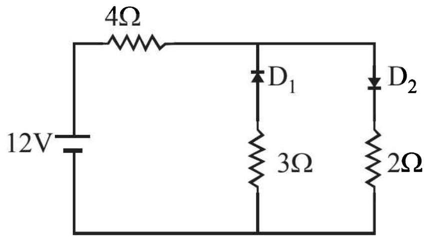
51. A solid which is not transparent to visible light and whose conductivity increases with temperature is formed by [2006]

(a) Ionic bonding (b) Covalent bonding
(c) Vander Waals bonding (d) Metallic bonding

52. If the ratio of the concentration of electrons to that of holes in a semiconductor is $\frac{7}{5}$ and the ratio of currents is $\frac{7}{4}$, then what is the ratio of their drift velocities? [2006]

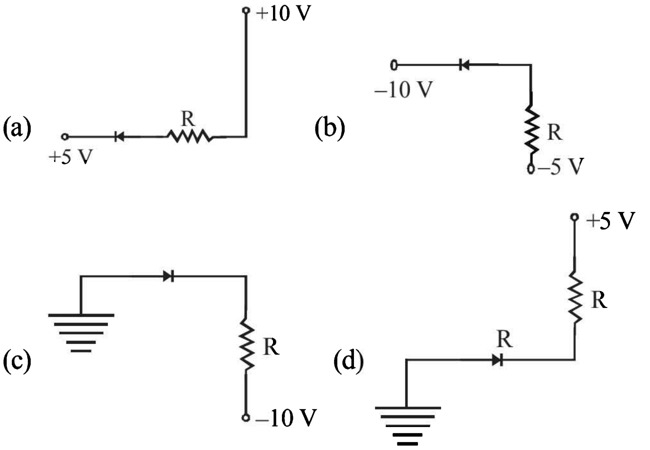
(a) $\frac{5}{8}$ (b) $\frac{4}{5}$ (c) $\frac{5}{4}$ (d) $\frac{4}{7}$

53. The circuit has two oppositively connected ideal diodes in parallel. What is the current flowing in the circuit? [2006]

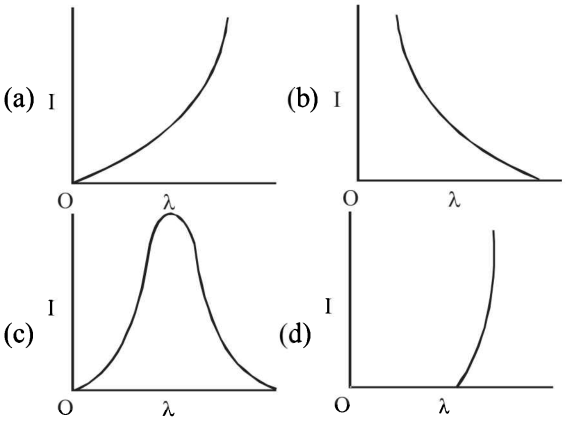


(a) 1.71 A (b) 2.00 A
(c) 2.31 A (d) 1.33 A

54. In the following, which one of the diodes reverse biased? [2006]



55. 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 [2006]



56. If the binding energy per nucleon in ^7_3Li and ^4_2He nuclei are 5.60 MeV and 7.06 MeV respectively, then in the reaction

$$p + {}^7_3Li \longrightarrow 2\,{}^4_2He$$

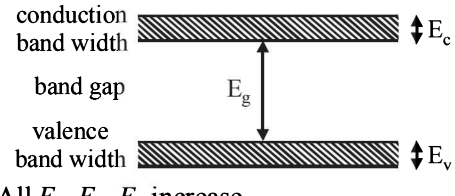
energy of proton must be [2006]

(a) 28.24 MeV (b) 17.28 MeV
(c) 1.46 MeV (d) 39.2 MeV

57. The 'rad' is the correct unit used to report the measurement of

(a) the ability of a beam of gamma ray photons to produce ions in a target [2006]
(b) the energy delivered by radiation to a target
(c) the biological effect of radiation
(d) the rate of decay of a radioactive source

58. If the lattice constant of this semiconductor is decreased, then which of the following is correct? [2006]



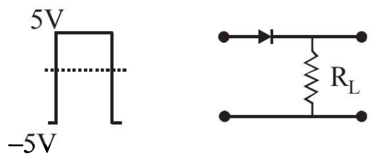
(a) All E_c, E_g, E_v increase
(b) E_c and E_v increase, but E_g decreases
(c) E_c and E_v decrease, but E_g increases
(d) All E_c, E_g, E_v decrease

59. The rms value of the electric field of the light coming from the Sun is 720 N/C. The average total energy density of the electromagnetic wave is **[2006]**
(a) 4.58×10^{-6} J/m^3 (b) 6.37×10^{-9} J/m^3
(c) 81.35×10^{-12} J/m^3 (d) 3.3×10^{-3} J/m^3

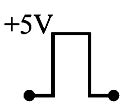
60. If M_O is the mass of an oxygen isotope $_8O^{17}$, M_P and M_N are the masses of a proton and a neutron respectively, the nuclear binding energy of the isotope is **[2007]**
(a) $(M_O - 17M_N)c^2$
(b) $(M_O - 8M_P)c^2$
(c) $(M_O - 8M_P - 9M_N)c^2$
(d) M_Oc^2

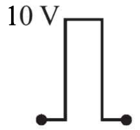
61. In gamma ray emission from a nucleus **[2007]**
(a) only the proton number changes
(b) both the neutron number and the proton number change
(c) there is no change in the proton number and the neutron number
(d) only the neutron number changes

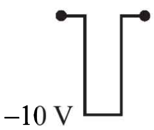
62. If in a *p-n* junction diode, a square input signal of 10 V is applied as shown **[2007]**

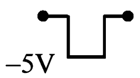


Then the output signal across R_L will be

(a) 

(b) 

(c) 

(d) 

63. Photon of frequency ν has a momentum associated with it. If c is the velocity of light, the momentum is **[2007]**
(a) hν / c (b) ν / c (c) h ν c (d) hν / c^2

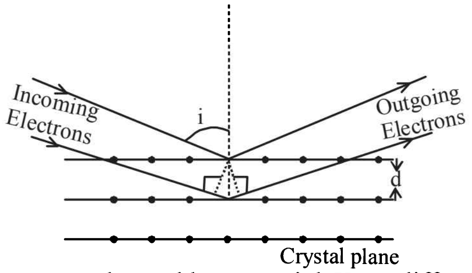
64. The half-life period of a radio-active element *X* is same as the mean life time of another radio-active element *Y*. Initially they have the same number of atoms. Then **[2007]**
(a) *X* and *Y* decay at same rate always
(b) *X* will decay faster than *Y*
(c) *Y* will decay faster than *X*
(d) *X* and *Y* have same decay rate initially

65. Carbon, silicon and germanium have four valence electrons each. At room temperature which one of the following statements is most appropriate ? **[2007]**
(a) The number of free electrons for conduction is significant only in Si and Ge but small in C.
(b) The number of free conduction electrons is significant in C but small in Si and Ge.
(c) The number of free conduction electrons is negligibly small in all the three.
(d) The number of free electrons for conduction is significant in all the three.

66. Which of the following transitions in hydrogen atoms emit photons of highest frequency? **[2007]**
(a) $n = 1$ to $n = 2$ (b) $n = 2$ to $n = 6$
(c) $n = 6$ to $n = 2$ (d) $n = 2$ to $n = 1$

DIRECTIONS: *Question No. 67 and 68 are based on the following paragraph.*

Wave property of electrons implies that they will show diffraction effects. Davisson and Germer demonstrated this by diffracting electrons from crystals. The law governing the diffraction from a crystal is obtained by requiring that electron waves reflected from the planes of atoms in a crystal interfere constructively (see figure).



67. Electrons accelerated by potential *V* are diffracted from a crystal. If d = 1Å and i = 30°, *V* should be about ($h = 6.6 \times 10^{-34}$ Js, $m_e = 9.1 \times 10^{-31}$ kg, $e = 1.6 \times 10^{-19}$ C) **[2008]**
(a) 2000 V (b) 50 V (c) 500 V (d) 1000 V

68. If a strong diffraction peak is observed when electrons are incident at an angle '*i*' from the normal to the crystal planes with distance '*d*' between them (see figure), de Broglie wavelength λ_{dB} of electrons can be calculated by the relationship (n is an integer) **[2008]**
(a) $d \sin i = n\lambda_{dB}$ (b) $2d \cos i = n\lambda_{dB}$
(c) $2d \sin i = n\lambda_{dB}$ (d) $d \cos i = n\lambda_{dB}$

69. This question contains Statement-1 and statement-2. Of the four choices given after the statements, choose the one that best describes the two statements. **[2008]**
Statement-1:
Energy is released when heavy nuclei undergo fission or light nuclei undergo fusion and
Statement-2 :
For heavy nuclei, binding energy per nucleon increases with increasing *Z* while for light nuclei it decreases with increasing *Z*.
(a) Statement-1 is false, Statement-2 is true
(b) Statement-1 is true, Statement-2 is true; Statement-2 is a correct explanation for Statement-1
(c) Statement-1 is true, Statement-2 is true; Statement-2 is not a correct explanation for Statement-1
(d) Statement-1 is true, Statement-2 is false

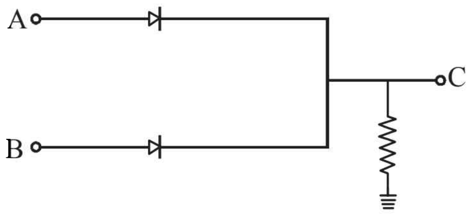
70. A working transistor with its three legs marked *P*, *Q* and *R* is tested using a multimeter. No conduction is found between *P* and *Q*. By connecting the common (negative) terminal of the multimeter to *R* and the other (positive) terminal to *P* or *Q*, some resistance is seen on the multimeter. Which of the following is true for the transistor? **[2008]**
(a) It is an npn transistor with *R* as base
(b) It is a pnp transistor with *R* as collector
(c) It is a pnp transistor with *R* as emitter
(d) It is an npn transistor with *R* as collector

71. Suppose an electron is attracted towards the origin by a force $\frac{k}{r}$ where 'k' is a constant and 'r' is the distance of the electron from the origin. By applying Bohr model to this system, the radius of the n^{th} orbital of the electron is found to be 'r_n' and the kinetic energy of the electron to be 'T_n'. Then which of the following is true? **[2008]**

(a) $T_n \propto \frac{1}{n^2}, r_n \propto n^2$ (b) T_n independent of n, $r_n \propto n$

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

72. In the circuit below, A and B represent two inputs and C represents the output. **[2008]**



The circuit represents

(a) NOR gate (b) AND gate

(c) NAND gate (d) OR gate

73. The transition from the state $n = 4$ to $n = 3$ in a hydrogen like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition from : **[2009]**

(a) $3 \to 2$ (b) $4 \to 2$

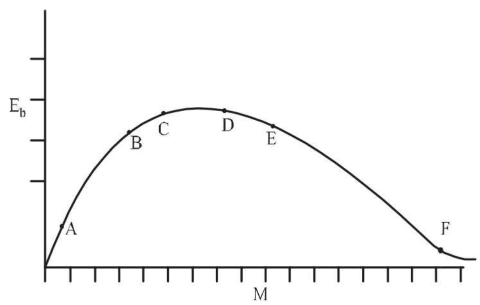
(c) $5 \to 4$ (d) $2 \to 1$

74. The surface of a metal is illuminted with the light of 400 nm. The kinetic energy of the ejected photoelectrons was found to be 1.68 eV. The work function of the metal is : **[2009]**
($hc = 1240$ eV.nm)

(a) 1.41 eV (b) 1.51 eV

(c) 1.68 eV (d) 3.09 eV

75.



The above is a plot of binding energy per nucleon E_b, against the nuclear mass M; A, B, C, D, E, F correspond to different nuclei. Consider four reactions : **[2009]**

(i) $A + B \to C + \varepsilon$ (ii) $C \to A + B + \varepsilon$

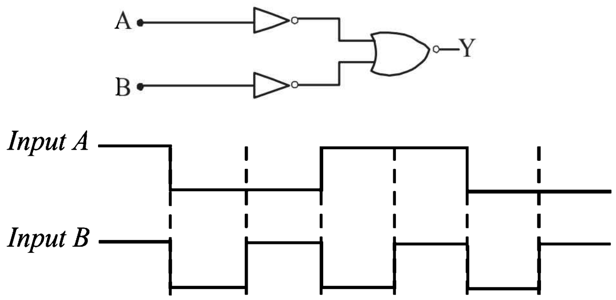
(iii) $D + E \to F + \varepsilon$ and (iv) $F \to D + E + \varepsilon$,

where ε is the energy released? In which reactions is ε positive?

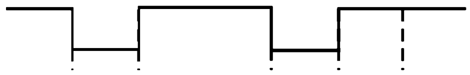
(a) (i) and (iii) (b) (ii) and (iv)

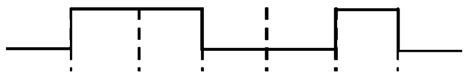
(c) (ii) and (iii) (d) (i) and (iv)

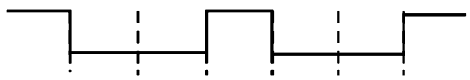
76. The logic circuit shown below has the input waveforms 'A' and 'B' as shown. Pick out the correct output waveform. **[2009]**

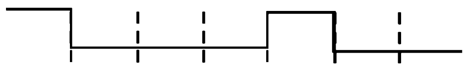


Output is

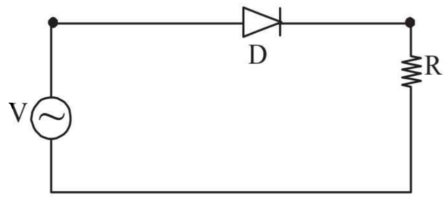
(a) 

(b) 

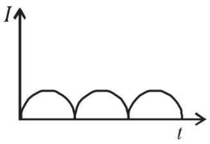
(c) 

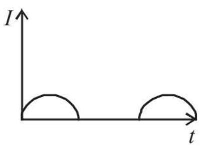
(d) 

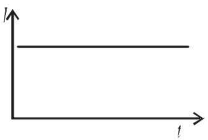
77. A p-n junction (D) shown in the figure can act as a rectifier. An alternating current source (V) is connected in the circuit.

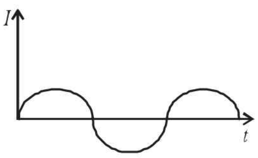


The current (I) in the resistor (R) can be shown by :

(a) 

(b) 

(c) 

(d) 

78. **Statement -1 :** When ultraviolet light is incident on a 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 -2 : Photoelectrons are emitted with speeds ranging from zero to a maximum value because of the range of frequencies present in the incident light. **[2010]**

(a) Statement -1 is true, Statement -2 is true ; Statement -2 is the correct explanation of Statement -1.

(b) Statement -1 is true, Statement -2 is true; Statement -2 is **not** the correct explanation of Statement -1

(c) Statement -1 is false, Statement -2 is true.

(d) Statement -1 is true, Statement -2 is false.

DIRECTIONS: *Questions number 79-80 are based on the following paragraph.*

A nucleus of mass $M + \Delta m$ is at rest and decays into two daughter nuclei of equal mass $\frac{M}{2}$ each. Speed of light is c.

79. The binding energy per nucleon for the parent nucleus is E_1 and that for the daughter nuclei is E_2. Then [2010]

(a) $E_2 = 2E_1$ (b) $E_1 > E_2$

(c) $E_2 > E_1$ (d) $E_1 = 2E_2$

80. The speed of daughter nuclei is [2010]

(a) $c\frac{\Delta m}{M + \Delta m}$ (b) $c\sqrt{\frac{2\Delta m}{M}}$

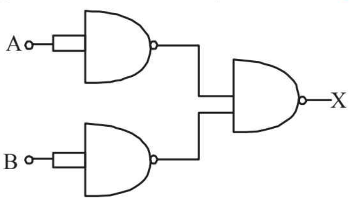
(c) $c\sqrt{\frac{\Delta m}{M}}$ (d) $c\sqrt{\frac{\Delta m}{M + \Delta m}}$

81. A radioactive nucleus (initial mass number A and atomic number Z emits 3 α - particles and 2 positrons. The ratio of number of neutrons to that of protons in the final nucleus will be [2010]

(a) $\frac{A-Z-8}{Z-4}$ (b) $\frac{A-Z-4}{Z-8}$

(c) $\frac{A-Z-12}{Z-4}$ (d) $\frac{A-Z-4}{Z-2}$

82. The combination of gates shown below yields [2010]



(a) OR gate

(b) NOT gate

(c) XOR gate

(d) NAND gate

83. If a source of power 4kW produces 10^{20} photons/second, the radiation belongs to a part of the spectrum called [2010]

(a) X -rays (b) ultraviolet rays

(c) microwaves (d) γ -rays

84. This question has Statement – 1 and Statement – 2. Of the four choices given after the statements, choose the one that best describes the two statements. [2011]

Statement – 1 : Sky wave signals are used for long distance radio communication. These signals are in general, less stable than ground wave signals.

Statement – 2 : The state of ionosphere varies from hour to hour, day to day and season to season.

(a) Statement–1 is true, Statement–2 is true, Statement–2 is the correct explanation of Statement–1.

(b) Statement–1 is true, Statement–2 is true, Statement–2 is not the correct explanation of Statement – 1.

(c) Statement – 1 is false, Statement – 2 is true.

(d) Statement – 1 is true, Statement – 2 is false.

85. Energy required for the electron excitation in Li^{++} from the first to the third Bohr orbit is : [2011]

(a) 36.3 eV (b) 108.8 eV (c) 122.4 eV (d) 12.1 eV

86. The half life of a radioactive substance is 20 minutes. The approximate time interval $(t_2 - t_1)$ between the time t_2 when $\frac{2}{3}$ of it had decayed and time t_1 when $\frac{1}{3}$ of it had decayed is :

(a) 14 min (b) 20 min [2011]

(c) 28 min (d) 7 min

87. This question has Statement – 1 and Statement – 2. Of the four choices given after the statements, choose the one that best describes the two statements. [2011]

Statement – 1: A metallic surface is irradiated by a monochromatic light of frequency $v > v_0$ (the threshold frequency). The maximum kinetic energy and the 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 – 2 : The maximum kinetic energy and the stopping potential of photoelectrons emitted from a surface are linearly dependent on the frequency of incident light.

(a) Statement–1 is true, Statement–2 is true, Statement – 2 is the correct explanation of Statement – 1.

(b) Statement–1 is true, Statement–2 is true, Statement – 2 is not the correct explanation of Statement – 1.

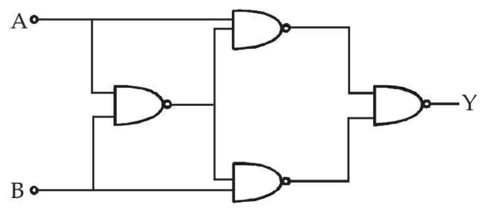
(c) Statement – 1 is false, Statement – 2 is true.

(d) Statement – 1 is true, Statement – 2 is false.

88. Hydrogen atom is excited from ground state to another state with principal quantum number equal to 4. Then the number of spectral lines in the emission spectra will be : [2012]

(a) 2 (b) 3 (c) 5 (d) 6

89. Truth table for system of four NAND gates as shown in figure is : [2012]



(a)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

(b)

A	B	Y
0	0	0
0	1	0
1	0	1
1	1	1

(c)

A	B	Y
0	0	1
0	1	1
1	0	0
1	1	0

(d)

A	B	Y
0	0	1
0	1	0
1	0	1
1	1	1

90. A radar has a power of 1kW and is operating at a frequency of 10 GHz. It is located on a mountain top of height 500 m. The maximum distance upto which it can detect object located on the surface of the earth (Radius of earth $= 6.4 \times 10^6$ m) is : [2012]

(a) 80 km (b) 16 km (c) 40 km (d) 64 km

91. Assume that a neutron breaks into a proton and an electron. The energy released during this process is : (mass of neutron $= 1.6725 \times 10^{-27}$ kg, mass of proton $= 1.6725 \times 10^{-27}$ kg, mass of electron $= 9 \times 10^{-31}$ kg). [2012]

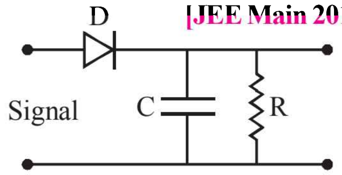
(a) 0.73 MeV (b) 7.10 MeV (c) 6.30 MeV (d) 5.4 MeV

92. A diatomic molecule is made of two masses m_1 and m_2 which are separated by a distance r. If we calculate its rotational energy by applying Bohr's rule of angular momentum quantization, its energy will be given by : (*n* is an integer)

(a) $\frac{(m_1+m_2)^2 n^2 h^2}{2m_1^2 m_2^2 r^2}$ (b) $\frac{n^2 h^2}{2(m_1+m_2)r^2}$

(c) $\frac{2n^2 h^2}{(m_1+m_2)r^2}$ (d) $\frac{(m_1+m_2)n^2\hbar^2}{2m_1 m_2 r^2}$

93. A diode detector is used to detect an amplitudemodulated wave of 60% modulation by using a condenser of capacity 250 picofarad in parallel with a load resistance 100 kilo ohm. Find the maximum modulated frequency which could be detected by it. [JEE Main 2013]

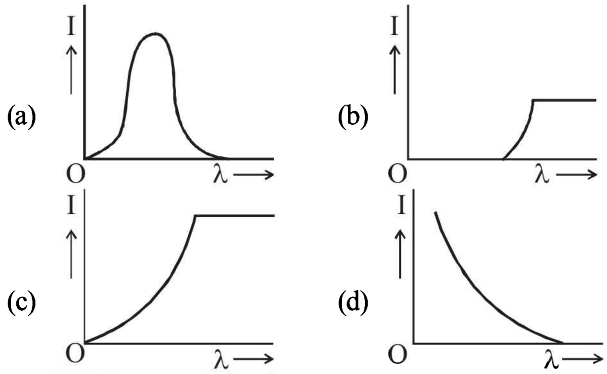


(a) 10.62 MHz
(b) 10.62 kHz
(c) 5.31 MHz
(d) 5.31 kHz

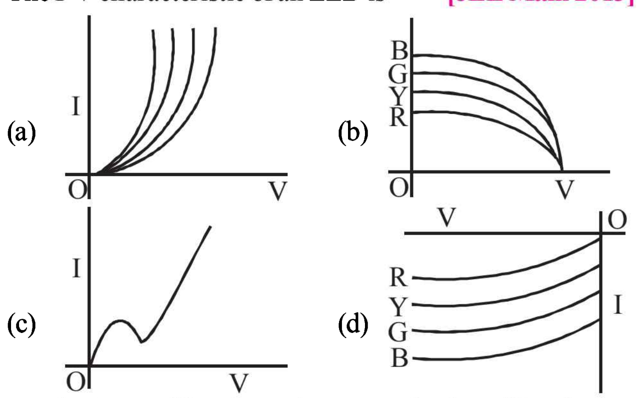
94. The magnetic field in a travelling electromagnetic wave has a peak value of 20 nT. The peak value of electric field strength is : [JEE Main 2013]

(a) 3 V/m (b) 6 V/m
(c) 9 V/m (d) 12 V/m

95. 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 : [JEE Main 2013]



96. The I-V characteristic of an LED is [JEE Main 2013]



97. In a hydrogen like atom electron make transition from an energy level with quantum number n to another with quantum number (n – 1). If n>>1, the frequency of radiation emitted is proportional to : [JEE Main 2013]

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

98. The current voltage relation of a diode is given by $I = \left(e^{1000V/T} - 1\right)$ mA, where the applied voltage V is in volts and the temperature T is in degree kelvin. If a student makes an error measuring ± 0.01 V while measuring the current of 5 mA at 300 K, what will be the error in the value of current in mA? [JEE Main 2014]

(a) 0.2 mA (b) 0.02 mA (c) 0.5 mA (d) 0.05 mA

99. During the propagation of electromagnetic waves in a medium: [JEE Main 2014]

(a) Electric energy density is double of the magnetic energy density.
(b) Electric energy density is half of the magnetic energy density.
(c) Electric energy density is equal to the magnetic energy density.
(d) Both electric and magnetic energy densities are zero.

