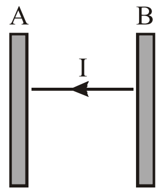
GUIDED REVISION

SECTION-I

Single Correct Answer Type **20 Q. [3 M (–1)]**

1. A parallel beam of light of intensity I is incident normally on a plane surface A which absorbs 50% of the incident light. The reflected light falls on B which is perfect reflector, the light reflected by B is again partly reflected and partly absorbed and this process continues. For all absorption by A, asborption coefficient is 0.5. The pressure experienced by A due to light is :-



(A) $\frac{1.5\,I}{c}$ (B) $\frac{I}{c}$ (C) $\frac{3I}{2c}$ (D) $\frac{3I}{c}$

2. 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 **[JEE 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) $\lambda_0 = \lambda$

3. A stationary hydrogen atom of mass M emits a photon corresponding to the longest wavelength of Balmer series. The recoil velocity acquired by the atom is (R = Rydberg constant and h = plank's constant)

(A) $\frac{Rh}{M}$ (B) $\frac{Rh}{4M}$ (C) $\frac{3}{4}\frac{Rh}{M}$ (D) $\frac{5}{36}\frac{Rh}{M}$

4. In an X-ray experiment target is made up of copper (Z = 29) having some impurity. The K_α line of copper have wavelength λ_0. It was observed that another K_α line due to impurity have wavelength $\frac{784}{625}\lambda_0$. The atomic number of the impurity element is

(A) 22 (B) 23 (C) 24 (D) 26

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

(A) $\frac{1}{n}$ (B) $\frac{1}{n^2}$ (C) $\frac{1}{n^{3/2}}$ (D) $\frac{1}{n^3}$

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

7. A parallel beam of photons of intensity I strike a plane surface at angle 45° to the surface. If plane surface have reflection coefficient 0.5 then pressure exerted by the beam on the surface (C is speed of light) is :

(A) $\frac{3I}{4C}$ (B) $\frac{3I}{2C}$ (C) $\frac{I}{2\sqrt{2}C}$ (D) $\frac{3I}{2\sqrt{2}C}$

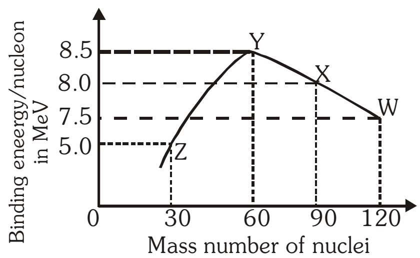
8. A photoelectric material having work-function ϕ_0 is illuminated with light of wavelength λ $\left(\lambda < \frac{hc}{\phi_0}\right)$.

The fastest photoelectron has a de-Broglie wavelength λ_d. A change in wavelength of the incident light by $\Delta\lambda$ results in a change $\Delta\lambda_d$ in λ_d. Then the ratio $\Delta\lambda_d/\Delta\lambda$ is proportional to

[JEE Advanced-2017]

(A) λ_d^3/λ^2 (B) λ_d^3/λ (C) λ_d^2/λ^2 (D) λ_d/λ

9. Binding energy per nucleon versus mass number curve for nuclei is shown in figure. W, X, Y and Z are four nuclei indicated on the curve. The process that would release energy is :



(A) Y → 2Z (B) W → X + Z (C) W → 2Y (D) X → Y + Z

10. Half life of radium is 1620 years. How many radium nuclei decay in 5 hours in 5 gm radium? (Atomic weight of radium = 223)

(A) 9.1×10^{12} (B) 3.23×10^{15} (C) 1.72×10^{20} (D) 3.3×10^{17}

11. In Bohr model of hydrogen, the force on electron depends on the principal quantum number as :

(A) $F \propto \frac{1}{n^2}$ (B) $F \propto \frac{1}{n^4}$ (C) $F \propto \frac{1}{n^5}$ (D) $F \propto \frac{1}{n}$

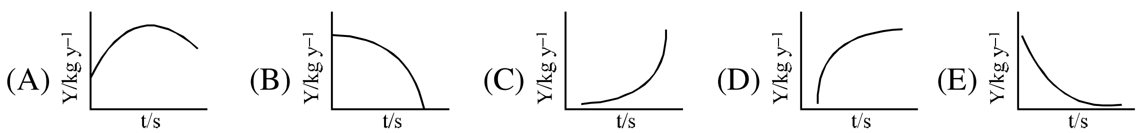
12. The rest mass of the deuteron, ${}_1^2H$, is equivalent to an energy of 1876 MeV, the rest mass of a proton is equivalent to 939 MeV and that of a neutron to 940 MeV. A deuteron may disintegrate to a proton and a neutron if it :

(A) emits a γ - ray photon of energy 2 MeV (B) captures a γ - ray photon of energy 2 MeV
(C) emits a γ - ray photon of energy 3 MeV (D) captures a γ - ray photon of energy 3 MeV

13. The half-life of substance X is 45 years, and it decomposes to substance Y. A sample from a meteorite was taken which contained 2% of X and 14% of Y by quantity of substance. If substance Y is not normally found on a meteorite, what is the approximate age of the meteorite?