100. The radiation corresponding to $3 \to 2$ transition of hydrogen atom falls on a metal surface to produce photoelectrons. These electrons are made to enter a magnetic field of 3×10^{-4} T. If the radius of the largest circular path followed by these electrons is 10.0 mm, the work function of the metal is close to: [JEE Main 2014]

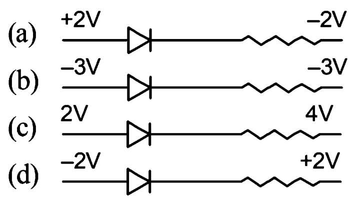
(a) 1.8 eV (b) 1.1 eV (c) 0.8 eV (d) 1.6 eV

101. Hydrogen $\left({}_1H^1\right)$, Deuterium $\left({}_1H^2\right)$, singly ionised Helium $\left({}_2He^4\right)^+$ and doubly ionised lithium $\left({}_3Li^6\right)^{++}$ all have one electron around the nucleus. Consider an electron transition from n = 2 to n = 1. If the wavelengths of emitted radiation are $\lambda_1, \lambda_2, \lambda_3$ and λ_4 respectively then approximately which one of the following is correct? [JEE Main 2014]

(a) $4\lambda_1 = 2\lambda_2 = 2\lambda_3 = \lambda_4$ (b) $\lambda_1 = 2\lambda_2 = 2\lambda_3 = \lambda_4$

(c) $\lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$ (d) $\lambda_1 = 2\lambda_2 = 3\lambda_3 = 4\lambda_4$

102. The forward biased diode connection is: [JEE Main 2014]



103. Match List - I (Electromagnetic wave type) with List - II (Its association/application) and select the correct option from the choices given below the lists: [JEE Main 2014]

	List 1		List 2
1.	Infrared waves	(i)	To treat muscular strain
2.	Radio waves	(ii)	For broadcasting
3.	X-rays	(iii)	To detect fracture of bones
4.	Ultraviolet rays	(iv)	Absorbed by the ozone layer of the atmosphere

	1	2	3	4
(a)	(iv)	(iii)	(ii)	(i)
(b)	(i)	(ii)	(iv)	(iii)
(c)	(iii)	(ii)	(i)	(iv)
(d)	(i)	(ii)	(iii)	(iv)

GP_3481

104. A red LED emits light at 0.1 watt uniformly around it. The amplitude of the electric field of the light at a distance of 1 m from the diode is : **[JEE Main 2015]**

(a) 5.48 V/m (b) 7.75 V/m
(c) 1.73 V/m (d) 2.45 V/m

105. A signal of 5 kHz frequency is amplitude modulated on a carrier wave of frequency 2 MHz. The frequencies of the resultant signal is/are : **[JEE Main 2015]**

(a) 2005 kHz, 2000 kHz and 1995 kHz
(b) 2000 kHz and 1995 kHz
(c) 2 MHz only
(d) 2005 kHz and 1995 kHz

106. As an electron makes a transition from an excited state to the ground state of a hydrogen - like atom/ion : **[JEE Main 2015]**

(a) kinetic energy decreases, potential energy increases but total energy remains same
(b) kinetic energy and total energy decrease but potential energy increases
(c) its kinetic energy increases but potential energy and total energy decrease
(d) kinetic energy, potential energy and total energy decrease

107. Match **List - I** (Fundamental Experiment) with **List - II** (its conclusion) and select the correct option from the choices given below the list: **[JEE Main 2015]**

List-I	List-II
A. Franck-Hertz Experiment	(i) Particle nature of light
B. Photo-electric experiment	(ii) Discrete energy levels of atom
C. Davison-Germer experiment	(iii) Wave nature of electron
	(iv) Structure of atom

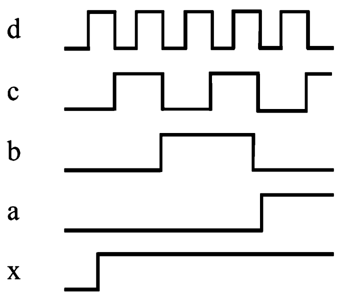
(a) (A)-(ii); (B)-(i); (C)-(iii)
(b) (A)-(iv); (B)-(iii); (C)-(ii)
(c) (A)-(i); (B)-(iv); (C)-(iii)
(d) (A)-(ii); (B)-(iv); (C)-(iii)

108. For a common emitter configuration, if α and β have their usual meanings, the incorrect relationship between α and β is : **[JEE Main 2016]**

(a) $\alpha = \frac{\beta}{1+\beta}$ (b) $\alpha = \frac{\beta^2}{1+\beta^2}$

(c) $\frac{1}{\alpha} = \frac{1}{\beta} + 1$ (d) $\alpha = \frac{\beta}{1-\beta}$

109. If a, b, c, d are inputs to a gate and x is its output, then, as per the following time graph, the gate is : **[JEE Main 2016]**



(a) OR (b) NAND
(c) NOT (d) AND

110. Choose the correct statement : **[JEE Main 2016]**

(a) In frequency modulation the amplitude of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal.
(b) In frequency modulation the amplitude of the high frequency carrier wave is made to vary in proportion to the frequency of the audio signal.
(c) In amplitude modulation the amplitude of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal.
(d) In amplitude modulation the frequency of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal.

111. Radiation of wavelength λ, is incident on a photocell. The fastest emitted electron has speed v. If the wavelength is changed to $\frac{3\lambda}{4}$, the speed of the fastest emitted electron will be: **[JEE Main 2016]**

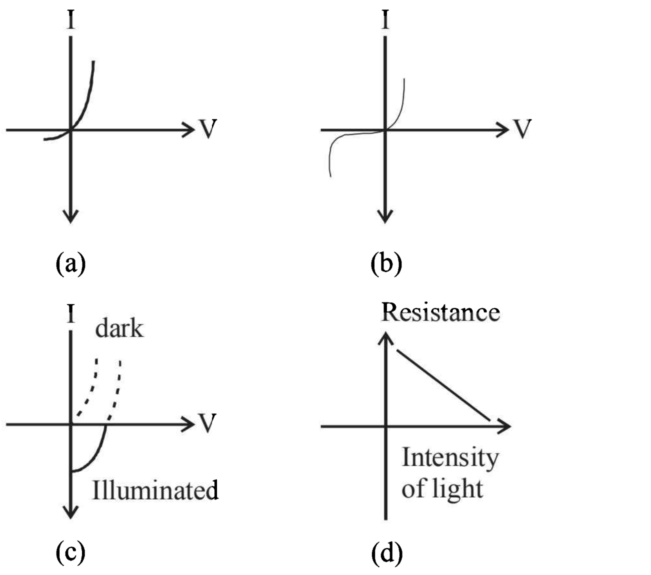
(a) $= v\left(\frac{4}{3}\right)^{\frac{1}{2}}$ (b) $= v\left(\frac{3}{4}\right)^{\frac{1}{2}}$

(c) $> v\left(\frac{4}{3}\right)^{\frac{1}{2}}$ (d) $< v\left(\frac{4}{3}\right)^{\frac{1}{2}}$

112. Half-lives of two radioactive elements A and B are 20 minutes and 40 minutes, respectively. Initially, the samples have equal number of nuclei. After 80 minutes, the ratio of decayed number of A and B nuclei will be : **[JEE Main 2016]**

(a) 1 : 4 (b) 5 : 4
(c) 1 : 16 (d) 4 : 1

113. Identify the semiconductor devices whose characteristics are given below, in the order (a), (b), (c), (d) : **[JEE Main 2016]**



(a) Solar cell, Light dependent resistance, Zener diode, simple diode
(b) Zener diode, Solar cell, simple diode, Light dependent resistance
(c) Simple diode, Zener diode, Solar cell, Light dependent resistance
(d) Zener diode, Simple diode, Light dependent resistance, Solar cell

17 Modern Physics

Section-A : JEE Advanced/ IIT-JEE

A
1. 30,000, 30,000 **2.** 500 disintegration/sec, 125 disintegration/sec
3. frequency **4.** eight, six
5. intensity, decreases **6.** lithium, 7 **7.** atomic number, mass number **8.** 23.6 MeV
9. positive, *p*-part, *n*-part **10.** reverse, negative terminal **11.** 0.27Å **12.** 3.81Å
13. *B* and *D*, *A* and *C* **14.** 3×10^8 **15.** –1 **16.** neutrino **17.** reverse
18. 0.62Å **19.** 41 **20.** fusion, 24.03

B
1. F **2.** F **3.** T **4.** F

C

1. (b)	**2.** (b)	**3.** (c)	**4.** (c)	**5.** (a)	**6.** (d)	**7.** (c)	**8.** (b)
9. (a)	**10.** (d)	**11.** (a)	**12.** (b)	**13.** (b)	**14.** (d)	**15.** (b)	**16.** (c)
17. (b)	**18.** (b)	**19.** (c)	**20.** (a)	**21.** (b)	**22.** (b)	**23.** (c)	**24.** (c)
25. (a)	**26.** (d)	**27.** (d)	**28.** (c)	**29.** (d)	**30.** (a)	**31.** (d)	**32.** (a)
33. (b)	**34.** (a)	**35.** (c)	**36.** (a)	**37.** (d)	**38.** (a)	**39.** (b)	**40.** (d)
41. (b)	**42.** (d)	**43.** (a)	**44.** (a)	**45.** (c)	**46.** (c)	**47.** (c)	**48.** (a)
49. (b)	**50.** (a)	**51.** (b)	**52.** (a)	**53.** (a)	**54.** (a)	**55.** (b)	**56.** (b)
57. (a)	**58.** (b)	**59.** (c)	**60.** (c)				

D

1. (b, d)	**2.** (c, d)	**3.** (b, c)	**4.** (a, c, d)	**5.** (a)	**6.** (d)	**7.** (c)	**8.** (c, d)
9. (a)	**10.** (a, b, c)	**11.** (c)	**12.** (d)	**13.** (c, d)	**14.** (b)	**15.** (b, d)	**16.** (b)
17. (b)	**18.** (b, d)	**19.** (b, c)	**20.** (c)	**21.** (a, b, c)	**22.** (a, d)	**23.** (a, c)	**24.** (a, c)
25. (c, d)	**26.** (a, d)	**27.** (d)	**28.** (c)	**29.** (b)	**30.** (c)	**31.** (c)	**32.** (a, c)
33. (b, d)	**34.** (a, c)	**35.** (a, c)	**36.** (a)	**37.** (a,b,d)	**38.** (c)		

E
1. **(i)** 5 **(ii)** 16.53 eV **(iii)** 3.65×10^{-9} m **(iv)** 340 eV, –680 eV, 1.05×10^{-34} J.s **(v)** 1.05×10^{-11} m **2.** 6, 18.835×10^{-7} m
3. 0, 11, 13 **4.** **(i)** 300Å **(ii)** 2.5×10^{-11} m **5.** **(i)** 1.142×10^{-8} **(ii)** 3 **6.** 8 mΩ, 12.5×10^{-3} s, 100
7. **(i)** $r = \dfrac{n^2 h^2 \epsilon_0}{624 \pi m e^2}$ **(ii)** 25 **(iii)** 5.478×10^{-11} m **8.** **(i)** 2 **(ii)** 14.46 eV **(iii)** 13.5 eV, 0.7 eV
9. 2 eV, 0.754 V **10.** 119.6 gm **12.** **(a)** 232, 90 **(b)** 5.34 MeV, 1823 MeV
13. **(a)** 2.55 eV **(b)** $4 \rightarrow 2$ **(c)** $-\dfrac{h}{\pi}$ **(d)** 0.814 m/s **14.** 5.95 ℓ **15.** 6, 3 **16.** **(i)** 3.4 eV **(ii)** 0.66×10^{-9} m
17. **(i)** 14.43 sec. **(ii)** 40 sec. **18.** 151 eV, 0.5 Å **19.** 3.32×10^{-5} W
20. **(a)** $\dfrac{1}{\lambda}\left[\alpha - (\alpha - \lambda N_0)e^{-\lambda t}\right]$ **(b)** $\dfrac{3}{2}N_0, 2N_0$ **21.** 3.4 eV, 3.84 eV and 2.64 eV **22.** 2, 4, 10.5 eV
23. 6.25×10^{11}, 0 eV, 5 eV **24.** 38451 Kg **25.** 10^{-12} J, 227.62 amu
26. $15 \log_e 3, \dfrac{10^{20}}{3\sqrt{3}}, 10^{20}\left(\dfrac{3\sqrt{3}-4}{3\sqrt{3}}\right)$ **27.** **(a)** 3 **(b)** 4052 nm
28. **(a)** 5×10^7 **(b)** 2000 N/C **(c)** 23 eV **29.** 42 **30.** $\dfrac{2}{\log_e(4/3)}$ **32.** 0.26
33. 0.55 eV **34.** $\sqrt{2}$ **35.** **(a)** 56 **(b)** 1.546×10^{18} Hz. **36.** 24

F	**1.** A-p; B-t; C-u; D-r		**2.** A-p, q; B-p, r; C-p, s; D-p, q, r				
	3. A-p, r; B-q, s; C-p; D-q		**4.** A-p, q, t; B-q; C-s; D-s		**5.** (c)		
	6. A-r, t; B-p, s; C-p, q, r, t; D-p, q, r, t						
G	**1.** (c)	**2.** (c)	**3.** (a)	**4.** (d)	**5.** (a)	**6.** (b)	
	7. (a)	**8.** (b)	**9.** (d)	**10.** (d)	**11.** (b)	**12.** (c)	
	13. (d)	**14.** (c)	**15.** (a)	**16.** (c)			
H	**1.** (b)						
I	**1.** (3)	**2.** (8)	**3.** (1)	**4.** (7)	**5.** (7)	**6.** (1)	**7.** (4)
	8. (3)	**9.** (2)	**10.** (2)	**11.** (2)	**12.** (9)	**13.** (6)	

Section-B : JEE Main/ AIEEE

1. (c)	**2.** (c)	**3.** (a)	**4.** (c)	**5.** (a)	**6.** (a)	**7.** (c)	**8.** (c)	**9.** (a)	**10.** (c)	**11.** (c)	**12.** (a)
13. (c)	**14.** (b)	**15.** (a)	**16.** (b)	**17.** (a)	**18.** (a)	**19.** (d)	**20.** (b)	**21.** (c)	**22.** (a)	**23.** (a)	**24.** (b)
25. (d)	**26.** (a)	**27.** (b)	**28.** (a)	**29.** (a)	**30.** (c)	**31.** (d)	**32.** (d)	**33.** (b)	**34.** (a)	**35.** (b)	**36.** (d)
37. (a)	**38.** (d)	**39.** (c)	**40.** (d)	**41.** (b)	**42.** (d)	**43.** (a)	**44.** (d)	**45.** (a)	**46.** (a)	**47.** (c)	**48.** (b)
49. (c)	**50.** (c)	**51.** (b)	**52.** (c)	**53.** (b)	**54.** (d)	**55.** (b)	**56.** (b)	**57.** (c)	**58.** (c)	**59.** (a)	**60.** (c)
61. (c)	**62.** (a)	**63.** (a)	64. (c)	**65.** (a)	**66.** (d)	**67.** (b)	**68.** (b)	**69.** **(d)**	**70.** (a)	**71.** (b)	**72.** (d)
73. (c)	**74.** (a)	**75.** (d)	**76.** (d)	**77.** (b)	**78.** (d)	**79.** (c)	**80.** (b)	**81.** (b)	**82.** (a)	**83.** (a)	**84.** (b)
85. (b)	**86.** (b)	**87.** (c)	**88.** (d)	**89.** (a)	**90.** (a)	**91.** (a)	**92.** (d)	**93.** (b)	**94.** (b)	**95.** (d)	**96.** (a)
97. (d)	**98.** (a)	**99.** (c)	**100.** (b)	**101.** (c)	**102.** (a)	**103.** (d)	**104.** (d)	**105.** (a)	**106.** (c)	**107.** (a)	**108.** (b, d)
109. (a)	**110.** (c)	**111.** (c)	**112.** **(b)**	**113.** **(c)**							

Section-A JEE Advanced/ IIT-JEE

A. Fill in the Blanks

1. For minimum accelerating voltage, the electron should jump from $n = 2$ to $n = 1$ level.
For characteristic X-rays

$$\frac{1}{\lambda} = R_\alpha (Z-1)^2 \left[1 - \frac{1}{n^2}\right] = = \frac{E}{hc}$$

$$\therefore \quad \frac{E_1}{hc} = R_\alpha (Z-1)^2 \left[1 - \frac{1}{2^2}\right] \qquad \text{......(i)}$$

The binding energy of innermost electron = 40 keV
$\therefore$ Ionisation potential of tungsten = 40 kV = 40×10^3 V

$$\Rightarrow \quad \frac{E_2}{hc} = R_\alpha (Z-1)^2 \left[1 - \frac{1}{\infty^2}\right] \qquad \text{.....(ii)}$$

$$\therefore \quad \frac{E_1}{E_2} = \frac{\left[1 - \frac{1}{2^2}\right]}{\left[1 - \frac{1}{\infty^2}\right]}$$

$$\Rightarrow \quad E_1 = \frac{3}{4} E_2 = \frac{3}{4} \times 40{,}000 \text{ eV} = 30{,}000 \text{ eV}$$

$\therefore$ Minimum accelerating voltage,

$$V_{\min} = \frac{E_1}{e} = 30{,}000\ V$$

2. $A = A_0 \left(\frac{1}{2}\right)^n$ where A_0 = Initial activity = 1000 dps (given)
A = Activity after n half lives

At $t = 1, n = 1 \therefore A = 1000 \left(\frac{1}{2}\right)^1 = 500$ dps

At $t = 3, n = 3 \therefore A = 1000 \left(\frac{1}{2}\right)^3 = 125$ dps

3. **Note :** According to law of photoelectric effect
$(\text{K.E.})_{\max} = h\nu - h\nu_0$
i.e., the maximum kinetic energy of electrons emitted in the photoelectric effect is linearly dependent on the frequency of incident radiation.

4. $^{238}_{92}\text{U} \rightarrow {}^{206}_{82}\text{Pb} + \text{x}\ {}^{4}_{2}\text{He} + \text{y}\ {}^{0}_{-1}\text{e}$
First we find the number of α- particles. The change in mass number during the decay from uranium to lead = 238 – 206 = 32. Therefore, the number of α-particles (with mass no. 4)

$$= \frac{32}{4} = 8$$

The change in atomic number (i.e, number of protons) taking place when 8 α-particles are emitted and lead is formed is $= 92 - (82 + 2 \times 8) = 92 - (82 + 16) = 92 - 98 = -6$
This change will take place by emitting of six β-particles.

5. **Note :** More the number of electrons striking the anode, more is the intensity of X-rays.
When the speed of the striking electrons on anode is increased, the emitted X-rays have greater energy. We know that energy, $E = \frac{hc}{\lambda}$. Therefore, when E increases then λ decreases.

6. ${}^{10}_{5}\text{B} + {}^{1}_{0}\text{n} \longrightarrow {}^{4}_{2}\text{He} + {}^{7}_{3}\text{Li}$
The resulting nucleus is of element lithium and mass number is 7.

7. Atomic number, mass number

8. ${}^{2}_{1}\text{H} + {}^{2}_{1}\text{H} \longrightarrow {}^{4}_{2}\text{He}$
Binding energy of two deuterons
$= 2\,[1.1 \times 2] = 4.4$ MeV
Binding energy of helium nucleus $= 4 \times 7.0 = 28\ MeV$
The energy released $= 28 - 4.4 = 23.6\ MeV$

9. Positive, p-part, n-part

10. Reverse, negative terminal.

11. We know that

For K_α, $\frac{1}{\lambda} = C\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$, where C is a constant

$$\Rightarrow \frac{1}{0.32\text{Å}} = C\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3C}{4} \quad \text{....(i)}$$

For K_β, $\frac{1}{\lambda} = C\left[\frac{1}{1^2} - \frac{1}{3^2}\right] = \frac{8C}{9}$

On dividing, we get $\lambda = 0.27$ Å.

12. The fifth valence electron of phosphorous is in its third shell, i.e., $n = 3$. For phosphorous, $Z = 15$. The Bohr's radius for nth orbit

$$= \left(\frac{n^2}{Z}\varepsilon_r\right) r_0 = \frac{3^2}{15} \times 12 \times 0.529\ \text{Å} = 3.81\text{Å}$$

13. *B and D is a.c. input* and *A and C is the d.c. output.*
Case (i) When B is –ve and D is +ve
Current passes from $D \to A \to C \to B$
Case (ii) When B is + ve and D is – ve
Current passes from $B \to A \to C \to B$
Thus curve is always from A to C in output (a d.c. current)

14. The speed of X-rays is always 3×10^8 m/s in vacuum. It does not depend on the potential differences through which electrons are accelerated in an X-ray tube.
Note : All electromagnetic waves propagate at 3×10^8 m/s in vacuum.

15. $\text{K.E.} = \frac{kZe^2}{2r}$ and

Total energy $\text{T.E.} = \frac{-kZ\,e^2}{2r}$ $\quad \therefore \frac{\text{K.E.}}{\text{T.E.}} = -1$

16. ${}^{11}_{6}C \to {}^{11}_{5}B + \beta^+ + X \Rightarrow {}^{11}_{6}C \to {}^{11}_{5}B + {}^{0}_{+1}e + \nu$ (neutrino)
The balancing of atomic number and mass number is correct. Therefore, X stands for neutrino.

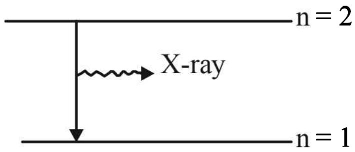
17. Reverse

18. $$\lambda_{min} = \frac{hc}{eV} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times 20 \times 10^3} = 0.62\text{Å}$$

19. $$\frac{1}{\lambda} = R(Z-1)^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$
Since for K_α, $n_2 = 2$ and $n_1 = 1$

$$\therefore \frac{1}{0.76 \times 10^{-10}} = 1.097\,(Z-1)^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$$

$\Rightarrow z - 1 = 40 \quad \Rightarrow Z = 41$



20. This is a nuclear fusion reaction
Energy released $= (\Delta m)\,[931.5\ MeV/u]$
$= [2 \times 2.0141 - 4.0024] \times 931.5\ MeV$
$= 24.03\ MeV$

B. True/ False

1. For photoelectric effect
$h\nu - h\nu_0 = (\text{K.E.})_{max}$
where h = Planck's constt.
ν_0 = Threshold frequency
$\Rightarrow (\text{K.E.})_{max} \propto \nu$
K.E. does not depend on the intensity of incident radiation.

2. $(\text{K.E.})_{max} = h\nu - h\nu_0 \Rightarrow (\text{K.E.})_{max} \propto \nu$
Thus maximum kinetic energy is proportional to frequency and not intensity.

3. **Note :** When the cathode temperature is higher, then more number of electrons will be emitted which in turn will increase the anode current.

4. $$\text{Density} = \frac{m}{V} = \frac{A \times 1.67 \times 10^{-27}}{\frac{4}{3}\pi\left[R_0 A^{1/3}\right]^3}$$

$$= \frac{1.67 \times 10^{-27}}{1.33 \times 3.14 \times (1.1 \times 10^{-15})} = 3 \times 10^{17}\ \text{kg/m}^3$$
where A = mass number.
Note : The order of nuclear density is 10^{17} kg/m^3.

C. MCQs with ONE Correct Answer

1. **(b)** **KEY CONCEPT :**
We know that $\mu = g_m \times r_0$
where μ = amplification factor,
g_m = mutual conductance
r_0 = plate resistance
$\therefore \quad \mu = 3 \times 10^3 \times 1.5 \times 10^{-3} = 4.5$

2. **(b)** $t_{1/2} = 3.8$ day

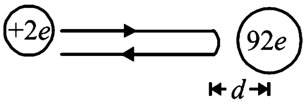
$$\therefore \quad \lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{3.8} = 0.182$$

If the initial number of atom is $a = A_0$ then after time t the number of atoms is $a/20 = A$. We have to find t.

$$t = \frac{2.303}{\lambda} \log \frac{A_0}{A} = \frac{2.303}{0.182} \log \frac{a}{a/20} = 16.46 \text{ days}$$

3. (c) One point charge is $\left({}^{235}_{92}\text{U}\right)$ uranium nucleus

$\therefore\ q_1 = 92e$



The other point charge is α particle $\therefore\ q_2 = +2e$

Here the loss in K.E. = Gain in P.E. (till α-particle reaches the distance d)

$$\Rightarrow \frac{1}{2}mv^2 = k\frac{q_1q_2}{r} \Rightarrow r = k\frac{2q_1q_2}{\frac{1}{2}mv^2}$$

$$\therefore\ r = \frac{9\times10^9 \times 2\times1.6\times10^{-19}\times92\times1.6\times10^{-19}}{5\times1.6\times10^{-13}}$$

$= 529.92 \times 10^{-16}$ m

$= 529.92 \times 10^{-14}$ cm $\quad = 5.2992 \times 10^{-12}$ cm

4. (c) β-particles are charged particles emitted by the nucleus.

5. (a) **KEY CONCEPT :** The maximum number of electrons in an orbit is $2n^2$. $n > 4$ is not allowed.

Therefore the number of maximum electron that can be in first four orbits are

$2(1)^2 + 2(2)^2 + 2(3)^2 + 2(4)^2$

$= 2 + 8 + 18 + 32 = 60$

Therefore, possible element are 60.

6. (d) We know that

$$\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right] \Rightarrow \frac{1}{\lambda} \propto Z^2$$

λ is shortest when $\frac{1}{\lambda}$ is largest i.e., when Z has a higher value. Z is highest for lithium.

7. (c) $4{}^1_1\text{H}^+ \to {}^4_2\text{He}^{2+} + 2\text{e}^- + 26\,\text{MeV}$

represent a fusion reaction.

8. (b) Fast neutrons can be easily slowed down by passing them through water.

9. (a) **Note :** The penetrating power is dependent on velocity. For a given energy, the velocity of γ radiation is highest and α-particle is least.

10. (d) When one e^- is removed from neutral helium atom, it becomes a one e^- species.

For one e^- species we know

$$E_n = \frac{-13.6Z^2}{n^2} \text{ eV/atom}$$

For helium ion, $Z = 2$ and for first orbit $n = 1$.

$$\therefore\ E_1 = \frac{-13.6}{(1)^2} \times 2^2 = -54.4 \text{ eV}$$

$\therefore$ Energy required to remove this $e^- = +54.4$ eV

$\therefore$ Total energy required = 54.4 + 24.6 = 79 eV

11. (a) $\frac{-dN}{dt} = \lambda_1 N + \lambda_2 N$

$$\Rightarrow \log_e \frac{N}{N_o} = -(\lambda_1 + \lambda_2)t$$

when N_0 is initial number of atoms

Here $\lambda_1 = \frac{0.693}{1620}$ and $\lambda_2 = \frac{0.693}{810}$;

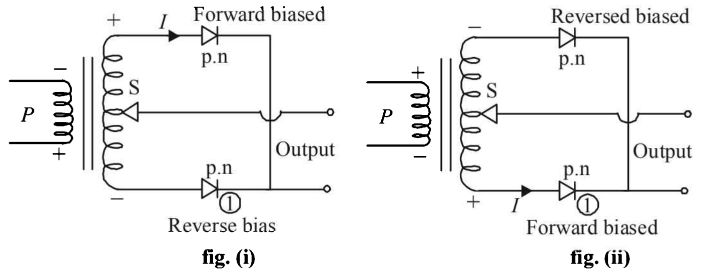
$$\frac{N}{N_o} = \frac{1}{4} \Rightarrow \log_e \frac{1}{4} = -\left(\frac{0.693}{1620} + \frac{0.693}{810}\right)t$$

$\Rightarrow t = 1\ 1080$ years

12. (b) **KEY CONCEPT :** For a semi conductor $n = n_0 e^{-Eg/kT}$ where n_0 = no. of free electrons at absolute zero, n = no. of free electrons at T kelvin, E_g = Energy gap, k = Boltzmann constant.

As E_g increases, n decreases exponentially.

13. (b) As shown in the fig. (i) during one half cycle the polarity of P and S are opposite such that diode (1) is reversed biased and hence non conducting.



During the other half cycle, diode (1) gets forward biased and is conducting. Thus diode (1) conducts in one half cycle and does not conduct in the other so the correct option is (b) (a and c.)

14. (d) **KEY CONCEPT :**

$$E_n = -13.6\frac{(Z^2)}{(n^2)} \text{eV}$$

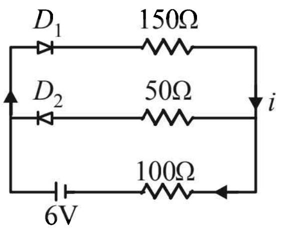
Therefore, ground state energy of doubly ionized lithium atom ($Z = 3$, $n = 1$) will be

$$E_1 = (-13.6)\frac{(3)^2}{(1)^2} = -122.4 \text{ eV}$$

$\therefore$ Ionization energy of an electron in ground state of doubly ionized lithium atom will be 122.4eV.

15. (b) In the circuit, diode D_1 is forward biased, while D_2 is reverse biased. Therefore, current i (through D_1 and 100Ω resistance) will be

$$i = \frac{6}{50 + 100 + 150} = 0.02A$$



Here, 50Ω is the resistance of D_1 in forward biasing.

16. (c) In n-type semiconductors, electrons are the majority charge carriers.

17. (b) **Note :**
Stopping potential is the negative potential applied to stop the electrons having maximum kinetic energy. Therefore, stopping potential will be 4 volt.

18. (b) **KEY CONCEPT :**
According to Doppler's effect of light, the wavelength shift is given by

$$\Delta\lambda = \frac{v}{c} \times \lambda$$

$$\Rightarrow \quad v = \frac{\Delta\lambda \times c}{\lambda} = \frac{(706-656)}{656} \times 3 \times 10^8 \approx 2 \times 10^7 \text{ m/s}$$

19. (c) Applying conservation of linear momentum,
Initial momentum = Final momentum
$0 = m_1v_1 - m_2v_2 \Rightarrow m_1v_1 = m_2v_2$

Now, $\frac{\lambda_1}{\lambda_2} = \frac{h/m_1v_1}{h/m_2v_2} = 1$

20. (a) Beta rays are same as cathode rays as both are stream of electrons.

21. (b) Nuclear density of an atom of mass number A,

$$d = \frac{\text{mass}}{\text{volume}} = \frac{A(1.67 \times 10^{-27})}{\frac{4}{3}\pi[1.25 \times 10^{-15} A^{1/3}]^3}$$

$$\left[\because V = \frac{4}{3}\pi R^3, R = R_0A^{1/3}, R_0 = 1.25 \times 10^{-15}\right]$$

$\therefore \quad d = 2 \times 10^{17}$ kg/m^3.

22. (b) ${}^{22}_{10}\text{Ne} \to {}^{4}_{2}\text{He} + {}^{4}_{2}\text{He} + {}^{14}_{6}\text{X}$
The new element X has atomic number 6. Therefore, it is carbon atom.

23. (c) **KEY CONCEPT :** Energy is released when stability increases. This will happen when binding energy per nucleon increases.

Reactant	**Product**
Reaction (a) $60 \times 8.5\text{MeV} = 510\text{MeV}$	$2 \times 30 \times 5 = 300$ MeV
Reaction (b) $120 \times 7.5 = 900$ MeV	$(90 \times 8 + 30 \times 5) = 870$ MeV
Reaction (c) $120 \times 7.5 = 900$ MeV	$2 \times 60 \times 8.5 = 1020$ MeV
Reaction (d) $90 \times 8 = 720$ MeV	$(60 \times 8.5 + 30 \times 5) = 600$ MeV

24. (c) **KEY CONCEPT :**

$$\lambda \propto \frac{1}{m}$$

For ordinary hydrogen atom, longest wavelength

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5R}{36} \text{ or } \lambda = \frac{36}{5R}$$

With hypothetical particle, required wavelength

$$\lambda' = \frac{1}{2} \times \frac{36}{5R} = \frac{18}{5R}$$

25. (a) **NOTE :**
As the electron comes nearer to the nucleus the potential energy decreases

$$\left(\because \frac{-k.Ze^2}{r} = \text{P.E. and } r \text{ decreases}\right)$$

The K.E. will increase $\left[\because \text{K.E.} = \frac{1}{2}|\text{P.E.}| = \frac{1}{2}\frac{kZe^2}{r}\right]$

The total energy decreases $\left[\text{T.E.} = -\frac{1}{2}\frac{kZe^2}{r}\right]$

26. (d) $N_1 = N_0e^{-10\lambda t}$ and $N_2 = N_0e^{-\lambda t}$.

$$\therefore \quad \frac{N_1}{N_2} = \frac{e^{-10\lambda t}}{e^{-\lambda t}} = \frac{1}{e^{9\lambda t}}$$

Given $\frac{N_1}{N_2} = \frac{1}{e}$; $\therefore \frac{1}{e^{9\lambda t}} = \frac{1}{e}$

or, $9\lambda t = 1$ or $t = \left(\frac{1}{9\lambda}\right)$

27. (d) **KEY CONCEPT :**

$$\lambda_{\min} = \frac{hc}{E}$$

$$\therefore \quad \lambda_{\min} = \frac{12400}{80 \times 10^3} \text{Å} = 0.155\text{Å}$$

Energy of incident electrons is greater than the ionization energy of electrons in K-shell, the K-shell electrons will be knocked off. Hence, characteristic X-ray spectrum will be obtained.

28. (c) **Note :** In a nucleus neutron converts into proton as follows
$n \to p^+ + e^{-1}$
Thus, decay of neutron is responsible for β-radiation origination

29. (d) For 2 to 1, 3 to 2 and 4 to 2 we get energy that $n = 4$ to $n = 3$,
I.R. radiation has less energy than U.V. radiation.

30. (a) **KEY CONCEPT :**
In case of Coolidge tube

$$\lambda_{\min} = \frac{hc}{eV} = \lambda \text{ (as given here)}$$

Thus the cut off wavelength is inversely proportional to accelerating voltage. As V increases, λ_c decreases. λ_k is the wavelength of K_α line which is a characteristic of an atom and does not depend on accelerating voltage of bombarding electron since λ_k always refers to a photon wavelength of transition of e^- from the target element from $2 \to 1$.
The above two facts lead to the conclusion that
$\lambda_k - \lambda_c$ increases as accelerating voltage is increased.

31. (d) $N_1 = N_0e^{-\lambda_1 t} = N_0e^{-\frac{t}{\tau}}$ ....(i)

as $\tau = \frac{1}{\lambda_1}$

$N_2 = N_0e^{-\lambda_2 t} = N_0e^{-\frac{t}{5\tau}}$ ....(i) as $5\tau = \frac{1}{\lambda_2}$

Adding (i) and (ii) we get

$N = N_1 + N_2 = N_0(e^{-t/\tau} + e^{-t/5\tau})$

(a) is NOT the correct option as there is a time τ for which N is constant which means for time τ there is no process of radioactivity which does not makes sense. (b) and (c) shows intermediate increase in the number of radioactive atom which is IMPOSSIBLE as N will only decrease exponentially.

32. (a) KEY CONCEPT :

$I = \frac{q}{t} = \frac{ne}{t}$

No. of electrons striking the target per second

$= \frac{I}{e} = 2 \times 10^{16}$

33. (b) $l = \frac{nh}{2\pi}, |E| \propto Z^2/n^2; n = 3$

$\Rightarrow l_H = l_{Li}$ and $|E_H| < |E_{Li}|$

34. (a) $A = A_0 (1/2)^n$; n = number of half lives.

$\frac{A_0}{16} = A_0\left(\frac{1}{2}\right)^n \quad \therefore \left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^n$

$\Rightarrow \quad n = 4$

$\therefore \quad t = (4 \times 100)\mu s = 400\ \mu s$

35. (c) In γ-decay, the atomic number and mass number do not change.

36. (a) Given potential energy between electron and proton

$= eV_0 \log \frac{r}{r_0} \qquad [\because |U| = eV]$

$\therefore \quad |F| = \frac{d}{dr}\left[eV_0 \log_e \frac{r}{r_0}\right] = \frac{eV_0}{r_0} \times \frac{1}{r}$

But this force acts as centripetal force

$\therefore \quad \frac{mv^2}{r} = \frac{eV_0}{rr_0} \Rightarrow mv^2 = \frac{eV_0}{r_0}$ ...(i)

By Bohr's postulate, $mvr = \frac{nh}{2\pi}$ ....(ii)

From (i) and (ii),

$\frac{m^2v^2r^2}{mv^2} = \frac{n^2h^2r_0}{4\pi^2 \times V_0 e}$

$\Rightarrow r^2 = \frac{n^2h^2r_0}{4\pi V_0 me} \Rightarrow r \propto n$

37. (d) KEY CONCEPT : For an atom following Bohr's model, the radius is given by

$r_m = \frac{r_0 m^2}{Z}$ where r_0 = Bohr's radius and m = orbit number.

For Fm, $m = 5$ (Fifth orbit in which the outermost electron is present)

$\therefore \quad r_m = \frac{r_0 5^2}{100} = nr_0$ (given) $\Rightarrow n = \frac{1}{4}$

38. (a) KEY CONCEPT : We know that radius of the nucleus $R = R_0 A^{1/3}$, where A is the mass number.

$\therefore \ R^3 = R_0^3 A$

$\Rightarrow \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A \Rightarrow$ Volume $\propto$ mass.

39. (b) By conservation of momentum, $p_1 = p_2$

$\sqrt{2K_1 m_1} = \sqrt{2K_2 m_2}$

$\Rightarrow \ \sqrt{2K_1(216)} = \sqrt{2K_2(4)}$

$\Rightarrow \ K_2 = 54K_1$ ...(i)

Also, $K_1 + K_2 = 5.5$ MeV ...(ii)

Solve equation (i) and (ii)

40. (d) From the graph it is clear that A and B have the same stopping potential and therefore, the same frequency. Also, B and C have the same intensity.

41. (b) In two half lives, the activity will remain $\frac{1}{4}$ of its initial activity.

42. (d) For photon,

$\lambda_2 = \frac{hc}{E}$ ...(i)

For proton, $p = \sqrt{2mE}$

$\lambda_1 = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$ ...(ii)

$\frac{\lambda_2}{\lambda_1} = \frac{hc}{E \times \frac{h}{\sqrt{2mE}}} \propto E^{-1/2}$

43. (a) For K_α, $\frac{1}{\lambda} \propto (Z-1)^2$

From (i), $\frac{\lambda_2}{\lambda_1} = \frac{(Z_1-1)^2}{(Z_2-1)^2} \Rightarrow \frac{4\lambda}{\lambda} = \frac{(11-1)^2}{(Z_2-1)^2}$

$\Rightarrow Z_2 - 1 = \frac{10}{2} \Rightarrow Z_2 = 6$

44. (a) Initially a photon of energy 10.2eV collides inelastically with a hydrogen atom in ground state. For hydrogen atom,

$E_1 = -13.6$ eV; $E_2 = -\frac{13.6}{4}$ eV $= -3.4$eV

$\therefore \ E_2 - E_1 = 10.2$ eV

The electron of hydrogen atom will jump to second orbit after absorbing the photon of energy 10.2 eV. The electron jumps back to its original state in less than microsecond and release a photon of energy 10.2 eV. Another photon of energy 15 eV strikes the hydrogen atom inelastically. This energy is sufficient to knock out the electron from the atom as ionisation energy is 13.6 eV. The remaining energy of 1.4 eV is left with electron as its kinetic energy.

45. (c) Note : Since electron shows wave nature, it will show the phenomenon of interference.

For electron, $\lambda = \frac{h}{mv}$

When speed of electron increases, λ will decrease. The distance between two consecutive fringes

$$\beta = \frac{\lambda D}{d}$$

As λ decreases, β also decrease.

46. (c) $4\,{}_2^4He \longrightarrow {}_8^{16}O$

B.E. = $\Delta m \times 931.5$ MeV

$= (4 \times 4.0026 - 15.9994) \times 931.5 = 10.24$ MeV

47. (c) For a nucleus to disintegrate in two half life, the probability is $\frac{3}{4}$ as 75% of the nuclei will disintegrate in this time.

48. (a) Iodine and Yttrium are medium sized nuclei and therefore, have more binding energy per nucleon as compared to Uranium which has a big nuclei and less B.E./nucleon.

In other words, Iodine and Yttrium are more stable and therefore possess less energy and less rest mass. Also when Uranium nuclei explodes, it will convert into *I* and *Y* nuclei having kinetic energies.

49. (b) The smallest frequency and largest wavelength in ultraviolet region will be for transition of electron from orbit 2 to orbit 1.

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

$$\Rightarrow \frac{1}{122 \times 10^{-9} m} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = R\left[1 - \frac{1}{4}\right] = \frac{3R}{4}$$

$$\Rightarrow R = \frac{4}{3 \times 122 \times 10^{-9}} m^{-1}$$

The highest frequency and smallest wavelength for infrared region will be for transition of electron from ∞ to 3rd orbit.

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

$$\Rightarrow \frac{1}{\lambda} = \frac{4}{3 \times 122 \times 10^{-9}}\left(\frac{1}{3^2} - \frac{1}{\infty}\right)$$

$$\therefore \lambda = \frac{3 \times 122 \times 9 \times 10^{-9}}{4} = 823.5\text{nm}$$

50. (a) The cut off wavelength is given by

$$\lambda_0 = \frac{hc}{eV} \quad \text{...(i)}$$

According to de Broglie equation

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$$

$$\Rightarrow \lambda^2 = \frac{h^2}{2meV} \Rightarrow V = \frac{h^2}{2me\lambda^2} \quad \text{..(ii)}$$

From (i) and (ii),

$$\lambda_0 = \frac{hc \times 2me\lambda^2}{eh^2} = \frac{2mc\lambda^2}{h}$$

51. (b) The continuous spectrum depends on the accelerating voltage. It has a definite minimum wavelength.

Greater the accelerating voltage for electrons, higher will be the kinetic energy it attains before striking the target, higher will be the frequency of X - rays and smaller will be the wavelength. The wavelength of continuous X - rays is independent of the atomic number of target material.

52. (a)

Sample S – 1	**Sample S – 2**
Activity 5 μCi	10 μCi
No. of nuclei $N_1 = 2N$	$N_2 = N$
$-\left(\frac{dN}{dt}\right)_1 = \lambda_1 N_1$	$-\left(\frac{dN}{dt}\right)_2 = \lambda_2 N_2$
$\Rightarrow -5 = \lambda_1 \times 2N$ ...(i)	$-10 = \lambda_2 \times N$ ...(ii)
From (i) and (ii)	
$\frac{5}{10} = \frac{\lambda_1 \times 2N}{\lambda_2 \times N} \Rightarrow$	$\frac{\lambda_1}{\lambda_2} = \frac{1}{4}$

$$\Rightarrow \frac{(T_{1/2})_2}{(T_{1/2})_1} = \frac{1}{4} \quad \left[\because \lambda \propto \frac{1}{T_{1/2}}\right]$$

53. (a) The energy possessed by photons of wavelength 550 nm is $\frac{1240}{550} = 2.25$ eV

The energy possessed by photons of wavelength 450 nm is $\frac{1240}{450} = 2.76$ eV

The energy possessed by photons of wavelength 350 nm is $\frac{1240}{350} = 3.54$ eV

For metal plate *p* :

$$\phi_p = 2\,eV.$$

All the wavelengths are capable of ejecting electrons. Therefore, the current is maximum. Also as the work function is lowest in *p*, the kinetic energy of ejected electron will be highest and therefore, the stopping potential is highest.

For metal plate *q* :

$$\phi_q = 2.5\,eV.$$

Photons of wavelength 550 nm will not be able to eject electrons and therefore, the current is smaller than *p*. The work function is greater than *q* therefore the stopping potential is lower in comparison to *p*.

For metal plate *r* :

$$\phi_r = 3\,eV$$

Only wavelength of 350 nm will be able to eject electrons and therefore, current is minimum. Also the stopping potential is least.

54. (a) We know that $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

The wave length of first spectral line in the Balmer series of hydrogen atom is 6561Å. Here $n_2 = 3$ and $n_1 = 2$

$$\therefore \frac{1}{6561} = R(1)^2\left(\frac{1}{4}-\frac{1}{9}\right) = \frac{5R}{36} \quad ...(i)$$

For the second spectral line in the Balmer series of singly ionised helium ion $n_2 = 4$ and $n_1 = 2$; $Z = 2$

$$\therefore \frac{1}{\lambda} = R(2)^2\left[\frac{1}{4}-\frac{1}{16}\right] = \frac{3R}{4} \quad ...(ii)$$

Dividing equation (i) and equation (ii) we get

$$\frac{\lambda}{6561} = \frac{5R}{36}\times\frac{4}{3R} = \frac{5}{27}$$

$\therefore \quad \lambda = 1215$ Å

55. (b) $p = \frac{E}{c} = \frac{P\times t}{c} = \frac{30\times10^{-3}\times100\times10^{-9}}{3\times10^{8}} = 10^{-17}\text{kg ms}^{-1}$

option (b) is correct

56. (b) $\frac{\lambda_{Cu}}{\lambda_{Mo}} = \frac{(Z_{Mo}-1)^2}{(Z_{Cu}-1)^2} = \left(\frac{42-1}{29-1}\right)^2 = \left(\frac{41}{28}\right)^2 = 2.14$

$$\left[\begin{array}{l} \because \sqrt{\nu} = (Z-b) \text{ here } b = 1 \\ \nu = (Z-1)^2 \\ \frac{1}{\lambda} \propto (Z-1)^2 \end{array}\right]$$

57. (a) $\frac{hC}{\lambda_1} - W = \frac{1}{2}mu_1^2$

and $\frac{hC}{\lambda_2} - W = \frac{1}{2}mu_2^2$

Dividing the above two equations, we get

$$\frac{\frac{hC}{\lambda_1}-W}{\frac{hC}{\lambda_2}-W} = \frac{u_1^2}{u_2^2}$$

$$\therefore \quad \frac{\frac{1240}{248}-W}{\frac{1240}{310}-W} = \frac{4}{1}$$

$$\therefore \quad \frac{1240}{248} - W = \frac{4\times1240}{310} - 4W$$

$\therefore \quad W = 3.7$ eV

58. (b) $\frac{hc}{e\lambda_1} - \frac{\phi}{e} = V_{0_1}$ and $\frac{hc}{e\lambda_2} - \frac{\phi}{e} = V_{0_2}$

$$\therefore \frac{hc}{e}\left[\frac{1}{\lambda_1}-\frac{1}{\lambda_2}\right] = V_{0_1} - V_{0_2}$$

$$\therefore h = \frac{e(V_{0_1}-V_{0_2})\lambda_1\lambda_2}{(\lambda_2-\lambda_1)c}$$

From the first two values given in data

$$h = \frac{1.6\times10^{-19}[2-1]\times0.4\times0.3\times10^{-6}}{0.1\times3\times10^{8}}$$

$h = 0.64\times10^{-33} = 6.4\times10^{-34}$ J-s

Similarly if we calculate h for the last two values of data $h = 6.4\times10^{-34}$J-s

59. (c) Binding energy of nitrogen atom
$= [8\times1.008665 + 7\times1.007825 - 15.000109]\times931$
Binding energy of oxygen atom
$= [7\times1.008665 + 8\times1.007825 - 15.003065]\times931$
$\therefore$ Difference $= 0.0037960\times931$ MeV ...(I)

Also $E_O = \frac{3}{5}\times\frac{8\times7}{R}\times\frac{e^2}{4\pi\epsilon_0} = \frac{3}{5}\times\frac{56}{R}\times1.44\text{MeV}$

$E_N = \frac{3}{5}\times\frac{7\times6}{R}\times\frac{e^2}{4\pi\epsilon_0} = \frac{3}{5}\times\frac{42}{R}\times1.44\text{MeV}$

$\therefore E_O - E_N = \frac{3}{5}\times\frac{14}{R}\times1.44\text{MeV}$ ...(II)

From (i) & (ii)

$\frac{3}{5}\times\frac{14}{R}\times1.44 = 0.0037960\times931$

$\therefore$ R = 3.42 fm

60. (c) $\frac{A}{A_0} = \frac{1}{2^n}$

$\therefore 2^n = \frac{A_0}{A} = \frac{64}{1} = 2^6 \Rightarrow n = 6$

$\therefore$ time $= 6\times t_{1/2} = 6\times18 = 108$

D. MCQs with ONE or MORE THAN ONE Correct

1. **(b,d) Note :** Shortest wavelength means highest frequency. This means highest energy.
The energy of X-rays depends on the accelerating voltage provided in the X-ray tube.
Also, according to Moseley's law $\sqrt{\nu} = a(Z-b)$.
Thus the frequency also depends on the atomic number.

2. **(c,d)** The threshold wavelength is 5200Å. For ejection of electrons, the wavelength of the light should be less than 5200 Å, so that frequency increases and hence the energy of incident photon increases. U.V light has less wavelength than 5200 Å.

3. **(b,c)** Nuclear fusion occurs when two or more lighter nuclei combine to form a heavier nucleus with release of a huge amount of energy.

4. **(a,c,d)** We know, $r_n \propto n^2$

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

Angular momentum, $L_n = \frac{nh}{2\pi}$

GP_3481

|P.E.| = 2 × |K.E.|

5. (a) A diode can be used as a rectifier.

6. (d) is the correct option. The electrons emitted by emitter are collected to the maximum by the plate in this case.

7. (c) is the correct option.

$$\lambda_{min} = \frac{hc}{eV}$$

8. (c,d) In the case of hydrogen, atomic number = mass number
In the other atoms, atomic number < mass number.

9. (a)

10. (a,b,c) are correct options.

11. (c) is the correct option.

12. (d) is the correct option.

13. (c,d) are correct options.

14. (b) **Note:** The intensity of radiation emitted is proportional to the rate of decay which in turn is proportional to number of atoms left (radioactive).

$$t = \frac{2.303}{\lambda} \log_{10} \frac{N_0}{N}$$

$$\Rightarrow t = \frac{2.303}{0.693/2} \log_{10} \frac{N_0}{N_0/64} \Rightarrow t = 12 \text{ hours.}$$

15. (b, d) are correct options.
Boron and Aluminium are trivalent impurities.

16. (b) Since the *p-n* junction arrangement are in series, therefore the potential drop across a *p-n* junction will be proportional to their resistances. When the resistances will be equal, the potential drops will be equal. In circuit *I*, the two *p-n* junctions are attached such that one is forward biased (low resistance) and other is reverse biased (high resistance). Whereas in the other two circuits both are either forward biased or reversed biased.

17. (b) $T_{1/2} = \frac{\ell n\, 2}{\lambda}$ and Mean life, $\tau = \frac{1}{\lambda}$

18. (b, d) Since the stopping potential depends on the frequency and not on the intensity and the source is same, the stopping potential remains unaffected. The saturation current depends on the intensity of incident light on the cathode of the photocell which in turn depends on the distance of the source from cathode. The intensity (I) of light is inversely proportional to the square of the distance between the light source and photocell.

$I \propto \frac{1}{r^2}$ and saturation current $\propto I$

$$\Rightarrow \text{Saturation Current} \propto \frac{1}{r^2}$$

$$\Rightarrow \frac{(\text{Saturation Current})_{\text{final}}}{(\text{Saturation Current})_{\text{initial}}} = \frac{r^2_{\text{Initial}}}{r^2_{\text{final}}}$$

$$\Rightarrow (\text{Saturation Current})_{\text{final}} = \frac{0.2 \times 0.2}{0.6 \times 0.6} \times 18 = 2\text{mA}$$

19. (b,c) $I_c = 10$ mA
90% of electrons emitted produce a collector current of 10 mA. The base current

$$I_b = 10\% \text{ of } I_c = \frac{10}{100} \times 10 = 1\text{mA}$$

Now, $I_e = I_b + I_c = 1 + 10 = 11$mA

20. (c) ${}_1H^2 + {}_1H^2 \rightarrow {}_1H^3 + p$
${}_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + n$
Net Reaction $3\,{}_1H^2 \rightarrow {}_2He^4 + p + n$
$\Delta m = 3\,(2.014) - [4.001 + 1.007 + 1.008] = 0.026$
3 deuterons release 3.87×10^{-12} J

$$\therefore 10^{40} \text{ deuterons release } = \frac{3.87 \times 10^{-12} \times 10^{40}}{3}$$

$= 1.29 \times 10^{28}$J

$$P = \frac{E}{t} \Rightarrow t = \frac{E}{P} = \frac{1.29 \times 10^{28}}{10^{16}} = 1.29 \times 10^{12} \text{ sec}$$

21. (a,b,c) **For metal *A***
$4.25 = W_A + T_A$ ...(i)

$$\text{Also } T_A = \frac{1}{2} m v_A^2 = \frac{1}{2} \frac{m^2 v_A^2}{m} = \frac{p_A^2}{2m} = \frac{h^2}{2m\lambda_A^2} \quad \text{...(ii)}$$

$$\left[\because \lambda = \frac{h}{p}\right]$$

For metal *B*
$4.7 = (T_A - 1.5) + W_B$ ...(iii)

Also $T_B = \frac{h^2}{2m\lambda_B^2}$ ...(iv) [as eq. (ii)]

Dividing equation (iv) by (ii),

$$\frac{T_B}{T_A} = \frac{h^2}{2m\lambda_B^2} \times \frac{2m\lambda_A^2}{h^2} = \frac{\lambda_A^2}{\lambda_B^2}$$

$$\Rightarrow \frac{T_A - 1.5}{T_A} = \frac{\lambda_A^2}{(2\lambda_A)^2} = \frac{\lambda_A^2}{4\lambda_A^2} = \frac{1}{4}$$

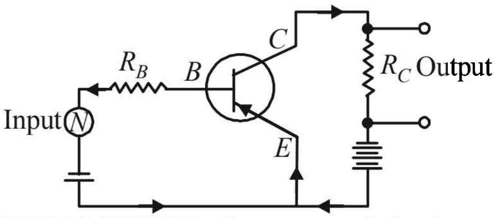
$[\because \lambda_B = 2\lambda_A \text{ given}]$

$\Rightarrow 4T_A - 6 = T_A \Rightarrow T_A = 2$ eV
From (i), $W_A = 2.25$ eV
From (iii), $W_B = 4.2$ eV
Also $T_B = T_A - 1.5 \Rightarrow T_B = 0.5$eV

22. (a,d) are correct options.

23. (a,c) Holes are electron vacancies which participate in electrical conductivity. These are produced in semiconductors.

24. (a,c) The circuit for a *p-n-p* transistor used in the common emitter mode as an amplifier is shown in figure. The base emitter junction is forward-biased and the input signal is connected in series with the voltage applied to bias the base emitter junction.



25. **(c, d) KEY CONCEPT :** Due to mass defect (which is finally responsible for the binding energy of the nucleus), mass of a nucleus is always less than the sum of masses of its constituent particles.

$^{20}_{10}$Ne is made up of 10 protons plus 10 neutrons.

Therefore, mass of $^{20}_{10}$Ne nucleus

$M_1 < 10\,(m_p + m_n)$

Note :

Heavier the nucleus, more is the mass defect.

$20\,(m_n + m_p) - M_2 > 10\,(m_p + m_n) - M_1$

Thus, $10\,(m_n + m_p) > M_2 - M_1$

or $M_2 < M_1 + 10\,(m_p + m_n)$

Now, since $M_1 < 10\,(m_p + m_n)$

$\therefore \quad M_2 < 2M_1$

26. **(a, d)** The time period of the electron in a Bohr orbit is given by $T = \dfrac{2\pi r}{v}$

Since for the nth Bohr orbit, $mvr = n\,(h/2\pi)$, the time period becomes

$$T = \frac{2\pi r}{nh/(2\pi mr)} = \left(\frac{4\pi^2 m}{nh}\right) r^2$$

Since the radius of the orbit r depends on n, we replace r. Bohr radius of a hydrogen atom is

$$r = n^2\left(\frac{h^2\varepsilon_0}{\pi m e^2}\right)$$

$$\text{Hence, } T = \left(\frac{4\pi^2 m}{nh}\right)\left(\frac{n^4 h^4 \varepsilon_0^2}{\pi^2 m^2 e^4}\right) = n^3\left(\frac{4h^3\varepsilon_0^2}{me^4}\right)$$

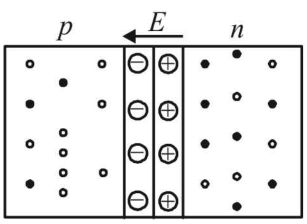
For two orbits, $\dfrac{T_1}{T_2} = \left(\dfrac{n_1}{n_2}\right)^3$

It is given that $T_1 / T_2 = 8$, hence, $n_1/n_2 = 2$.

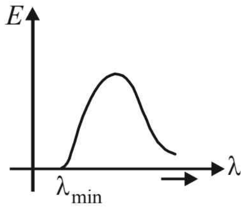
27. **(d)** The result follows from the formula based on laws of radioactive decay $N = N_0 e^{-\lambda t}$

The nucleus start decaying after time $t = 0$

28. **(c)** At junction a potential barrier/depletion layer is formed as shown, with n-side at higher potential and p-side at lower potential. Therefore, there is an electric field at the junction directed from the n-side to p-side



29. **(b)** The continuous X-ray spectrum is shown in figure.



All wavelengths $> \lambda_{min}$ are found.

where $\lambda_{min} = \dfrac{12400}{V \text{ (in volts)}}$ Å

Here V is the applied voltage.

30. **(c)** $\lambda_{min} = \dfrac{hc}{W} = \dfrac{6.63 \times 10^{-34} \times 3 \times 10^8}{4(1.6 \times 10^{-19})} = 310 \times 10^{-9}$m.

$= 310$ nm

31. **(c)** $(t_{1/2})_X = (t_{mean})Y \Rightarrow \dfrac{0.693}{\lambda_x} = \dfrac{1}{\lambda_Y}$

$\therefore \lambda_x = 0.693\,\lambda_Y$

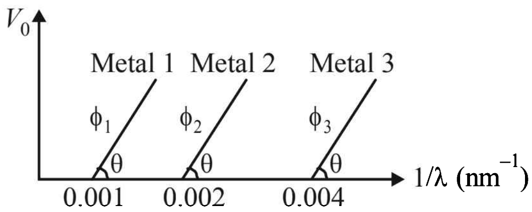
$\lambda_x < \lambda_Y$. Now, rate of decay $= \lambda N$

Initially, number of atoms (N) of both are equal but since $\lambda_Y < \lambda_x$, therefore Y will decay at a faster rate than x.

32. **(a, c)** $\phi_1 : \phi_2 : \phi_3 = eV_{0_1} : eV_{0_2} : eV_{0_3}$

$V_{0_1} : V_{0_2} : V_{03} = 0.001 : 0.002 : 0.004 = 1 : 2 : 4$

Therefore option (a) is correct



By Einstein's photoelectric equation, $\dfrac{hc}{\lambda} - \phi = \text{eV}$

$\Rightarrow V = \dfrac{hc}{e\lambda} - \dfrac{\phi}{e}$ ...(i)

Comparing equation (i) by $y = mx + c$, we get the slope of the line $m = \dfrac{hc}{e} = \tan\theta$

$\Rightarrow$ Option (c) is correct.

From the graph it is clear that,

$\dfrac{1}{\lambda_{0_1}} = 0.001(\text{nm})^{-1} \Rightarrow \lambda_{0_1} = \dfrac{1}{0.001} = 1000$mn

Also $\dfrac{1}{\lambda_{0_2}} = 0.002(\text{nm})^{-1} \Rightarrow \lambda_{0_2} = 500$nm

and $\lambda_{0_3} = 250$nm

Note : Violet colour light will have wavelength less than 400 nm.

Therefore, this light will be unable to show photoelectric effect on plate 3 $\Rightarrow$ Option (d) is wrong.

33. (b,d) Note : When binding energy per nucleon increases for a nuclear process, energy is released.

- When two nuclei of mass numbers between 51 to 100 fuse, the mass number of the resulting nuclei will come out to be between 100 to 200. The graph shows that in this process the binding energy per nucleon increases and therefore energy is released.
- When nucleus of mass number 200 to 260 breaks; it will produce nuclei of mass numbers lying between 100 to 200 if we assume that the two daughter nuclei are of nearly same mass. This in fact happens practically that when a heavy nucleus splits into two parts during nuclear fission, two moderate size nuclei are formed in general. The graph shows that in this process also the binding energy per nucleon increases. Therefore energy is released.

34. (a, c) Angular momentum $=\frac{nh}{2\pi}=\frac{3h}{2\pi}$. Therefore n = 3.

Also $r_n=\frac{a_o n^2}{z}=4.5a_o$

$\therefore \quad \frac{n^2}{z}=4.5 \quad \Rightarrow \frac{9}{z}=4.5 \Rightarrow z=2$

we know that

$$\frac{1}{\lambda}=Rz^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]=\frac{1}{\lambda}=4R\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$$

For $n_2=3, n_1=1$ we get $\lambda=\frac{9}{8\times 4R}=\frac{9}{32R}$

For $n_2=3, n_1=2$ we get $\lambda=\frac{36}{5\times 4R}=\frac{9}{5R}$

For $n_2=2, n_1=1$ we get $\lambda=\frac{4}{3\times 4R}=\frac{1}{3R}$

(a), (c) are correct options

35. (a, c)

We know that $\frac{hC}{\lambda}-W=eV_0 \Rightarrow \frac{hc}{e\lambda}-\frac{W}{e}=V_0$

For V_0 versus $\frac{1}{\lambda}$ we should get a straight line with negative slope and positive intercept.

For V_0 vesus λ, we will get a hyperbola. As λ decreases V_0 increases.

(a) and (c) are the correct options

36. (a) ${}^{236}_{92}U \rightarrow {}^{140}_{54}Xe + {}^{94}_{38}Sr + x + y$

The number of proton in reactants is equal to the products (leaving x and y) and mass number of product (leaving x and y) is two less than reactants

$\therefore \quad x=p, y=e^-$ is ruled out [B] is incorrect

and $x=p, y=n$ is ruled out [C] is incorrect

Total energy loss $=(236\times 7.5)-[140\times 8.5+94\times 8.5]$ $=219$ MeV

The energies of kx and ky together is 4MeV

The energy remain is distributed by Sr and Xe which is equal to $219-4=215$ MeV

$\therefore \quad$ A is the correct option

Also momentum is conserved

$\therefore K.E. \propto \frac{1}{m}$. Therefore $K.E_{sr} > K.E_{xe}$

The energies of kx and ky together is 4MeV

The energy remain is distributed by Sr and Xe which is equal to $219-4=215$ MeV

$\therefore \quad$ A is the correct option

Also momentum is conserved

. Therefore $K.E_{sr} > K.E_{xe}$

37. (a, b, d)

We know that $r=r_0\frac{n^2}{z}$, $E_n=-\frac{13.6Z^2}{n^2}$, $L_n=\frac{nh}{2\pi}$

Relative change in the radii of two consecutive orbitals

$$\frac{r_n-r_{n-1}}{r_n}=1-\frac{r_{n-1}}{r_n}=1-\frac{(n-1)^2}{n^2} \text{ does not depend on Z}$$

$$=\frac{2n-1}{n^2}\approx\frac{2}{n} \quad (\because n>>1)$$

Relative change in the energy of two consecutive orbitals

$$\frac{E_n-E_{n-1}}{E_n}=1-\frac{E_{n-1}}{E_n}=1-\frac{n^2}{(n-1)^2}=\frac{-2n+1}{(n-1)^2}\approx\frac{-2}{n}$$

$$\frac{L_n-L_{n-1}}{L_n}=1-\frac{L_{n-1}}{L_n}=1-\frac{(n-1)}{n}=\frac{1}{n}$$

38. (c) The wavelength of emitted photoelectron as per de Broglie is

$$\lambda_e=\frac{h}{p}=\frac{h}{\sqrt{2m(K.E)}}$$

When ϕ increases, K.E. decreases and therefore λ_e increases

When λ_{ph} increases, N_{ph} decreases, K.E decreases and therefore λe increases.

λe is independent of the distance d.

Also $\frac{hc}{\lambda_{ph}}+eV-\phi=\frac{h^2}{2m\lambda_e^2} \quad \left[\lambda_e=\frac{h}{\sqrt{2\text{ mk. E}}}\right]$

$$\therefore \quad \frac{hc}{e\lambda_{ph}}+V-\frac{\phi}{e}=\frac{h^2}{2me\lambda_e^2} \quad ...(1)$$

For $V>>\frac{\phi}{e}$, $\phi<<eV$

Also $\frac{hc}{e\lambda_{Ph}}<<V$. Then from eq (1).

$$\lambda_e\propto\frac{1}{\sqrt{V}}$$

Therefore if V is made our times, λ_e is approximately half.

E. Subjective Problems

1. (i) $E_2 = -\frac{13.6}{4}Z^2,\ E_3 = -\frac{13.6}{9}Z^2$

$E_3 - E_2 = -13.6Z^2\left(\frac{1}{9}-\frac{1}{4}\right) = +\frac{13.6\times 5}{36}Z^2$

But $E_3 - E_2 = 47.2$ eV (Given)

$\therefore\ \frac{13.6\times 5}{36}Z^2 = 47.2 \quad \therefore\ Z = \frac{\sqrt{47.2\times 36}}{13.6\times 5} = 5$

(ii) $E_4 = \frac{-13.6}{16}Z^2$

$\therefore\ E_4 - E_3 = -13.6Z^2\left[\frac{1}{16}-\frac{1}{9}\right] = -13.6Z^2\left[\frac{9-16}{9\times 16}\right]$

$= \frac{+13.6\times 25\times 7}{9\times 16} = 16.53\,\text{eV}$

(iii) $E_1 = -\frac{13.6}{1}\times 25 = -340\,\text{eV}$

$\therefore\ E = E_\infty - E_1 = 340\text{ eV} = 340\times 1.6\times 10^{-19}\text{ J} \quad [E_\infty = 0\,\text{eV}]$

But $E = \frac{hc}{\lambda}$

$\therefore\ \lambda = \frac{hc}{E} = \frac{6.6\times 10^{-34}\times 3\times 10^{8}}{340\times 10^{-19}\times 1.6} = 3.65\times 10^{-19}\,\text{m}$

(iv) Total Energy of 1st orbit = – 340 eV

We know that – (T.E). = K.E. [in case of electron revolving around nucleus]

and 2T.E. = P.E.

$\therefore$ K.E. = 340 eV ; P.E. = – 680 eV

KEY CONCEPT :

Angular momentum in 1st orbit :

According to Bohr's postulate,

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

For $n = 1$,

$mvr = \frac{h}{2\pi} = \frac{6.6\times 10^{-34}}{2\pi} = 1.05\times 10^{-34}$ J-s.

(v) Radius of first Bohr orbit

$r_1 = \frac{5.3\times 10^{-11}}{Z} = \frac{5.3\times 10^{-11}}{5}$

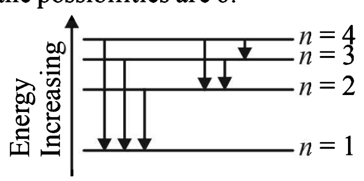
$= 1.06\times 10^{-11}$ m

2. $E = \frac{12400}{\lambda(\text{in Å})}\text{ eV} = \frac{12400}{975} = 12.75\,\text{eV}$ ...(i)

Also

$13.6\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right] = 12.75 \Rightarrow \left[\frac{1}{1}-\frac{1}{n_2^2}\right] = \frac{12.75}{13.6} \Rightarrow n_2 = 4$

For every possible transition one downward arrow is shown therefore the possibilities are 6.



Note : For longest wavelength, the frequency should be smallest.

This corresponds to the transition from $n = 4$ to $n = 3$, the energy will be $E_4 = -\frac{13.6}{4^2};\ E_3 = -\frac{13.6}{3^2}$

$\therefore\ E_4 - E_3 = \frac{-13.6}{4^2} - \left(\frac{-13.6}{3^2}\right) = 13.6\left[\frac{1}{9}-\frac{1}{16}\right]$

$= 0.66\text{ eV} = 0.66\times 1.6\times 10^{-19}\text{J} = 1.056\times 10^{-19}\text{J}$

Now, $E = \frac{12400}{\lambda(\text{in Å})}$ eV $\quad\therefore\quad \lambda = 18787$ Å

3. (i) In a nucleus, number of electrons = 0 ($\because$ electrons don't reside in the nucleus of atom).

(ii) number of protons = 11

(iii) number of neutrons = 24 – 11 = 13

4. (i) $E_n = -\frac{\text{I.E.}}{n^2}$ for Bohr's hydrogen atom.

Here, I.E. = $4R$ $\therefore\ E_n = \frac{-4R}{n^2}$

$\therefore\ E_2 - E_1 = \frac{-4R}{2^2} - \left(-\frac{4R}{1^2}\right) = 3R$ ..(i)

$E_2 - E_1 = h\nu = \frac{hc}{\lambda}$ ...(ii)

From (i) and (ii)

$\frac{hc}{\lambda} = 3R$

$\therefore\ \lambda = \frac{hc}{3R} = \frac{6.6\times 10^{-34}\times 3\times 10^{8}}{2.2\times 10^{-18}\times 3} = 300\text{Å}$

(ii) **The radius of the first orbit**

Bohr's radius of hydrogen atom = 5×10^{-11} m (given)

$|E_n| = +0.22\times 10^{-17}Z^2 = 4R = 4\times 2.2\times 10^{-18}$

$\therefore\ Z = 2$

$\therefore\ r_n = \frac{r_0}{Z} = \frac{5\times 10^{-11}}{Z} = \frac{5\times 10^{-11}}{2} = 2.5\times 10^{-11}$m

5. (i) $E_n = -\frac{13.6}{n^2}Z^2$ eV/atom

For Li^{2+}, $Z = 3$ $\therefore\ E_n = \frac{-13.6\times 9}{n^2}$ eV/atom

$\therefore\ E_1 = -\frac{13.6\times 9}{1}$ and $E_3 = -\frac{13.6\times 9}{9} = -13.6$

$\Delta E = E_3 - E_1 = -13.6 - (-13.6\times 9)$

$= 13.6\times 8 = 108.8$ eV/atom

$\lambda = \frac{12400}{E\text{ (in eV)}}\text{ Å} = \frac{12400}{108.8} = 114\text{Å}$

(ii) The spectral line observed will be three namely $3\to 1$, $3\to 2, 2\to 1$.

6. $I = 0.125\,V - 7.5$

$\Rightarrow dI = 0.125\,dV$ or $\frac{dV}{dI} = \frac{1}{0.125} = 8$

We know that plate resistance, $r_p = \frac{dV}{dI} = 8\text{m}\Omega$

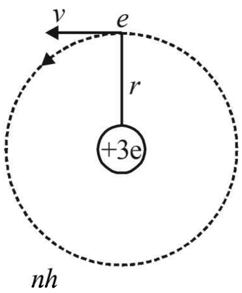
The transconductance, $g_m = \left[\dfrac{dI}{dV_g}\right]_{V=\text{constt}}$

At $V_g = -1$ volt, $V = 300$ volt, the plate current
$I = [0.125 \times 300 - 7.5]$ mA $= 30$ mA
Also it is given that $V_g = -3V$, $V = 300$ V and $I = 5$mA

$$\therefore g_m = \left[\frac{30-5}{-1-(-3)}\right] = \frac{25}{2} \times 10^{-3} = 12.5 \times 10^{-3}\text{s}$$

The characteristics are given in the form of parallel lines.
Amplification factor
$= r_p g_m = 8 \times 10^3 \times 12.5 \times 10^{-3} = 100$

7. **(i)** Let m be the mass of electron. Then the mass of mu-meson is 208 m. According to Bohr's postulate, the angular momentum of mu-meson should be an integral multiple of $h/2\pi$.



$$\therefore \quad (208\text{m})\, vr = \frac{nh}{2\pi}$$

$$\therefore \quad v = \frac{nh}{2\pi \times 208mr} = \frac{nh}{416\pi mr} \qquad \text{...(i)}$$

Note: Since mu-meson is moving in a circular path, therefore, it needs centripetal force which is provided by the electrostatic force between the nucleus and mu-meson.

$$\therefore \quad \frac{(208m)v^2}{r} = \frac{1}{4\pi\varepsilon_0} \times \frac{3e \times e}{r^2}$$

$$\therefore \quad r = \frac{3e^2}{4\pi\varepsilon_0 \times 208mv^2}$$

Substituting the value of v from (1), we get

$$r = \frac{3e^2 \times 416\pi mr \times 416\pi mr}{4\pi\varepsilon_0 \times 208mn^2h^2}$$

$$\Rightarrow r = \frac{n^2h^2\varepsilon_0}{624\pi me^2} \qquad \text{....(i)}$$

(ii) The radius of the first orbit of the hydrogen atom

$$= \frac{\varepsilon_0 h^2}{\pi me^2} \qquad \text{...(ii)}$$

To find the value of n for which the radius of the orbit is approximately the same as that of the first Bohr orbit for hydrogen atom, we equate eq. (i) and (ii)

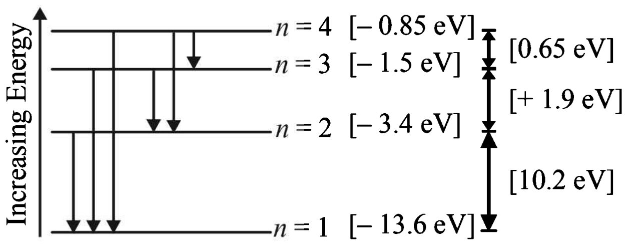
$$\frac{n^2h^2\varepsilon_0}{624\pi me^2} = \frac{\varepsilon_0 h^2}{\pi me^2} \quad \Rightarrow n = \sqrt{624} \approx 25$$

(iii) $\dfrac{1}{\lambda} = 208R \times Z^2\left[\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right]$

$$\Rightarrow \frac{1}{\lambda} = 208 \times 1.097 \times 10^7 \times 3^2\left[\frac{1}{1^2} - \frac{1}{3^2}\right]$$

$\Rightarrow \lambda = 5.478 \times 10^{-11}$m

8. **(i)** The transition state of six different photon energies are shown.



Since after absorbing monochromatic light, some of the emitted photons have energy more and some have less than 2.7 eV, this indicates that the excited level B is $n = 2$. (This is because if $n = 3$ is the excited level then energy less than 2.7 eV is not possible).

(ii) For hydrogen like atoms we have

$$E_n = \frac{-13.6}{n^2} Z^2 \text{ eV/atom}$$

$$E_4 - E_2 = \frac{-13.6}{16} Z^2 - \left(\frac{-13.6}{4}\right) Z^2 = 2.7$$

$$\Rightarrow Z^2 \times 13.6\left[\frac{1}{4} - \frac{1}{16}\right] = 2.7$$

$$\Rightarrow Z^2 = \frac{2.7}{13.6} \times \frac{4 \times 16}{12} \Rightarrow \text{I.E.} = 13.6Z^2\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right)$$

$$= 13.6 \times \frac{2.7}{13.6} \times \frac{4 \times 16}{12} = 14.46\,\text{eV}$$

(iii) Max. Energy

$$E_4 - E_3 = -13.6Z^2\left(\frac{1}{4^2} - \frac{1}{1^2}\right)$$

$$= 13.6 \times \frac{2.7}{13.6} \times \frac{4 \times 16}{12} \times \frac{15}{16} = 13.5 \text{ eV}$$

Min. Energy

$$E_4 - E_3 = -13.6Z^2\left(\frac{1}{4^2} - \frac{1}{3^2}\right)$$

$$= 13.6 \times \frac{2.7}{13.6} \times \frac{4 \times 16}{12} \times \frac{7}{9 \times 16} = 0.7\text{eV}$$

9. For hydrogen like atom energy of the nth orbit is

$$E_n = -\frac{13.6}{n^2} Z^2 \text{ eV/atom}$$

For transition from $n = 5$ to $n = 4$,

$$h\nu = 13.6 \times 9\left[\frac{1}{16} - \frac{1}{25}\right] = \frac{13.6 \times 9 \times 9}{16 \times 25} = 2.754 \text{ eV}$$

For transition from $n = 4$ to $n = 3$,

$$h\nu' = 13.6 \times 9\left[\frac{1}{9} - \frac{1}{16}\right] = \frac{13.6 \times 9 \times 7}{9 \times 16} = 5.95\text{eV}$$

For transition $n = 4$ to $n = 3$, the frequency is high and hence wavelength is short.

For photoelectric effect, $h\nu' - W = eV_0$, where W = work function

$5.95 \times 1.6 \times 10^{-19} - W = 1.6 \times 10^{-19} \times 3.95$

$\Rightarrow W = 2 \times 1.6 \times 10^{-19} = 2$ eV

Again applying $h\nu - W = eV'_0$

We get, $2.754 \times 1.6 \times 10^{-19} - 2 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-19} V'_0$

$\Rightarrow V'_0 = 0.754$ V

10. Energy required per day

$E = P \times t = 200 \times 10^6 \times 24 \times 60 \times 60$

$= 1.728 \times 10^{13}$J

Energy released per fusion reaction

$= [2(2.0141) - 4.0026] \times 931.5$ MeV

$= 23.85$ MeV $= 23.85 \times 106 \times 1.6 \times 10^{-19}$

$= 38.15 \times 10^{-13}$J

∴ No. of fusion reactions required

$$= \frac{1.728 \times 10^{13}}{38.15 \times 10^{-13}} = 0.045 \times 10^{26}$$

∴ No. of deuterium atoms required

$= 2 \times 0.045 \times 10^{26} = 0.09 \times 10^{26}$

Number of moles of deuterium atoms

$$= \frac{0.09 \times 10^{26}}{6.02 \times 10^{23}} = 14.95$$

∴ Mass in gram of deuterium atoms

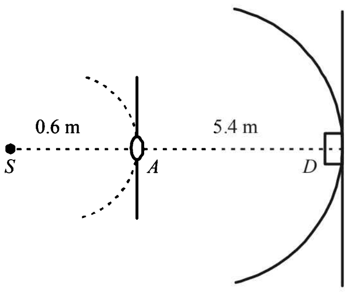
$= 14.95 \times 2 = 29.9$ g

But the efficiency is 25%.

Therefore, the actual mass required = 119.6 g

11. Energy of one photon, $E = \dfrac{hc}{\lambda} = \dfrac{(6.6 \times 10^{-34})(3.0 \times 10^8)}{6000 \times 10^{-10}}$

$= 3.3 \times 10^{-19}$ J



Power of the source is 2 W or 2 J/s. Therefore, number of photons emitting per second,

$$n_1 = \frac{2}{3.3 \times 10^{-19}} = 6.06 \times 10^{18}/\text{s}$$

At distance 0.6 m, number of photons incident per unit area per unit time :

$$n_2 = \frac{n_1}{4\pi(0.6)^2} = 1.34 \times 10^{18}/\text{m}^2/\text{s}$$

Area of aperture is,

$$S_1 = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.1)^2 = 7.85 \times 10^{-3}\text{ m}^2$$

∴ Total number of photons incident per unit time on the aperture,

$$n_3 = n_2 S_1 = (1.34 \times 10^{18})(7.85 \times 10^{-3})/\text{s}$$
$$= 1.052 \times 10^{16}/\text{s}$$

The aperture will become new source of light.

Now these photons are further distributed in all directions. Hence, at the location of detector, photons incident per unit area per unit time :

$$n_4 = \frac{n_3}{4\pi(6-0.6)^2} = \frac{1.052 \times 10^{16}}{4\pi(5.4)^2}$$
$$= 2.87 \times 10^{13}\text{ s}^{-1}\text{ m}^{-2}$$

This is the photon flux at the centre of the screen. Area of detector is 0.5 cm^2 or 0.5×10^{-4} m^2. Therefore, total number of photons incident on the detector per unit time :

$$n_5 = (0.5 \times 10^{-4})(2.87 \times 10^{13} d) = 1.435 \times 10^9\text{ s}^{-1}$$

The efficiency of photoelectron generation is 0.9. Hence, total photoelectrons generated per unit time :

$$n_6 = 0.9 n_5 = 1.2915 \times 10^9\text{ s}^{-1}$$

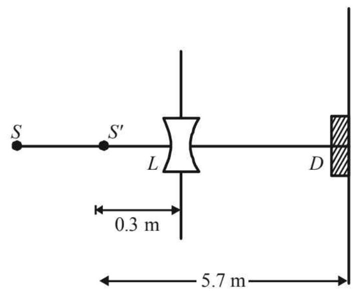
or, photocurrent in the detector :

$$i = (e)n_6 = (1.6 \times 10^{-19})(1.2915 \times 10^9) = 2.07 \times 10^{-10}\text{ A}$$

(b) Using the lens formula :

$$\frac{1}{v} - \frac{1}{-0.6} = \frac{1}{-0.6} \text{ or } v = -0.3\text{ m}$$

i.e., image of source (say S', is formed at 0.3 m from the lens.)



Total number of photons incident per unit time on the lens are still n_3 or 1.052×10^{16}/s. 80% of it transmits to second medium. Therefore, at a distance of 5.7 m from S' number of photons incident per unit are per unit time will be :

$$n_7 = \frac{(80/100)(1.05 \times 10^{16})}{(4\pi)(5.7)^2} = 2.06 \times 10^{13}\text{ s}^{-1}\text{m}^{-2}$$

This is the photon flux at the detector.

New value of photocurrent is :

$$i = (2.06 \times 10^{13})(0.5 \times 10^{-4})(0.9)(1.6 \times 10^{-19})$$
$$= 1.483 \times 10^{-10}\text{ A}$$

(c) For stopping potential

$$\frac{hc}{\lambda} = (E_K)_{max} + W = eV_0 + W$$

$\therefore \quad eV_0 = \frac{hc}{\lambda} - W = \frac{3.315 \times 10^{-19}}{1.6 \times 10^{-19}} - 1 = 1.07\text{eV}$

$\therefore \quad V_0 = 1.07$ Volt

Note : The value of stopping potential is not affected by the presence of concave lens as it changes the intensity and not the frequency of photons. The stopping potential depends on the frequency of photons.

12. **(a)** ${}^{A}_{92}X \rightarrow {}^{228}_{X}Y + {}^{4}_{2}He$

$A = 228 + 4 = 232; 92 = Z + 2 \Rightarrow Z = 90$

(b) Let v be the velocity with which α - particle is emitted. Then

$$\frac{mv^2}{r} = qvB \Rightarrow v = \frac{qrB}{m} = \frac{2 \times 1.6 \times 10^{-19} \times 0.11 \times 3}{4.003 \times 10^{-27}}$$

$\Rightarrow v = 1.59 \times 10^7 \text{ms}^{-1}$.

Applying law of conservation of linear momentum during α-decay we get

$m_Y v_Y = m_\alpha v_\alpha$ ...(1)

The total kinetic energy of α-particle and Y is

$$E = \text{K.E.}_\alpha + \text{K.E.}_Y = \frac{1}{2} m_\alpha v_\alpha^2 + \frac{1}{2} m_Y v_Y^2$$

$$= \frac{1}{2} m_\alpha v_\alpha^2 + \frac{1}{2} m_Y \left[\frac{m_\alpha v_\alpha}{m_Y}\right]^2 = \frac{1}{2} m_\alpha v_\alpha^2 + m_\alpha v_\alpha^2 + \frac{m_\alpha^2 v_\alpha^2}{2m_Y}$$

$$= \frac{1}{2} m_\alpha v_\alpha^2 \left[1 + \frac{m_\alpha}{m_Y}\right]$$

$$= \frac{1}{2} \times 4.033 \times 1.6 \times 10^{-27} \times (1.59 \times 10^7)^2 \left[1 + \frac{4.003}{228.03}\right] \text{J}$$

$= 8.55 \times 10^{-13}$ J

$= 5.34$ MeV

$\therefore$ Mass equivalent of this energy

$= \frac{5.34}{931.5} = 0.0051$ a.m.u.

Also, $m_x = m_Y + m_\alpha$ + mass equivalent of energy (E)

$= 228.03 + 4.003 + 0.0057 = 232.0387$ u.

The number of nucleus = 92 protons + 140 neutron.

$\therefore$ Binding energy of nucleus X

$= [92 \times 1.008 + 140 \times 1.009] - 232.0387 = 1.9571$ u

$= 1.9571 \times 931.5 = 1823$ MeV.

13. **(a)** The energy of photon causing photoelectric emission = Work function of sodium metal + KE of the fastest photoelectron

$= 1.82 + 0.73 = 2.55$ eV

(b) We know that $E_n = \frac{-13.6}{n^2} \frac{\text{eV}}{\text{atom}}$ for hydrogen atom.

Let electron jump from n_2 to n_1 then

$$E_{n_2} - E_{n_1} = \frac{-13.6}{n_2^2} - \left(\frac{-13.6}{n_1^2}\right)$$

$$\Rightarrow 2.55 = 13.6\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

By hit and trial we get $n_2 = 4$ and $n_1 = 2$

[angular momentum mvr $= \frac{nh}{2\pi}$]

(c) Change in angular momentum

$$= \frac{n_1 h}{2\pi} - \frac{n_2 h}{2\pi} = \frac{h}{2\pi}(2-4) = \frac{h}{2\pi} \times (-2) = -\frac{h}{\pi}$$

(d) The momentum of emitted photon can be found by de Broglie relationship

$$\lambda = \frac{h}{p} \Rightarrow p = \frac{h}{\lambda} = \frac{h\nu}{c} = \frac{E}{c} \quad \therefore \; p = \frac{2.55 \times 1.6 \times 10^{-19}}{3 \times 10^8}$$

Note : The atom was initially at rest the recoil momentum of the atom will be same as emitted photon (according to the conservation of angular momentum).

Let m be the mass and v be the recoil velocity of hydrogen atom then

$$m \times v = \frac{2.55 \times 1.6 \times 10^{-19}}{3 \times 10^8}$$

$$\Rightarrow v = \frac{2.55 \times 1.6 \times 10^{-19}}{3 \times 10^8 \times 1.67 \times 10^{-27}} = 0.814 \text{ m/s}$$

14. $t_{1/2} = 15$ hours

Activity initially $A_0 = 10^{-6}$ Curie (in small quantity of solution of ${}^{24}Na$) $= 3.7 \times 10^4$ dps

Observation of blood of volume 1 cm³

After 5 hours, $A = 296$ dpm

The initial activity can be found by the formula

$$t = \frac{2.303}{\lambda} \log_{10} \frac{A_0}{A} \Rightarrow 5 = \frac{2.303}{0.693/15} \times \log_{10} \frac{A_0}{296}$$

$$\Rightarrow \log_{10} \frac{A_0}{296} = \frac{5 \times 0.693}{2.303 \times 15} = \frac{0.3010}{3} = 0.10033$$

$$\Rightarrow \frac{A_0}{296} = 1.26 \Rightarrow A_0 = 373 \text{ dpm} = \frac{373}{60} \text{ dps}$$

This is the activity level in 1 cm³. Comparing it with the initial activity level of 3.7×10^4 dps we find the volume of blood.

$$V = \frac{3.7 \times 10^4}{373/60} = 5951.7 \text{ cm}^3 = 5.951 \text{ litre}$$

15. For hydrogen like atoms

$$E_n = -\frac{13.6}{n^2} Z^2 \text{ eV/atom}$$

Given $E_n - E_2 = 10.2 + 17 = 27.2$ eV ..(i)

$E_n - E_3 = 4.24 + 5.95 = 10.2$ eV

$\therefore E_3 - E_2 = 17$

$$\text{But } E_3 - E_2 = -\frac{13.6}{9} Z^2 - \left(-\frac{13.6}{4} Z^2\right)$$

$$= -13.6 Z^2 \left[\frac{1}{9} - \frac{1}{4}\right]$$

$$= -13.6Z^2\left[\frac{4-9}{36}\right] = \frac{13.6\times 5}{36}Z^2$$

$$\therefore \frac{13.6\times 5}{36}Z^2 = 17 \Rightarrow Z = 3$$

$$E_n - E_2 = -\frac{13.6}{n_2}\times 3^2 - \left[-\frac{13.6}{2^2}\times 3^2\right]$$

$$= -13.6\left[\frac{9}{n^2} - \frac{9}{4}\right] = -13.6\times 9\left[\frac{4-n^2}{4n^2}\right] \quad ...(ii)$$

From eq. (i) and (ii),

$$-13.6\times 9\left[\frac{4-n^2}{4n^2}\right] = 27.2$$

$$\Rightarrow -122.4\,(4-n^2) = 108.8n^2$$

$$\Rightarrow n^2 = \frac{489.6}{13.6} = 36 \Rightarrow n = 6$$

16. (i) $E_n = -3.4$ eV

The kinetic energy is equal to the magnitude of total energy in this case.

$\therefore$ K.E. $= +3.4$ eV

(ii) The de Broglie wavelength of electron

$$\lambda = \frac{h}{\sqrt{2mK}} = \frac{6.64\times 10^{-34}}{\sqrt{2\times 9.1\times 10^{-31}\times 3.4\times 1.6\times 10^{-19}}}\text{ eV}$$

$= 0.66\times 10^{-9}$ m

17. **(i)** From the given information, it is clear that half life of the radioactive nuclei is 10 sec (since half the amount is consumed in 10 second. 12.5% is half of 25% pls. note).

Mean life

$$\tau = \frac{1}{\lambda} = \frac{1}{0.693/t_{1/2}} = \frac{t_{1/2}}{0.693} = \frac{10}{0.693} = 14.43\text{ sec.}$$

(ii) $N = N_0 e^{-\lambda t} \Rightarrow \dfrac{N}{N_0} = \dfrac{6.25}{100}$

$$\lambda = 0.0693\,\text{s}^{-1}$$

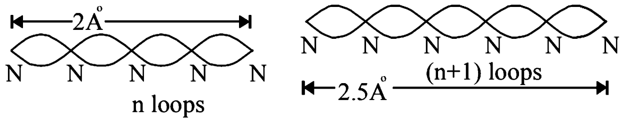
$$\frac{6.25}{100} = e^{-0.0693t} \Rightarrow e^{+0.0693t} = \frac{100}{6.25} = 16$$

$$0.0693t = \ln 16 = 2.773 \text{ or } t = \frac{2.733}{0.0693} = 40\text{ sec.}$$

18. As nodes are formed at each of the atomic sites, hence

$$2\text{Å} = n\left(\frac{\lambda}{2}\right) \quad ...(1)$$

[$\because$ Distance between successive nodes $= \lambda/2$]



and $2.5\text{ Å} = (n+1)\dfrac{\lambda}{2}$

$$\therefore \frac{2.5}{2} = \frac{n+1}{n}, \frac{5}{4} = \frac{n+1}{n} \text{ or } n = 4$$

Hence, from equation (1),

$$2\text{Å} = 4\frac{\lambda}{2} \text{ i.e., } \lambda = 1\text{Å}$$

Now, de broglie wavelength is given by

$$\lambda = \frac{h}{\sqrt{2mK}} \text{ or } K = \frac{h^2}{\lambda^2.2m}$$

$$\therefore \quad K = \frac{(6.63\times 10^{-34})^2}{(1\times 10^{-10})^2\times 2\times 9.1\times 10^{-31}\times 1.6\times 10^{-19}}\text{ eV}$$

$$= \frac{(6.63)^2}{8\times 9.1\times 1.6}\times 10^2\text{ eV} = 151\text{ eV}$$

d will be minimum, when

$$n = 1, d_{min} = \frac{\lambda}{2} = \frac{1\text{Å}}{2} = 0.5\text{Å}$$

19. The reaction involved in α-decay is

$${}^{248}_{96}\text{Cm} \rightarrow {}^{244}_{94}\text{Pu} + {}^{4}_{2}\text{He}$$

Mass defect

Δm = Mass of ${}^{248}_{96}$Cm – Mass of ${}^{244}_{94}$Pu – Mass of ${}^{4}_{2}$He

$= (248.072220 - 244.064100 - 4.002603)$ u

$= 0.005517$u

Therefore, energy released in α-decay will be

$E_\alpha = (0.005517\times 931)$ MeV $= 5.136$ MeV

Similarly, $E_{fission} = 200$ MeV (given)

Mean life is given as $t_{mean} = 10^{13}\text{s} = \dfrac{1}{\lambda}$

$\therefore$ Disintegration constant $\lambda = 10^{-13}\text{ s}^{-1}$

Rate of decay at the moment when number of nuclei are 10^{20} is

$$\frac{dN}{dt} = \lambda N = (10^{-13})(10^{20}) = 10^7\text{ dps}$$

Of these distintegrations, 8% are in fission and 92% are in α-decay.

Therefore, energy released per second

$= (0.08\times 10^7\times 200 + 0.92\times 10^7\times 5.136)$ MeV

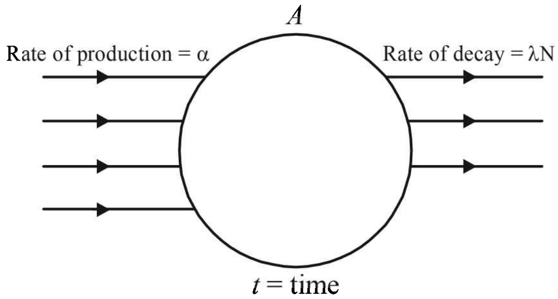
$= 2.074\times 10^8$ MeV

$\therefore$ Power output (in watt) = Energy released per second (J/s)

$= (2.074\times 10^8)(1.6\times 10^{-13})$

$\therefore$ Power output $= 3.32\times 10^{-5}$ watt.

20.



N = Number of radioactive nuclei

(a) Let at time 't' number of radioactive nuclei are N.
Net rate of formation of nuclei of A.

$$\frac{dN}{dt} = \alpha - \lambda N \text{ or } \frac{dN}{\alpha - \lambda N} = dt$$

$$\text{or } \int_{N_0}^{N} \frac{dN}{\alpha - \lambda N} = \int_0^t dt$$

Solving this equation, we get

$$N = \frac{1}{\lambda}\left[\alpha - (\alpha - \lambda N_0)e^{-\lambda t}\right] \quad \text{........(1)}$$

(b) Substituting $\alpha = 2\lambda N_0$ and

$t = t_{1/2} = \frac{\ln(2)}{\lambda}$ in equation (1),

we get, $N = \frac{3}{2}N_0$

(ii) Substituting $\alpha = 2\lambda N_0$ and $t \to \infty$ in equation (1), we get

$$N = \frac{\alpha}{\lambda} = 2N_0.$$

21. The energy of the incident photon is

$$E_1 = \frac{hc}{\lambda} = \frac{(4.14 \times 10^{-15}\text{eVs})(3 \times 10^8 \text{m/s})}{(400 \times 10^{-9}\text{m})} = 3.1\text{eV}$$

The maximum kinetic energy of the emitted electrons is
$E_{max} = E_1 - W = 3.1 \text{ eV} - 1.9 \text{ eV} = 1.2\text{eV}$
It is given that,

$$\begin{pmatrix}\text{Emitted electrons} \\ \text{of maximum energy}\end{pmatrix} + {}_2He^{2+} \longrightarrow \underset{\text{in 4th excited state}}{He^+} + \text{photon}$$

The fourth excited state implies that the electron enters in the n =5 state.
In this state its energy is

$$E_5 = -\frac{(13.6\text{eV})Z^2}{n^2} = -\frac{(13.6\text{eV})(2)^2}{5^2}$$

$= -2.18$ eV.
The energy of the emitted photon in the above combination reaction is
$E = E_{max} + (-E_5) = 1.2 \text{ eV} + 2.18 \text{ eV} = 3.4 \text{ eV}$
Note : After the recombination reaction, the electron may undergo transition from a higher level to a lower level thereby emitting photons.
The energies in the electronic levels of He^+ are

$$E_4 = \frac{(-13.6\text{eV})(2^2)}{4^2} = -3.4\text{eV}$$

$$E_3 = \frac{(-13.6\text{eV})(2^2)}{3^2} = -6.04\text{eV}$$

$$E_2 = \frac{(-13.6\text{eV})(2^2)}{2^2} = -13.6\text{eV}$$

The possible transitions are
$n = 5 \to n = 4$
$\Delta E = E_5 - E_4 = [-2.18 - (-3.4)]$ eV $= 1.28$ eV
$n = 5 \to n = 3$
$\Delta E = E_5 - E_3 = [-2.18 - (-6.04)]$ eV $= 3.84$ eV
$n = 5 \to n = 2$
$\Delta E = E_5 - E_2 = [-2.18 - (-13.6)]$ eV $= 11.4$ eV
$n = 4 \to n = 3$
$\Delta E = E_4 - E_3 = [-3.4 - (-6.04)]$ eV $= 2.64$ eV
Hence, the photons that are likely to be emitted in the range of 2 eV to 4 eV are 3.4 eV, 3.84 eV and 2.64 eV.

22. Energy for an orbit of hydrogen like atoms is

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

For transition from $2n$ orbit to 1 orbit

$$\text{Maximum energy} = 13.6Z^2\left(\frac{1}{1} - \frac{1}{(2n)^2}\right)$$

$$\Rightarrow 204 = 13.6Z^2\left(\frac{1}{1} - \frac{1}{4n^2}\right) \quad \text{...(i)}$$

Also for transition $2n \to n$.

$$40.8 = 13.6Z^2\left(\frac{1}{n^2} - \frac{1}{4n^2}\right) \Rightarrow 40.8 = 13.6Z^2\left(\frac{3}{4n^2}\right)$$

$$\Rightarrow 40.8 = 40.8\frac{Z^2}{4n^2} \Rightarrow 4n^2 = Z^2 \text{ or } 2n = Z \text{ ....(ii)}$$

From (i) and (ii)

$$204 = 13.6Z^2\left(1 - \frac{1}{Z^2}\right) = 13.6Z^2 - 13.6$$

$13.6Z^2 = 204 + 13.6 = 217.6$

$$Z^2 = \frac{217.6}{13.6} = 16,\ Z = 4,\ n = \frac{Z}{2} = \frac{4}{2} = 2$$

orbit no. $= 2n = 4$
For minimum energy = Transition from 4 to 3.

$$E = 13.6 \times 4^2\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = 13.6 \times 4^2\left(\frac{7}{9 \times 16}\right)$$

$= 10.5$ eV.
Hence $n = 2, Z = 4, E_{min} = 10.5$ eV

23. No. of photons/sec

$$= \frac{\text{Energy incident on platinum surface per second}}{\text{Energy of one photon}}$$

No. of photons incident per second

$$= \frac{2 \times 10 \times 10^{-4}}{10.6 \times 1.6 \times 10^{-19}} = 1.18 \times 10^{14}$$

As 0.53% of incident photon can eject photoelectrons
$\therefore$ No. of photoelectrons ejected per second

$$= 1.18 \times 10^{14} \times \frac{0.53}{100} = 6.25 \times 10^{11}$$

Minimum energy = 0 eV,
Maximum energy = (10.6 – 5.6) eV = 5 eV

24. The formula for η of power will be

$$\eta = \frac{P_{out}}{P_{in}}$$

$$\therefore\ P_{in} = \frac{P_{out}}{\eta} = \frac{1000\times10^6}{0.1} = 10^{10}\,\text{W}$$

Energy required for this power is given by

$$E = P\times t$$
$$= 10^{10}\times 86{,}400\times 365\times 10$$
$$= 3.1536\times10^{18}\,\text{J}$$

$200\times1.6\times10^{-13}$ J of energy is released by 1 fission

$\therefore$ 3.1536×10^{18} J of energy is released by

$$\frac{3.1536\times10^{18}}{200\times1.6\times10^{-13}}\ \text{fission}$$

$= 0.9855\times10^{29}$ fission

$= 0.985\times10^{29}$ of U^{235} atoms.

6.023×10^{23} atoms of Uranium has mass 235g

$\therefore$ 0.9855×10^{29} atoms of Uranium has

$$\frac{235\times0.9855\times10^{29}}{6.023\times10^{23}}\ \text{g} = 38451\ \text{kg}$$

25. Let the reaction be

$${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

Here, $m_y = 223.61$ amu and $m_\alpha = 4.002$ amu

We know that

$$\lambda = \frac{h}{mv} \Rightarrow m^2v^2 = \frac{h^2}{\lambda^2} = p^2$$

$$\Rightarrow \text{But K.E.} = \frac{p^2}{2m}.\ \text{Therefore K.E.} = \frac{h^2}{2m\lambda^2} \qquad ...(i)$$

Applying eq. (i) for Y and α, we get

$$\text{K.E.}_\alpha = \frac{(6.6\times10^{-34})^2}{2\times4.002\times1.67\times10^{-27}\times5.76\times10^{-15}\times5.76\times10^{-15}}$$

$= 0.0982243\times10^{-11} = 0.982\times10^{-12}$J

Similarly $(\text{K.E.})_Y = 0.0178\times10^{-12}$ J

Total energy $= 10^{-12}$ J

We know that $E = \Delta mc^2$

$$\therefore \Delta m = \frac{E}{c^2} = \frac{10^{-12}}{(3\times10^8)^2}\text{kg}$$

1.65×10^{-27}kg = 1 amu

$$\because \frac{10^{-12}}{(3\times10^8)^2}\ \text{kg} = \frac{10^{-12}\,\text{amu}}{1.67\times10^{-27}\times(3\times10^8)^2}$$

$$= \frac{10^{-12}\,\text{amu}}{1.67\times9\times10^{-27}\times10^{16}} = 0.00665\ \text{amu}$$

The mass of the parent nucleus X will be

$m_x = m_y + m_\alpha + \Delta m$

$= 223.61 + 4.002 + 0.00665 = 227.62$ amu

26.
$$X \xrightarrow[\lambda_x = 0.1\text{s}^{-1}]{T_{1/2} = 10\text{sec}} Y \xrightarrow[\lambda_y = \frac{1}{30}\text{s}^{-1}]{T_{1/2} = 30\text{sec}} Z$$

The rate of equation for the population of X, Y and Z will be

$$\frac{dN_x}{dt} = -\lambda_x N_x \qquad ...(i)$$

$$\frac{dN_y}{dt} = -\lambda_y N_y + \lambda_x N_x \qquad ...(ii)$$

$$\frac{dN_z}{dt} = -\lambda_y N_y \qquad ...(iii)$$

$\Rightarrow$ On integration, we get

$$N_x = N_0 e^{-\lambda_x t} \qquad ...(iv)$$

Given

$$N_y = \frac{\lambda_x N_0}{\lambda_x - \lambda_Y}\left[e^{-\lambda_y t} - e^{\lambda_x t}\right]$$

To determine the maximum N_Y, we find

$$\frac{dN_Y}{dt} = 0$$

From (ii)

$$-\lambda_y N_y + \lambda_x N_x = 0$$

$$\Rightarrow \lambda_x N_x = \lambda_y N_y \qquad ....(v)$$

$$\Rightarrow \lambda_x(N_0\, e^{-\lambda_x t}) = \lambda_y\left[\frac{\lambda_x N_0}{\lambda_x - \lambda_y}\left(e^{-\lambda_y t} - e^{\lambda_x t}\right)\right]$$

$$\Rightarrow \frac{\lambda_x - \lambda_y}{\lambda_y} = \frac{e^{-\lambda_y t} - e^{-\lambda_x t}}{e^{-\lambda_x t}} \Rightarrow \frac{\lambda x}{\lambda_y} = e^{(\lambda_x - \lambda_y)t}$$

$$\Rightarrow \log_e \frac{\lambda_x}{\lambda_y} = \left(\lambda_x - \lambda_y\right)t$$

$$\Rightarrow t = \frac{\log_e\left(\lambda_x/\lambda\gamma\right)}{\lambda_x - \lambda_\gamma} = \frac{\log_e\left[0.1/\left(\frac{1}{30}\right)\right]}{0.1 - \frac{1}{30}} = 15\log_e 3$$

$$\therefore\ N_x = N_0 e^{-0.1(15\log_e 3)} = N_0 e^{\log_e(3^{-1.5})}$$

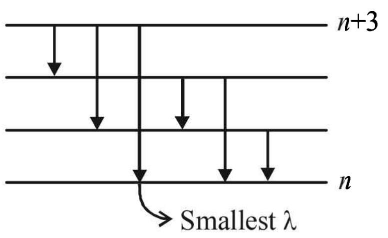
$$\Rightarrow N_x = N_0 3^{-1.5} = \frac{10^{20}}{3\sqrt{3}}$$

Since, $\frac{dN_y}{dt} = 0$ at $t = 15\log_e 3$, $\therefore\ N_y = \frac{\lambda_x N_x}{\lambda_y} = \frac{10^{20}}{\sqrt{3}}$

and $N_z = N_0 - N_x - N_y$

$$= 10^{20} - \left(\frac{10^{20}}{3\sqrt{3}}\right) - \frac{10^{20}}{\sqrt{3}} = 10^{20}\left(\frac{3\sqrt{3}-4}{3\sqrt{3}}\right)$$

27. **(a)** If x is the difference in quantum number of the states than $^{x+1}C_2 = 6 \Rightarrow x = 3$



Now, we have $\frac{-z^2(13.6\text{eV})}{n^2} = -0.85\text{eV}$ ...(i)

and $\frac{-z^2(13.6\text{eV})}{(n+3)^2} = -0.544 \text{ eV}$ ...(ii)

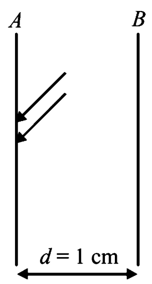
Solving (i) and (ii) we get n = 12 and z = 3

(b) Smallest wavelength λ is given by

$$\frac{hc}{\lambda} = (0.85 - 0.544) \text{ eV}$$

Solving, we get λ = 4052 nm.

28. **(a)** Number of electrons falling on the metal plate *A* $= 10^{16} \times (5 \times 10^{-4})$



∴ Number of photoelectrons emitted from metal plate *A* upto 10 seconds is

$$n_e = \frac{(5 \times 10^4) \times 10^{16}}{10^6} \times 10 = 5 \times 10^7$$

(b) Charge on plate *B* at *t* = 10 sec
$Q_b = 33.7 \times 10^{-12} - 5 \times 10^7 \times 1.6 \times 10^{-19} = 25.7 \times 10^{-12}\, C$
also $Q_a = 8 \times 10^{-12}\, C$

$$E = \frac{\sigma_B}{2\varepsilon_0} - \frac{\sigma_A}{2\varepsilon_0} = \frac{1}{2A\varepsilon_0}(Q_B - Q_A)$$

$$= \frac{17.7 \times 10^{-12}}{5 \times 10^{-4} \times 8.85 \times 10^{-12}} = 2000\, N/C$$

(c) K.E. of most energetic particles $= (h\nu - \phi) + e\,(Ed) = 23$ eV

Note : $(h\nu - \phi)$ is energy of photoelectrons due to light $e\,(Ed)$ is the energy of photoelectrons due to work done by photoelectrons between the plates.

29. According to Bohr's model, the energy released during transition from n_2 to n_1 is given by

$$\Delta E = h\nu = Rhc(Z-b)^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

For transition from *L* shell to *K* shell
$b = 1, n_2 = 2, n_1 = 1$

$$\therefore\ (Z-1)^2 Rhc\left[\frac{1}{1} - \frac{1}{4}\right] = h\nu$$

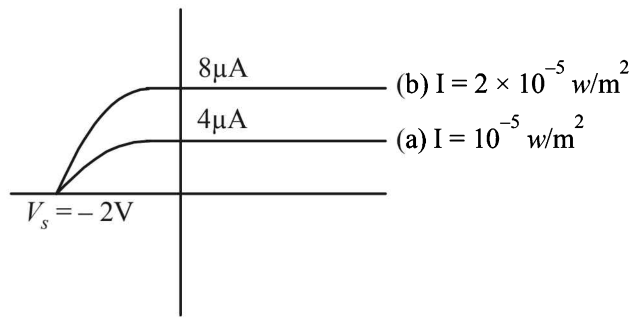
On putting the value of $R = 1.1 \times 10^7 \text{ m}^{-1}$ (given), $c = 3 \times 10^8$ m/s, we get
Z = 42

30. $$\lambda = \frac{\log_e \frac{A_0}{A}}{t} = \frac{1}{2}\log_e \frac{n}{0.75n}$$

$$\Rightarrow \text{Mean Life} = \frac{1}{\lambda} = \frac{2}{\log_e 4/3}$$

31. **(a)** $eV_0 = h\nu - h\nu_0 = 5 - 3 = 2$ eV
∴ $V_0 = 2$ volt

(b) **Note :** When the intensity is doubled, the saturation current is also doubled.



32. a = Initial Uranium atom
$(a - x)$ = Uranium atoms left

$$(a - x) = a\left(\frac{1}{2}\right)^n$$

and $n = \frac{t}{t_{1/2}} = \frac{1.5 \times 10^9}{4.5 \times 10^9} = \frac{1}{3}$

$$\therefore\ a - x = a(\frac{1}{2})^{1/3}$$

$$\Rightarrow \frac{a}{a-x} = \frac{1}{(1/2)^{1/3}} = \frac{2^{1/3}}{1} = 1.26$$

$$\Rightarrow \frac{x}{a-x} = 1.26 - 1 = 0.26$$

33. **KEY CONCEPT :**
The wavelength λ, of photon for different lines of Balmer series is given by

$$\frac{hc}{\lambda} = 13.6\left[\frac{1}{2^2} - \frac{1}{n^2}\right] \text{eV, where } n = 3, 4, 5$$

Using above relation, we get the value of λ = 657nm, 487 nm between 450 nm and 700 nm. Since 487 nm, is smaller than 657 nm, electron of max. K.E. will be emitted for photon corresponding to wavelength 487 nm with

$$(\text{K.E.}) = \frac{hc}{\lambda} - W = \left(\frac{1242}{487} - 2\right) = 0.55 \text{ eV}$$

34. The de Broglie wave length is given by

$$\lambda=\frac{h}{mv}\Rightarrow\lambda=\frac{h}{\sqrt{2mK}}$$

Case (i) $0\le x\le 1$

For this, potential energy is E_0 (given)

Total energy = $2E_0$ (given)

$\therefore$ Kinetic energy = $2E_0-E_0=E_0$

$$\lambda_1=\frac{h}{\sqrt{2mE_0}}\quad ...(i)$$

Case (ii) $x>1$

For this, potential energy = 0 (given)

Here also total energy = $2E_0$ (given)

$\therefore$ Kinetic energy = $2E_0$

$$\therefore\lambda_2=\frac{h}{\sqrt{2m(2E_0)}}\quad ....(ii)$$

Dividing (i) and (ii)

$$\frac{\lambda_1}{\lambda_2}=\sqrt{\frac{2E_0}{E_0}}\Rightarrow\frac{\lambda_1}{\lambda_2}=\sqrt{2}$$

35. **(a) KEY CONCEPT :** We know that radius of nucleus is given by formula

$r=r_0A^{1/3}$ where r_0 = constt, and A = mass number.

For the nucleus $r_1=r_0 4^{1/3}$

For unknown nucleus $r_2=r_0(A)^{1/3}$

$$\therefore\ \frac{r_2}{r_1}=\left(\frac{A}{4}\right)^{1/3},\ (14)^{1/3}=\left(\frac{A}{4}\right)^{1/3}\Rightarrow A=56$$

$\therefore$ No of proton = A – no. of neutrons = $56-30=26$

$\therefore$ Atomic number = 26

(b) We know that $\nu=Rc(Z-b)^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$

Here, $R=1.1\times10^7, c=3\times10^8, Z=26$

$b=1$ (for K_α), $n_1=1, n_2=2$

$$\therefore\ \nu=1.1\times10^7\times3\times10^8[26-1]^2\left[\frac{1}{1}-\frac{1}{4}\right]$$

$$=3.3\times10^{15}\times25\times25\times\frac{3}{4}=1.546\times10^{18}\text{ Hz}$$

36. **Note :** nth line of Lyman series means electron jumping from $(n+1)$th orbit to 1st orbit.

For an electron to revolve in $(n+1)$th orbit.

$2\pi r=(n+1)\lambda$

$$\Rightarrow\lambda=\frac{2\pi}{(n+1)}\times r=\frac{2\pi}{(n+1)}\left[0.529\times10^{-10}\right]\frac{(n+1)^2}{Z}$$

$$\Rightarrow\frac{1}{\lambda}=\frac{Z}{2\pi\left[0.529\times10^{-10}\right](n+1)}\quad ..(i)$$

Also we know that when electron jumps from $(n+1)$th orbit to 1st orbit.

$$\frac{1}{\lambda}=RZ^2\left[\frac{1}{1^2}-\frac{1}{(n+1)^2}\right]=1.09\times10^7Z^2\left[1-\frac{1}{(n+1)^2}\right]\quad ...(ii)$$

From (i) and (ii)

$$\frac{Z}{2\pi(0.529\times10^{-10})(n+1)}=1.09\times10^7Z^2\left[1-\frac{1}{(n+1)^2}\right]$$

On solving, we get $n=24$

F. Match the Following

1. **A → p; B → t; C → u; D → r**

The correct match is as follows :

(A)	Energy of thermal neutrons	(p) 0.025 eV
(B)	Energy of X-rays	(t) 10 keV
(C)	Binding energy per nucleon	(u) 8 MeV
(D)	Photoelectric threshold of a metal	(r) 3 eV

2. **A → p, q; B → p, r; C → p, s; D → p, q, r**

In a nuclear fusion reaction matter is converted into energy and nuclei of low atomic number generally given this reaction. In a nuclear fission reaction matter is converted into energy and nuclei of high atomic number generally given this reaction.

3. **A → p, r**

Reason : Characteristic X-ray are produced due to transition of electrons from one energy level to another.

Similarly the lines in the hydrogen spectrum is obtained due to transition of electrons from one energy level to another.

B → q, s

Reason : In photoelectric effect electrons from the metal surface are emitted out upon the incidence of light of appropriate frequency.

Note : In β-decay, electrons are emitted from the nucleus of an atom.

C → p

Moseley gave a law which related frequency of emitted X-ray with the atomic number of the target material

$$\sqrt{\nu}=a(Z-b)$$

D → q

In photoelectric effect, energy of photons of incident ray gets converted into kinetic energy of emitted electrons.

4. **A → p, q, t; B → q; C → s; D → s**

(p) When an uncharged capacitor is connected to a battery, it becomes charged and energy is stored in the capacitor. (A) is the correct option.

(q) When a gas in an adiabatic container fitted with an adiabatic piston is compressed by pushing the piston

(i) the internal energy of the system increases

$$\Delta U=Q-W=0-(-PdV)=+PdV$$

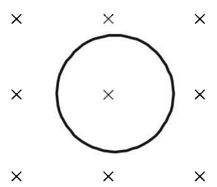
(ii) Mechanical energy is proceeded to the piston which is converted into kinetic energy of the gas molecules.

(r) None of the options in column I matches. As the gas in a rigid container gets cooled, the internal energy of the system will decrease. The average kinetic energy per molecule will decrease.

(s) When a heavy nucleus initially at rest splits into two nuclei of nearly equal masses and some neutrons are emitted then

(i) Internal energy of the system is converted into mechanical energy (precisely speaking kinetic energy) and

(ii) Mass of the system decreases which converts into energy.



(t) When a resistive wire loops is placed in a time varying magnetic field perpendicular to its palne.

(i) Induced current shows in the loop due to which the energy of system is increased.

5. **(c)** $^{15}_{8}O \longrightarrow\, ^{15}_{7}N + \underset{\beta^+ \text{ particle}}{^{0}_{1}\beta}$

$^{238}_{92}U \longrightarrow\, ^{234}_{90}Th + \underset{\alpha-\text{particle}}{^{4}_{2}He}$

$^{185}_{83}Bi \longrightarrow\, ^{184}_{82}Pb + \underset{\text{proton}}{^{1}_{1}H}$

$^{239}_{94}Pu \longrightarrow\, ^{140}_{57}La + ^{99}_{37}X$

(c) is the correct option.

19. $A \rightarrow r, t; B \rightarrow p, s; C \rightarrow p, q, r, t; D \rightarrow p, q, r, t$

Based on facts

G. Comprehension Based Questions

1. **(c)** For hydrogen like atoms $E_n = \dfrac{-13.6\, Z^2}{n^2} eV/atom$

$\dfrac{\text{For hydrogen atom}}{(Z=1)}$ $E_1 = -13.6 eV$

$E_2 = -3.4 eV$

$\therefore \Delta E = E_2 - E_1 = -3.4 - (-13.6) = 10.2\, eV$

i.e., when hydrogen comes to ground state it will release 10.2 eV of energy.

$\dfrac{\text{For He}^+\text{ion}}{(Z=2)}$ $E_1 = -13.6 \times 4\, eV = -54.4\, eV$

$E_2 = -13.6\, eV$

$E_3 = -6.04\, eV$

$E_4 = -3.4 eV$

Here He^+ ion is in the first excited state i.e., possessing energy – 13.6 eV. After receiving energy of + 10.2 eV from excited hydrogen atom on collision, the energy of electron will be (–13.6 + 10.2) eV = –3.4 eV. This means that the electron will jump to n = 4.

2. **(c)** After collision with hydrogen atom the He^+ ion is in its third excited state (n = 4). After that the electron can jump into n = 3.

$$\Delta E = h\nu = \frac{hc}{\lambda} = E_4 - E_3$$

$$= \left[\frac{-13.6 \times 4}{16} - \left(\frac{-13.6 \times 4}{9}\right)\right] \times 1.6 \times 10^{-19}$$

$$\therefore \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{\lambda} = -13.6 \times 4\left[\frac{1}{16} - \frac{1}{9}\right]$$

$$\lambda = \frac{6.6 \times 10^{-34} \times 3 \times 10^8 \times 9 \times 16}{7 \times 13.6 \times 4 \times 1.6 \times 10^{-19}} = 4.68 \times 10^{-7}\, m$$

Since only one option is correct, we need not work out the case of electron jumping from n = 4 to n = 2.

3. **(a)** K. E. for hydrogen atom (for n = 2) $= \dfrac{+13.6 \times 1^2}{4} eV$

K. E for He^+ (for n = 2) $= \dfrac{13.6 \times 2^2}{2^2} = 13.6\ eV$

$\therefore$ Ratio $= \dfrac{1}{4}$

4. **(d)** The collection of ^2_1H nuclei and electron is known as plasma which is formed due to high temperature inside the reactor core.

5. **(a)** Applying conservation of mechanical energy we get Loss of kinetic energy of two deuteron nuclei = Gain in their potential energy.

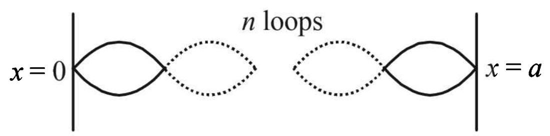
$$2 \times 1.5kT = \frac{1}{4\pi\varepsilon_0}\frac{e \times e}{r}$$

$$\Rightarrow 2 \times 1.5 \times \left(8.6 \times 10^{-5} \frac{eV}{k}\right) \times T = \frac{(1.44 \times 10^{-9} eVm)}{4 \times 10^{-15} m}$$

$$\Rightarrow T = \frac{1.44 \times 10^{-9}}{2 \times 1.5 \times 8.6 \times 10^{-5} \times 4 \times 10^{-15}} = 1.4 \times 10^9 K$$

6. **(b)** For the reading B we get $nt_0 > 5 \times 10^{14}$ which is the Lawson criterion for a reactor to work successfully.

7. **(a)** $\lambda = \dfrac{h}{p}$ and $E = \dfrac{p^2}{2m}$



$$\Rightarrow E = \frac{h^2}{2m\lambda^2}$$

The length in which the particle is restricted to move is a. This length is a multiple of $\dfrac{\lambda}{2}$.

Now, $n\dfrac{\lambda}{2} = a \Rightarrow \lambda = \dfrac{2a}{n}$

$$\Rightarrow E = \frac{h^2 n^2}{2m \times 4a^2} = \frac{n^2 h^2}{8ma^2}$$

$\Rightarrow \quad E \propto a^{-2}$ for a particular value of *n*.

8. **(b)** For ground state $n = 1$,
Given $m = 1.0 \times 10^{-30}$ kg, $a = 6.6 \times 10^{-9}$ m

$$\therefore \quad E = \frac{1^2 \times (6.6 \times 10^{-34})^2}{8 \times 1 \times 10^{-30} \times (6.6 \times 10^{-9})^2} \text{J} = 8 \text{ meV}$$

9. **(d)** $\lambda = \frac{h}{p} \Rightarrow \lambda = \frac{h}{mv} \Rightarrow mv = \frac{h}{\lambda}$

But $\frac{n\lambda}{2} = a \Rightarrow \lambda = \frac{2a}{n}$

$$\therefore \quad mv = \frac{nh}{2a} \Rightarrow v = \frac{nh}{2am} \Rightarrow v \propto n$$

10. **(d)** According to Bohr's quantisation principle $L = \frac{nh}{2\pi}$

Rotational kinetic energy $= \frac{1}{2} I\omega^2 = \frac{1}{2} I \left[\frac{L}{I}\right]^2$

$[\because L = I\omega]$

$$= \frac{1}{2}\frac{L^2}{I} = \frac{1}{2I} \times \frac{n^2h^2}{4\pi^2} = n^2\left[\frac{h^2}{8\pi^2 I}\right] \quad ...(i)$$

11. **(b)** Energy given = change in kinetic energy

$$h\nu = K_f - K_i = \frac{h^2}{8\pi^2 I}[2^2 - 1^2] \quad \text{[From (i)]}$$

$$h\nu = \frac{3h^2}{8\pi^2 I}$$

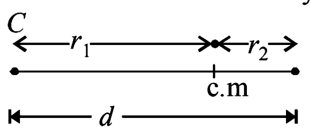
$$\Rightarrow I = \frac{3h}{8\pi^2 \nu} = \frac{3 \times 2\pi \times 10^{-34}}{8\pi^2 \times \frac{4}{\pi} \times 10^{11}} = \frac{3}{16} \times 10^{-45}$$

$= 1.87 \times 10^{-46}$ kg m^2

12. **(c)** Centre of mass divides the distance between the point masses in inverse ratio of their masses.

$$\therefore r_1 = \frac{m_2 d}{m_1 + m_2} \text{ and } r_2 = \frac{m_1 d}{m_1 + m_2}$$

Also the moment of inertia of the system is



$$I = m_1 r_1^2 + m_2 r_2^2$$

$$\Rightarrow 1.87 \times 10^{-46} = 12 \times \frac{5}{3} \times 10^{-27}\left[\frac{16 \times \frac{5}{3} \times 10^{-27} \times d}{28 \times \frac{5}{3} \times 10^{-27}}\right]^2$$

$$+ 16 \times \frac{5}{3} \times 10^{-2}\left[\frac{12 \times \frac{5}{3} \times 10^{-27} d}{28 \times \frac{5}{3} \times 10^{-27}}\right]^2$$

$\Rightarrow$ d = 1.3×10^{-10} m

13. **(d)** K should be less than 0.8×10^6 eV as anti-neutrino will have some energy.

14. **(c)** The energy shared between anti-neutrino and electron. If the energy of electron is almost zero then the maximum energy of anti-neutrino is nearly 0.8×10^6 eV.

15. **(a)** ${}^{210}_{84}\text{Po} \longrightarrow {}^{206}_{82}\text{Pb} + {}^{4}_{2}\text{He}$

Here Δm = [209.982876 – (205.974455 + 4.002603)] × 932 MeV = 5.422 MeV = 5422 keV

By conservation of linear momentum

Linear momentum of α-particle = linear momentum of lead

$$p_\alpha = p_{lead}$$

$$\sqrt{2m_\alpha K.E_\alpha} = \sqrt{2m_{lead} K.E_{lead}}$$

$$\therefore K.E = \frac{m_{lead} \times K.E_{lead}}{m_\alpha} = \frac{206 \times K.E_{lead}}{4} \quad ...(1)$$

Also $K.E_\alpha + K.E_{lead} = 5422$ keV ...(2)

On solving the above two equations we get

$K.E_\alpha = 5319$ keV

(a) is the correct option.

16. **(c)** Only in case of c we have $m_3 + m_4 > M'$

(c) is the correct option.

In other cases of fission $m_1 + m_2 \not< M$ and in the other case of fusion $m_3 + m_4 \not> M'$

H. Assertion & Reason Type Questions

1. **(b) Statement 1 :** The wavelength of characteristic X-rays depends on the type of atoms of which the target material is made. It does not depend on the accelerating potential. Therefore, statement I is true.

Statement 2 : When an electric beam strikes the target in an X-ray tube, part of the kinetic energy is converted into X-ray energy. This statement is true. But statement 2 does not explain statement 1.

I. Integer Value Correct Type

1. **(3)** We know that, $\lambda = \frac{h}{\sqrt{2mqV}}$

$$\therefore \frac{\lambda_1}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}} = \sqrt{\frac{4}{1} \times \frac{2}{1}} = \sqrt{8} \approx 3$$

2. **(8)** We know that $N = N_0 e^{-\lambda t}$

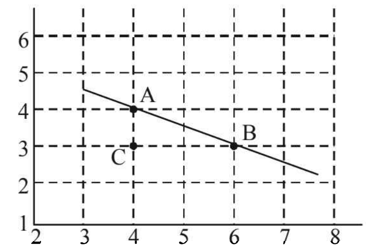
$$\therefore \frac{dN}{dt} = N_0 e^{-\lambda t}(-\lambda) = -N_0 \lambda e^{-\lambda t}$$

Taking log on both sides

$$\log_e \frac{dN}{dt} = \log_e(-N_0\lambda) - \lambda t$$

Comparing it with the graph line,

we get $\lambda = \frac{1}{2}\text{yr}^{-1}$ $\left[\frac{AC}{BC} = \frac{1}{2}\right]$



$\therefore T_{1/2} = \frac{0.693}{\lambda} = 0.693 \times 2 = 1.386$ years

Now $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow \frac{1}{p} = \left(\frac{1}{2}\right)^{\frac{4.16}{1.386}} = \frac{1}{8}$

3. (1)

We know that , $\left|\frac{dN}{dt}\right| = \lambda N = \frac{1}{T_{mean}} N$

$\therefore \quad 10^{10} = \frac{1}{10^9} \times N$

$\therefore \quad N = 10^{19}$

i.e. 10^{19} radioactive atoms are present in the freshly prepared sample.

The mass of the sample = $10^{19} \times 10^{-25}$ kg = 10^{-6}kg = 1 mg

4. (7)

Stopping potential = $\frac{1}{e}\left[\frac{hc}{\lambda} - \phi\right]$ where hc = 1240eV –nm

$= \frac{1}{e}\left[\frac{1240}{200} - 4.7\right] = \frac{1}{e}[6.2 - 4.7]$

$= \frac{1}{e} \times 1.5 eV = 1.5$V

But $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} = \frac{1}{4\pi\varepsilon_0}\frac{ne}{r}$

$\therefore n = \frac{Vr(4\pi\varepsilon_0)}{e} = \frac{1.5 \times 10^{-2}}{9 \times 10^9 \times 1.6 \times 10^{-19}}$

$\therefore n = 1.04 \times 10^7$

Comparing it with $A \times 10^z$ we get, $z = 7$

5. (7) Loss in K.E. of proton = Gain in potential energy of the proton – nucleus system

$$\frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$

$$\therefore \frac{p^2}{2m} = \frac{1}{4\pi \epsilon_0}\frac{q_1 q_2}{r}$$

$$\therefore \frac{1}{2m}\left(\frac{h^2}{\lambda^2}\right) = \frac{1}{4\pi \epsilon_0}\frac{q_1 q_2}{r}$$

$$\therefore \lambda = \sqrt{\frac{4\pi \epsilon_0 r . h^2}{q_1 q_2 (2m)}} = 7 \text{ fm}$$

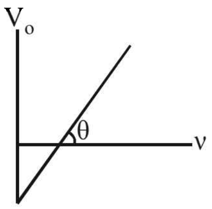
6. (1) For photoelectric effect

$\frac{h\nu}{e} - \frac{\phi_0}{e} = V_0$

The slope is

$\tan\theta = \frac{h}{e}$ = constant

$\therefore$ The ratio will be 1.



7. (4) For a radioactive decay

$N = N_0 \ e^{-\lambda t}$

$\therefore \frac{N}{N_0} = e^{-\lambda t} \therefore 1 - \frac{N}{N_0} = 1 - e^{-\lambda t}$

$\therefore \frac{N_0 - N}{N} = 1 - e^{-\frac{0.693}{t_{1/2}} \times t} = 1 - e^{-0.04} = 1 - (1 - 0.04)$

$\approx 0.04 = 4\% \qquad [\because e^{-x} = 1 - x \ x << 1]$

8. (3) $N_o \xrightarrow{T} \frac{N_o}{2} \xrightarrow{T} \frac{N_o}{4} \xrightarrow{T} \frac{N_o}{8}$

100% 50% 25% 12.5%

Three half life are required. Therefore $n = 3$

9. (2) $\frac{hc}{\lambda} = \frac{13.6}{n^2} + 10.2$

$\therefore \quad \frac{1242}{90} = \frac{13.6}{n^2} + 10.2 \therefore \quad n^2 = 4 \therefore n = 2$

10. (2) $R = -\frac{dA}{dt} = -\frac{d}{dt}\left[-\frac{dN}{dt}\right] = \frac{d^2N}{dt^2} = \frac{d^2\left(N_o e^{-\lambda t}\right)}{dt^2}$

$\therefore \quad R = N_0 \lambda^2 e^{-\lambda t} = (N_0\lambda)\lambda e^{-\lambda t} = A_0 \lambda e^{-\lambda t}$

$[\because A_0 = N_0 \lambda]$

$\therefore \quad \frac{R_P}{R_Q} = \frac{\lambda_P e^{-\lambda_P t}}{\lambda_Q e^{-\lambda_Q t}} = \frac{\lambda P}{\lambda Q} \times \frac{e^{\lambda_Q t}}{e^{\lambda_P t}} = \frac{2\tau}{\tau}\frac{e^{\frac{2\tau}{2\tau}}}{e^{\frac{2\tau}{\tau}}} = \frac{2}{e}$

$\therefore \quad n = 2$

11. (2) Given $mvr = \frac{3h}{2\pi} \Rightarrow n = 3$

$\therefore \quad \frac{h r}{\lambda} = \frac{3h}{2\pi} \qquad \left[\because \lambda = \frac{h}{mv}\right]$

$\therefore \quad \lambda = \frac{2\pi r}{3} = \frac{2}{3}\pi\left[a_0 \frac{n^2}{z}\right] \qquad \left[\because r = a_0 \frac{n^2}{z}\right]$

$\therefore \quad \lambda = \frac{2}{3}\pi a_0\left[\frac{3 \times 3}{3}\right] = 2\pi a_0$

$\therefore \quad p = 2$

12. (9) Maximum kinetic energy of β-particle

$= [\text{mass of } {}^{12}_{5}B - \text{mass of } {}^{12}_{6}C] \times 931.5 - 4.041$

$= [12.014 - 12] \times 931.5 - 4.041] = 9$MeV

13. (6) $E = \frac{hc}{\lambda} = \frac{1.237 \times 10^{-6}}{970 \times 10^{-10}} eV = 12.75 eV$

$\therefore$ The energy of electron after absorbing this photon $= -13.6 + 12.75 = -0.85$eV

This corresponds to n = 4

Number of spectral line = $\frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$

Section-B JEE Main/ AIEEE

1. **(c)** **KEY CONCEPT :**
The energy of nth orbit of hydrogen is given by

$$E_n = -\frac{13.6}{n^2} \text{ eV/atom}$$

For $n = 2$, $E_n = \frac{-13.6}{4} = -3.4\,eV$

Therefore the energy required to remove electron from $n = 2$ is $+3.4$ eV.

2. **(c)** Pure silicon, at absolute zero, will contain all the electrons in bounded state. The conduction band will be empty. So there will be no free electrons (in conduction band) and holes (in valence band) due to thermal agitation. Pure silicon will act as insulator.

3. **(a)** Charged particles are deflected in magnetic field.

4. **(c)** We know that work function is the energy required and energy $E = h\upsilon$

$$\therefore \frac{E_{Na}}{E_{Cu}} = \frac{h\upsilon_{Na}}{h\upsilon_{Cu}} = \frac{\lambda_{Cu}}{\lambda_{Na}} \qquad \left[\because \upsilon \propto \frac{1}{\lambda} \text{ for light}\right]$$

$$\therefore \frac{\lambda_{Na}}{\lambda_{Cu}} = \frac{E_{Cu}}{E_{Na}} = \frac{4.5}{2.3} \approx \frac{2}{1}$$

5. **(a)** Formation of covalent bond is best explained by molecular orbital theory.

6. **(a)** After every half-life, the mass of the substance reduces to half its initial value.

$$N_0 \xrightarrow{\text{5 years}} \frac{N_0}{2} \xrightarrow{\text{5 years}} \frac{N_0}{2^2} \xrightarrow{5\,years} \frac{N_0}{8}$$

7. **(c)** Specific resistance is resistivity which is given by

$$\rho = \frac{m}{ne^2\tau}$$

where n = no. of free electrons per unit volume
and τ = average relaxation time

For a conductor with rise in temperature n increases and τ decreases. But decrease in τ is more dominant than increase in n resulting an increase in the value of ρ

For a semiconductor with rise in temperature, n increases and τ decreases. But the increase in n is more dominant than decrease in τ resulting in a decrease in the value of ρ.

8. **(c)** The energy band gap is maximum in insulators.

9. **(a)** Emitter sends the majority charge carrriers towards the collector. Therefore emitter is most heavily doped.

10. **(c)** β -rays are fast moving beam of electrons.

11. **(c)** The resistance of metal (like Cu) decreases with decrease in temperature whereas the resistance of a semi-conductor (like Ge) increases with decrease in temperature.

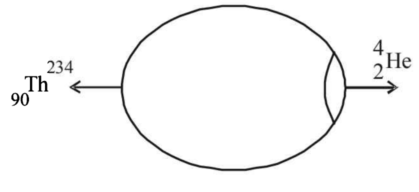
12. **(a)** The electromagnetic spectrum is as follows

increasing wavelength →

γ–rays · x-rays · UV rays · visible rays · IR rays · microwaves · radiowaves

$\therefore$ γ-rays has least wavelength

13. **(c)** Here, conservation of linear momentum can be applied



$$238 \times 0 = 4u + 234v \Rightarrow \therefore\ v = -\frac{4}{234}u$$

$$\therefore \text{ speed} = |\vec{v}| = \frac{4}{234}u$$

14. **(b)** When the temperature increases, certain bounded electrons become free which tend to promote conductivity. Simultaneously number of collisions between electrons and positive kernels increases

15. **(a)** $\lambda = \frac{1}{t}\log_e \frac{A_o}{A} = \frac{1}{5}\log_e \frac{5000}{1250} = 0.4\log_e 2$

16. **(b)** The number of α - particles released =8
Therefore the atomic number should decrease by 16

The number of β^- -particles released = 4
Therefore the atomic number should increase by 4.

Also the number of β^+ particles released is 2, which should decrease the atomic number by 2.
Therefore the final atomic number is
$92 - 16 + 4 - 2 = 78$

17. **(a)** For one photocathode

$$hf_1 - W = \frac{1}{2}mv_1^2 \qquad \text{....(i)}$$

For another photo cathode

$$hf_2 - W = \frac{1}{2}mv_2^2 \qquad \text{....(ii)}$$

Subtracting (ii) from (i) we get

$$(hf_1 - W) - (hf_2 - W) = \frac{1}{2}mv_1^2 - \frac{1}{2}mv_2^2$$

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

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

18. **(a)** The radioactive substances emit α -particles (Helium nucleus), $\beta-$ particles (electrons) and neutrinoes.

19. (d) The average kinetic energy per molecule $= \frac{3}{2}kT$

This kinetic energy should be able to provide the repulsive potential energy

$\therefore \frac{3}{2}kT = 7.7\times10^{-14}$

$\Rightarrow T = \frac{2\times7.7\times10^{-14}}{3\times1.38\times10^{-23}} = 3.7\times10^{9}$

20. (b) The ionisation potential increases from left to right in a period and decreases from top to bottom in a group. Therefore ceasium will have the lowest ionisation potential.

21. (c) The wavelength of spectrum is given by

$\frac{1}{\lambda} = Rz^2\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$ where $R = \frac{1.097\times10^7}{1+\frac{m}{M}}$

where m = mass of electron

M = mass of nucleus.

For different M, R is different and therefore λ is different

22. (a) As in reverse bias, the current through the 0000 is zero through the electric field is also zero.

23. (a) $E_n = -\frac{13.6}{n^2}Z^2 \text{eV/atom}$

For lithium ion $Z = 3$; $n = 2$ (for first excited state)

$E_n = -\frac{13.6}{2^2}\times3^2 = -30.6 \text{ eV}$

24. (b) Momentum of photon $= \frac{E}{c}$

Change in momentum $= \frac{2E}{c}$

= momentum transferred to the surface

(the photon will reflect with same magnitude of momentum in opposite direction)

25. (d) From Equation $K.E = h\nu - \phi$

slope of graph of K.E & ν is h (Plank's constant) which is same for all metals

26. (a) For the longest wavelength to emit photo electron

$\frac{hc}{\lambda} = \phi \Rightarrow \lambda = \frac{hc}{\phi}$

$\Rightarrow \lambda = \frac{6.63\times10^{-34}\times3\times10^8}{40\times1.6\times10^{-16}} = 310 \text{nm}$

27. (b) From conservation of momentum $m_1v_1 = m_2v_2$

$\Rightarrow \left(\frac{m_1}{m_2}\right) = \left(\frac{v_2}{v_1}\right)$ *given* $\frac{v_1}{v_2} = 2$

$\Rightarrow \frac{m_1}{m_2} = \frac{1}{2} \Rightarrow \frac{r_1^3}{r_2^3} = \frac{1}{2} \Rightarrow \left(\frac{r_1}{r_2}\right) = \left(\frac{1}{2}\right)^{1/3}$

28. (a) The nuclear reaction of process is $2\,{}_1^2\text{H} \rightarrow {}_2^4\text{He}$

Energy released $= 4\times(7) - 4(1.1) = 23.6$ MeV

29. (a) **KEY CONCEPT :**

Distance of closest approach

$r_0 = \frac{Ze(2e)}{4\pi\varepsilon_0 E}$

Energy, $E = 5\times10^6\times1.6\times10^{-19}$ J

$\therefore r_0 = \frac{9\times10^9\times(92\times1.6\times10^{-19})(2\times1.6\times10^{-19})}{5\times10^6\times1.6\times10^{-19}}$

$\Rightarrow r = 5.2\times10^{-14} m = 5.3\times10^{-12}$ cm

30. (d) Electrons move from base to emmitter.

31. (d) In common emitter configuration current gain

$A_i = \frac{-hf_e}{1+b_{oe}R_L} = \frac{-50}{1+25\times10^{-6}\times1\times10^3} = -48.78$

32. (d) Copper is a conductor, so its resistance decreases on decreasing temperature as thermal agitation decreases,; whereas germanium is semiconductor therefore on decreasing temperature resistance increases.

33. (b) Pauli's exclusion principle.

34. (a) Both the depletion region and barrier height is reduced.

35. (b) **KEY CONCEPT :** $R = R_0(A)^{1/3}$

$\therefore \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{27}{125}\right)^{1/3} = \frac{3}{5}$

$R_2 = \frac{5}{3}\times3.6 = 6$ fermi

36. (d) $\frac{7}{8}$ of Cu decays in 15 minutes.

$\therefore$ Cu undecayed $= N = 1 - \frac{7}{8} = \frac{1}{8} = \left(\frac{1}{2}\right)^3$

$\therefore$ No. of half lifes = 3

$n = \frac{t}{T}$ or $3 = \frac{15}{T}$

$\Rightarrow T$ = half life period $= \frac{15}{3} = 5$ minutes

37. (a) $I \propto \frac{1}{r^2}$; $\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2 = \frac{1}{4}$

$I_2 \rightarrow 4$ times I_1

When intensity becomes 4 times, no. of photoelectrons emitted would increase by 4 times, since number of electrons emitted per second is directly proportional to intensity.

38. (d) Band gap = energy of photon of wavelength 2480 nm. So,

$$\Delta E = \frac{hc}{\lambda} = \left(\frac{6.63\times10^{-34}\times3\times10^{8}}{2480\times10^{-9}}\right)\times\frac{1}{1.6\times10^{-19}}\text{eV}$$

$= 0.5$ eV

39. (c) **KEY CONCEPT :** Intensity $I = I_0.e^{-\mu d}$,

Applying logarithm on both sides,

$$-\mu d = \log\left(\frac{I}{I_0}\right)$$

$$-\mu\times36 = \log\left(\frac{I/8}{I}\right) \quad ....(i)$$

$$-\mu\times d = \log\left(\frac{I/2}{I}\right) \quad ....(ii)$$

Dividing (i) by (ii),

$$\frac{36}{d} = \frac{\log\left(\frac{1}{8}\right)}{\log\left(\frac{1}{2}\right)} = \frac{3\log\left(\frac{1}{2}\right)}{\log\left(\frac{1}{2}\right)} = 3 \text{ or } d = \frac{36}{3} = 12\text{ mm}$$

40. (d) Zero; In common base amplifier circuit, input and output voltage are in the same phase.

41. (b) **KEY CONCEPT :** $E = Rhc\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

E will be maximum for the transition for which $\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ is maximum. Here n_2 is the higher energy level.

Clearly, $\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ is maximum for the third transition, i.e. $2\to1$. I transition represents the absorption of energy.

42. (d) de-Broglie wavelength,

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2.m.(\text{K.E})}} \qquad \therefore\ \lambda \propto \frac{1}{\sqrt{\text{K.E}}}$$

If K.E is doubled, wavelength becomes $\frac{\lambda}{\sqrt{2}}$

43. (a) $_ZX^A + {}_0n^1 \longrightarrow {}_3Li^7 + {}_2He^4$

On comparison,

$A = 7+4-1 = 10, z = 3+2-0 = 5$

It is boron $_5B^{10}$

44. (d) Input frequency, $f = 50$ Hz $\Rightarrow T = \frac{1}{50}$

For full wave rectifier, $T_1 = \frac{T}{2} = \frac{1}{100} \Rightarrow f_1 = 100$ Hz.

45. (a) $I_C = 5.488$ mA, $I_e = 5.6$ mA, $I_B = I_E - I_C$

$$\beta = \frac{I_c}{I_B} = \frac{5.488}{5.6-5.485} = 49$$

46. (a) $\phi = 6.2\text{ eV} = 6.2\times1.6\times10^{-19}$ J

$V = 5$ volt, $\frac{hc}{\lambda} - \phi = eV_0$

$$\Rightarrow \lambda = \frac{hc}{\phi + eV_0} = \frac{6.6\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}(6.2+5)} \approx 10^{-7}\text{ m}$$

This range lies in ultra violet range.

47. (c) Work done to stop the α particle is equal to K.E.

$$\therefore qV = \frac{1}{2}mv^2 \Rightarrow q\times\frac{K(Ze)}{r} = \frac{1}{2}mv^2$$

$$\Rightarrow r = \frac{2(2e)K(Ze)}{mv^2} = \frac{4KZe^2}{mv^2}$$

$$\Rightarrow r \propto \frac{1}{v^2} \text{ and } r \propto \frac{1}{m}.$$

48. (b) The order of time is 10^{-10}5.

49. (c) $^7_3\text{Li} + {}^1_1\text{p} \longrightarrow {}^8_4\text{Be} + {}^0_0\gamma$

50. (c) The range of energy of β-particles is from zero to some maximum value.

51. (b) Van der Waal's bonding is attributed to the attractive forces between molecules of a liquid. The conductivity of semiconductors (covalent bonding) and insulators (ionic bonding) increases with increase in temperature while that of metals (metallic bonding) decreases.

52. (c) $\frac{I_e}{I_h} = \frac{n_e eAv_e}{n_h eAv_h} \Rightarrow \frac{7}{4} = \frac{7}{5}\times\frac{v_e}{v_h} \Rightarrow \frac{v_e}{v_h} = \frac{5}{4}$

53. (b) D_2 is forward biased whereas D_1 is reversed biased. So effective resistance of the circuit

$R = 4+2 = 6\Omega$

$$\therefore i = \frac{12}{6} = 2\text{ A}$$

54. (d) p-side connected to low potential and n-side is connected to high potential.

55. (b) As λ decreases, ν increases and hence the speed of photoelectron increases. The chances of photo electron to meet the anode increases and hence photo electric current increases.

56. (b) Let E be the energy of proton, then

$$E + 7\times5.6 = 2\times[4\times7.06]$$

$$\Rightarrow E = 56.48 - 39.2 = 17.28\text{MeV}$$

57. (c) The risk posed to a human being by any radiation exposure depends partly upon the absorbed dose, the amount of energy absorbed per gram of tissue. Absorbed dose is expressed in rad. A rad is equal to 100 ergs of energy absorbed by 1 gram of tissue. The more modern, internationally adopted unit is the gray (named after the English medical physicist L. H. Gray); one gray equals 100 rad.

58. (c) A crystal structure is composed of a unit cell, a set of atoms arranged in a particular way; which is periodically repeated in three dimensions on a lattice. The spacing between unit cells in various directions is called its lattice parameters or constants. Increasing these lattice constants will increase or widen the band-gap (E_g), which means more energy would be required by electrons to reach the conduction band from the valence band. Automatically E_c and E_v decreases.

59. (a) $E_{rms} = 720$

The average total energy density

$$= \frac{1}{2} \epsilon_0 E_0^2 = \frac{1}{2} \epsilon_0 [\sqrt{2}E_{rms}]^2 = \epsilon_0 E_{rms}^2$$

$$= 8.85 \times 10^{-12} \times (720)^2 = 4.58 \times 10^{-6}\ \text{J/m}^3$$

60. (c) Binding energy

$= [ZM_P + (A - Z)M_N - M]c^2$

$= [8M_P + (17 - 8)M_N - M]c^2$

$= [8M_P + 9M_N - M]c^2$

$= [8M_P + 9M_N - M_o]c^2$

61. (c) There is no change in the proton number and the neutron number as the γ-emission takes place as a result of excitation or de-excitation of nuclei. γ-rays have no charge or mass.

62. (a) The current will flow through R_L when the diode is forward biased.

63. (a) Energy of a photon of frequency ν is given by $E = h\nu$.

Also, $E = mc^2$, $mc^2 = h\nu$

$$\Rightarrow mc = \frac{h\nu}{C} \Rightarrow p = \frac{h\nu}{c}$$

64. (c) According to question,

Half life of X, $T_{1/2} = \tau_{av}$, average life of Y

$$\Rightarrow \frac{0.693}{\lambda_X} = \frac{1}{\lambda_Y} \Rightarrow \lambda_X = (0.693).\lambda_Y$$

$\therefore \lambda_X < \lambda_Y$.

Now, the rate of decay is given by

$$-\frac{dN}{dt} = \lambda N$$

$\therefore$ Y will decay faster than X. [$\because$ N is some]

65. (a) Si and Ge are semiconductors but C is an insulator. Also, the conductivity of Si and Ge is more than C because the valence electrons of Si, Ge and C lie in third, fourth and second orbit respectively.

66. (d) We have to find the frequency of emitted photons. For emission of photons the transition must take place from a higher energy level to a lower energy level which are given only in options (c) and (d).

Frequency is given by

$$h\nu = -13.6\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$$

For transition from $n = 6$ to $n = 2$,

$$\nu_1 = \frac{-13.6}{h}\left(\frac{1}{6^2} - \frac{1}{2^2}\right) = \frac{2}{9} \times \left(\frac{13.6}{h}\right)$$

For transition from n = 2 to n = 1,

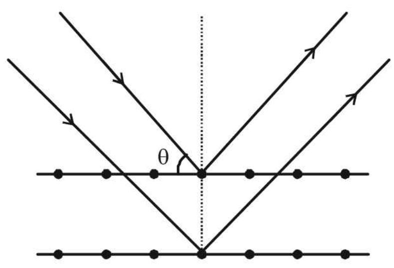
$$\nu_2 = \frac{-13.6}{h}\left(\frac{1}{2^2} - \frac{1}{1^2}\right) = \frac{3}{4} \times \left(\frac{13.6}{h}\right).$$

$\therefore \nu_1 > \nu_2$

67. (b) Using Bragg's equation $2d \sin\theta = n\lambda$

Here $n = 1$, $\theta = 90 - i = 90 - 30 = 60°$

$\therefore \quad 2d \sin\theta = \lambda$ ....(i)



Also, $\lambda = \frac{12.27}{\sqrt{V}} \times 10^{-10}$ m ....(ii)

From (i) & (ii) $2 \times 10^{-10} \times \sin 60^o = \frac{12.27}{\sqrt{V}} \times 10^{-10}$

$$V = \frac{(12.27)^2}{3} = 50\,\text{V}$$

68. (b) $2d \cos i = n\lambda_{dB}$

69. (d) We know that energy is released when heavy nuclei undergo fission or light nuclei undergo fusion. Therefore statement (1) is correct.

The second statement is false because for heavy nuclei the binding energy per nucleon decreases with increasing Z and for light nuclei, B.E/nucleon increases with increasing Z.

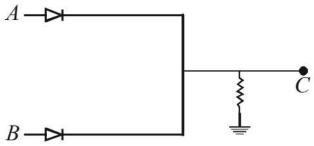
70. (a) It is a n-p-n transistor with R as base.

71. (b) When $F = \frac{k}{r}$ = centripetal force, then $\frac{k}{r} = \frac{mv^2}{r}$

$\Rightarrow mv^2$ = constat $\Rightarrow$ kinetic energy is constant

$\Rightarrow T$ is independent of n.

72. (d)



A	B	C
1	1	1
1	0	1
0	1	1
0	0	0

The truth table for the above logic gate is :
This truth table follows the boolean algebra $C = A + B$ which is for OR gate

73 (c) It is given that transition from the state $n = 4$ to $n = 3$ in a hydrogen like atom result in ultraviolet radiation. For infrared radiation the energy gap should be less. The only option is $5 \rightarrow 4$.

74. (a) $\lambda = 400$ nm, $hc = 1240$ eV.nm, K.E. = 1.68 eV

We know that $\frac{hc}{\lambda} - W = K.E \Rightarrow W = \frac{hc}{\lambda} - K.E$

$$\Rightarrow W = \frac{1240}{400} - 1.68 = 3.1 - 1.68 = 1.42 \text{ eV}$$

75. (d) For $A + B \rightarrow C + \varepsilon$, ε is positive. This is because E_b for C is greater than the E_b for A and B.

Again for $F \rightarrow D + E + \varepsilon$, ε is positive. This is because E_b for D and E is greater than E_b for F.

76. (d) Here $y = \overline{(\overline{A} + \overline{B})} = \overline{\overline{A}}.\overline{\overline{B}} = A \cdot B$. Thus it is an AND gate for which truth table is

A	B	y
0	0	0
0	1	0
1	0	0
1	1	1

77. (b) We know that a single *p-n* junction diode connected to an *a-c* source acts as a half wave rectifier [Forward biased in one half cycle and reverse biased in the other half cycle].

78. (d) We know that

$$eV_0 = K_{max} = hv - \phi$$

where, ϕ is the work function .

Hence, as ν increases (note that frequency of X-rays is greater than that of U.V. rays), both V_0 and K_{max} increase. So statement - 1 is correct

79. (c) In nuclear fission, the binding energy per nucleon of daughter nuclei is greater than the parent nucleus.

80. (b) By conservation of energy,

$$(M + \Delta m)c^2 = \frac{2M}{2}c^2 + \frac{1}{2}.\frac{2M}{2}v^2,$$

where v is the speed of the daughter nuclei

$$\Rightarrow \Delta mc^2 = \frac{M}{2}v^2 \qquad \therefore v = c\sqrt{\frac{2\Delta m}{M}}$$

81. (b) $^A_Z\text{X} \xrightarrow{A-12} {}_{Z-8}\text{Y} + 3\,^4_2\text{X}_e + {}^0_t\text{e}$

$A - 12 - (Z - 8)$

$\therefore$ Required ratio $= \frac{A - Z - Y}{Z - 8}$

82. (a) The final boolean expression is,

$$X = \overline{(\overline{A}.\overline{B})} = \overline{\overline{A}} + \overline{\overline{B}} = A + B \Rightarrow \text{OR gate}$$

83. (a) Power, $P = \frac{nh\nu}{t}$

$$\Rightarrow \nu = \frac{P \times t}{nh}$$

$$= \frac{4 \times 10^3 \times 1}{10^{20} \times 6.63 \times 10^{-34}} = 6 \times 10^{16} \text{ Hz}$$

84. (b) For long distance communication, sky wave signals are used.
Also, the state of ionosphere varies every time. So, both statements are correct.

85. (b) Energy of excitation,

$$\Delta E = 13.6 Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) eV$$

$$\Rightarrow \Delta E = 13.6 (3)^2 \left(\frac{1}{1^2} - \frac{1}{3^2}\right) = 108.8\, eV$$

86. (b) Number of undecayed atom after time t_2;

$$\frac{N_0}{3} = N_0 e^{-\lambda t_2} \qquad \text{...(i)}$$

Number of undecayed atom after time t_1;

$$\frac{2N_0}{3} = N_0 e^{-\lambda t_1} \qquad \text{...(ii)}$$

From (i), $e^{-\lambda t_2} = \frac{1}{3}$

$$\Rightarrow -\lambda t_2 = \log_e\left(\frac{1}{3}\right) \qquad \text{...(iii)}$$

From (ii) $- e^{-\lambda t_2} = \frac{2}{3}$

$$\Rightarrow -\lambda t_1 = \log_e\left(\frac{2}{3}\right) \qquad \text{...(iv)}$$

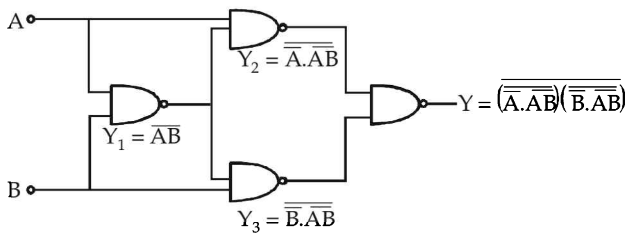
Solving (iii) and (iv), we get
$t_2 - t_1 = 20$ min

87. (c) By Einstein photoelectric equation,
$K_{max} = eV_0 = hv - hv_0$
When v is doubled, K_{max} and V_0 become more than double.

88. (d) The possible number of the spectral lines is given

$$= \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$$

89. (a)



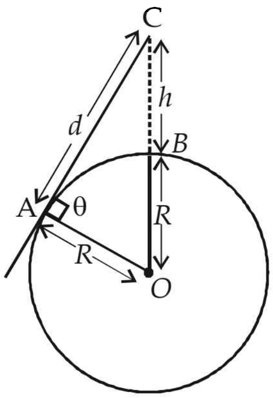
By expanding this Boolen expression

$$Y = A.\overline{B} + B.\overline{A}$$

Thus the truth table for this expression should be (1).

90. (a) Let d is the maximum distance, upto it the objects

From ΔAOC



$$OC^2 = AC^2 + AO^2$$

$$(h+R)^2 = d^2 + R^2$$

$$\Rightarrow \quad d^2 = (h+R)^2 - R^2$$

$$d = \sqrt{(h+R)^2 - R^2}$$

$$d = \sqrt{h^2 + 2hR}$$

$$d = \sqrt{500^2 + 2 \times 6.4 \times 10^6} = 80\,\text{km}$$

91. (a) ${}_0^1\text{n} \longrightarrow {}_1^1\text{H} + {}_{-1}\text{e}^0 + \bar{\nu} + Q$

The mass defect during the process

$$\Delta m = m_n - m_H - m_e$$

$= 1.6725 \times 10^{-27} - (1.6725 \times 10^{-27} + 9 \times 10^{-31}\text{kg})$

$= -9 \times 10^{-31}$ kg

The energy released during the process

$E = \Delta mc^2$

$E = 9 \times 10^{-31} \times 9 \times 10^{16} = 81 \times 10^{-15}$ Joules

$$E = \frac{81 \times 10^{-15}}{1.6 \times 10^{-19}} = 0.511\text{MeV}$$

92. (d) The energy of the system of two atoms of diatomic molecule $E = \frac{1}{2} I\omega^2$

where I = moment of inertia

$$\omega = \text{Angular velocity} = \frac{L}{I},$$

L = Angular momentum

$$I = \frac{1}{2}(m_1 r_1^2 + m^2 r_2^2)$$

Thus, $E = \frac{1}{2}(m_1 r_1^2 + m_2 r_2^2)\omega^2 \quad \ldots(\text{i})$

$$E = \frac{1}{2}(m_1 r_1^2 + m_2 r_2^2)\frac{L^2}{I^2}$$

$$L = n\frac{nh}{2n} \text{ (According Bohr's Hypothesis)}$$

$$E = \frac{1}{2}(m_1 r_1^2 + m_2 r_2^2)\frac{L^2}{(m_1 r_1^2 + m_2 r_2^2)^2}$$

$$E = \frac{1}{2}\frac{L^2}{(m_1 r_1^2 + m_2 r_2^2)} = \frac{n^2 h^2}{8\pi^2 (m_1 r_1^2 + m_2 r_2^2)}$$

$$E = \frac{(m_1 + m_2) n^2 h^2}{8\pi^2 r^2 m_1 m_2} \left[\because r_1 = \frac{m_2 r}{m_1 + m_2};\ r_2 = \frac{m_2 r}{m_1 + m_2}\right]$$

93. (b) Given : Resistance R = 100 kilo ohm = $100 \times 10^3\,\Omega$

Capacitance C = 250 picofarad = 250×10^{-12}F

τ = RC = $100 \times 10^3 \times 250 \times 10^{-12}$ sec

$= 2.5 \times 10^7 \times 10^{-12}$ sec

$= 2.5 \times 10^{-5}$ sec

The higher frequency whcih can be detected with tolerable distortion is

$$f = \frac{1}{2\pi m_a RC} = \frac{1}{2\pi \times 0.6 \times 2.5 \times 10^{-5}} Hz$$

$$= \frac{100 \times 10^4}{25 \times 1.2\pi} Hz = 10.61\text{ KHz}$$

This condition is obtained by applying the condition that rate of decay of capacitor voltage must be equal or less than the rate of decay modulated singnal voltage for proper detection of mdoulated signal.

94. (b) From question,

$B_0 = 20$ nT $= 20 \times 10^{-9}$T

($\because$ velocity of light in vacuum C = 3×10^8 ms^{-1})

$$\vec{E}_0 = \vec{B}_0 \times \vec{C}$$

$$|\vec{E}_0| = |\vec{B}|.|\vec{C}| = 20 \times 10^{-9} \times 3 \times 10^8$$

= 6 V/m.

95. (d) As λ is increased, there will be a value of λ above which photoelectrons will be cease to come out so photocurrent will become zero. Hence (d) is correct answer.

96. (a) For same value of current higher value of voltage is required for higher frequency hence (1) is correct answer.

97. (d) $$\frac{\nu}{x} = \frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$[\because n >> 1]$

$$\nu = RCZ^2\left[\frac{1}{(n-1)^2}-\frac{1}{n^2}\right]$$

$$RCZ^2\left[\frac{2n-1}{n^2(n-1)^2}\right]$$

98. (a) The current voltage relation of diode is

$$I=(e^{1000\,V/T}-1)\ \text{mA (given)}$$

When, $I=5mA,\ e^{1000\,V/T}=6mA$

Also, $dI=(e^{1000\,V/T})\times\frac{1000}{T}$

(By exponential function)

$$=(6\,mA)\times\frac{1000}{300}\times(0.01)$$

$=0.2$ mA

99. (c) $E_0=CB_0$ and $C=\frac{1}{\sqrt{\mu_0\varepsilon_0}}$

Electric energy density $=\frac{1}{2}\varepsilon_0 E_0{}^2=\mu_E$

Magnetic energy density $=\frac{1}{2}\frac{Bo^2}{\mu_0}=\mu_B$

Thus, $\mu_E=\mu_B$

Energy is equally divided between electric and magnetic field

100. (b) Radius of circular path followed by electron is given by,

$$r=\frac{m\upsilon}{qB}=\frac{\sqrt{2meV}}{eB}=\frac{1}{B}\sqrt{\frac{2m}{e}V}$$

$$\Rightarrow\quad V=\frac{B^2r^2e}{2m}=0.8V$$

For transition between 3 to 2.

$$E=13.6\left(\frac{1}{4}-\frac{1}{9}\right)=\frac{13.6\times5}{36}=1.88eV$$

Work function $=1.88\text{ eV}-0.8\text{ eV}$

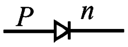
$=1.08\text{ eV}\approx1.1\text{eV}$

101. (c) Wave number $\frac{1}{\lambda}=RZ^2\left[\frac{1}{n_1^2}-\frac{1}{n^2}\right]$

$$\Rightarrow\quad \lambda\propto\frac{1}{Z^2}$$

By question $n=1$ and $n_1=2$

Then, $\lambda_1=\lambda_2=4\lambda_3=9\lambda_4$

102. (a) 

For forward bias, p-side must be at higher potential than *n*-side. $\Delta V=(+)Ve$

103. (d)

(1) Infrared rays are used to treat muscular strain because these are heat rays.

(2) Radio waves are used for broadcasting because these waves have very long wavelength ranging from few centimeters to few hundred kilometers

(3) X-rays are used to detect fracture of bones because they have high penetrating power but they can't penetrate through denser medium like bones.

(4) Ultraviolet rays are absorbed by ozone of the atmosphere.

104. (d) Using $U_{av}=\frac{1}{2}\varepsilon_0E^2$

But $U_{av}=\frac{P}{4\pi r^2\times c}$

$$\therefore\quad \frac{P}{4\pi r^2}=\frac{1}{2}\varepsilon_0E^2\times c$$

$$E_0^2=\frac{2P}{4\pi r^2\varepsilon_0 c}=\frac{2\times0.1\times9\times10^9}{1\times3\times10^8}$$

$\therefore\quad E_0=\sqrt{6}=2.45$V/m

105. (a) Amplitude modulated wave consists of three frequencies are $\omega_c+\omega_m,\ \omega,\omega_c-\omega_m$

i.e. 2005 KHz, 2000KHz, 1995 KHz

106. (c) $U=-K\frac{ze^2}{r}$; $T.E=-\frac{k}{2}\frac{ze^2}{r}$

$K.E=\frac{k}{2}\frac{ze^2}{r}$. Here r decreases

107. (a) Frank-Hertz experiment - Discrete energy levels of atom

Photoelectric effect - Particle nature of light

Davison - Germer experiment - wave nature of electron.

108. (b,d) We know that $\alpha=\frac{I_c}{I_e}$ and $\beta=\frac{I_c}{I_b}$

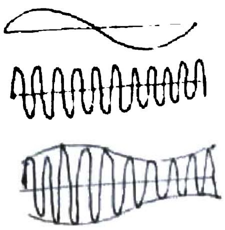
Also $I_e=I_b+I_c$

$$\therefore\ \alpha=\frac{Ic}{I_b+I_c}=\frac{\frac{I_c}{I_b}}{1+\frac{I_c}{I_b}}=\frac{\beta}{1+\beta}$$

Option (b) and (d) are therefore correct.

109. (a) In case of an 'OR' gate the input is zero when all inputs are zero. If any one input is ' 1', then the output is '1'.

110. (c) In amplitude modulation, the amplitude of the high frequency carrier wave made to vary in proportional to the amplitude of audio signal.



Audio signal

Carrier wave

Amplitude modulated wave

111. (c) $h\nu_0{}^2 - h\nu_0 = \frac{1}{2}mv^2$

$\therefore \quad \frac{4}{3}h\nu_0 - h\nu_0 = \frac{1}{2}mv'^2$

$\therefore \frac{v'^2}{v^2} = \frac{\frac{4}{3}\nu - \nu_0}{\nu - \nu_0} \qquad \therefore v' = v\sqrt{\frac{\frac{4}{3}\nu - \nu_0}{\nu - \nu_0}}$

$\therefore v' > v\sqrt{\frac{4}{3}}$

112. (b) For $A_{t½} = 20$ min, $t = 80$ min, number of half lifes $n = 4$

$\therefore$ Nuclei remaining $= \frac{N_o}{2^4}$. Therefore nuclei decayed

$= N_0 - \frac{N_o}{2^4}$

For $B_{t½} = 40$ min., $t = 80$ min, number of half lifes $n = 2$

$\therefore$ Nuclei remaining $= \frac{N_o}{2^2}$. Therefore nuclei decayed

$= N_0 - \frac{N_o}{2^2}$

$\therefore$ Required ratio $= \frac{No - \frac{No}{2^4}}{No - \frac{No}{2^2}} = \frac{1 - \frac{1}{16}}{1 - \frac{1}{4}} = \frac{15}{16} \times \frac{4}{3} = \frac{5}{4}$

113. (c) Graph (a) is for a simple diode.
Graph (b) is showing the V Break down used for zener diode.
Graph (c) is for solar cell which shows cut-off voltage and open circuit current.
Graph (d) shows the variation of resistance h and hence current with intensity of light.