(A) 270 years (B) 135 years (C) 90 years (D) 45 years

14. The radioactive nucleus of an element X decays to a stable nucleus of element Y. A graph of the rate of formation of Y against time would look like



15. The half life of a neutron is 800 sec. 10^8 neutrons at a certain instant are projected from one space station towards another space station, situated 3200 km away, with a velocity 2000 m/s. Their velocity remains constant during the journey. How many neutrons reach the other station?

(A) 50×10^6 (B) 25×10^6 (C) 80×10^5 (D) 25×10^5

16. A radioactive source in the form of a metal sphere of diameter 3.2×10^{-3} m emits β-particle at a constant rate of 6.25×10^{10} particle/sec. The source is electrically insulated and all the β-particle are emitted from the surface. The potential of the sphere will rise to 1 V in time

(A) 180 μ sec (B) 90 μ sec (C) 18 μ sec (D) 9 μ sec

17. 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]- **[AIEEE - 2003]**

(A) 10^7 K (B) 10^5 K (C) 10^3 K (D) 10^9 K

18. **Statement-1:** A nucleus having energy E_1 decays by β^- emission to daughter nucleus having energy E_2, but the β^- rays are emitted with a continuous energy spectrum having end point energy $E_1 - E_2$.

Statement-1: To conserve energy and momentum in β-decay at least three particles must take part in the transformation. **[AIEEE - 2011]**

(A) Statement-1 is incorrect, statement-2 is correct

(B) Statement-1 is correct, statement-2 is incorrect

(C) Statement-1 is correct, statement-2 correct; statement-2 is the correct explanation of statement-1

(D) Statement-1 is correct, statement-2 is correct; statement -2 is not the correct explanation of statement-1.

19. An electron from various excited states of hydrogen atom emit radiation to come to the ground state. Let λ_n, λ_g be the de Broglie wavelength of the electron in the n^{th} state and the ground state respectively. Let Λ_n be the wavelength of the emitted photon in the transition from the n^{th} state to the ground state. For large n, (A, B are constants) **[JEE-Main-2018]**

(A) $\Lambda_n \approx A + B\lambda_n$ (B) $\Lambda_n^2 \approx A + B\lambda_n^2$ (C) $\Lambda_n^2 \approx \lambda$ (D) $\Lambda_n \approx A + \dfrac{B}{\lambda_n^2}$

20. The electrostatic energy of Z protons uniformly distributed throughout a spherical nucleus of radius R is given by $E = \dfrac{3}{5}\dfrac{Z(Z-1)e^2}{4\pi\varepsilon_0 R}$ **[JEE Advance-2016]**

The measured masses of the neutron, ${}_1^1H$, ${}_7^{15}N$ and ${}_8^{15}O$ are 1.008665 u, 1.007825 u, 15.000109 u and 15.003065 u respectively. Given that the radii of both the ${}_7^{15}N$ and ${}_8^{15}O$ nuclei are same, $1u = 931.5$ MeV/c^2 (c is the speed of light) and $\dfrac{e^2}{(4\pi\varepsilon_0)}$ = 1.44 MeV fm. Assuming that the difference between the binding energies of ${}_7^{15}N$ and ${}_8^{15}O$ is purely due to the electrostatic energy, the radius of either of the nuclei is ($1\text{fm} = 10^{-15}$m)

(A) 2.85 fm (B) 3.03 fm (C) 3.42 fm (D) 3.80 fm

Multiple Correct Answer Type 4 Q. [4 M (–1)]

21. Mark out the **CORRECT** statement(s).

(A) Higher binding energy per nucleon means the nucleus is more stable.

(B) If the binding energy of nucleus were zero, then it would spontaneously break apart.

(C) Binding energy of a nucleus can be –ve.

(D) Binding energy of a nucleus is always +ve.

22. The collector of the photocell (in photoelectric experiment) is made of tungsten while the emitter is of Platinum having work function of 10 eV. Monochromatic radiation of wavelength 124 Å & power 100watt is incident on emitter which emits photo electrons with a quantum efficiency of 1%. The accelerating voltage across the photocell is of 10,000 volts (Use : hc = 12400eV Å)

(A) The power supplied by the accelerating voltage source is 100 watt

(B) The minimum wavelength of radiation coming from the tungsten target (collector) is 1.23 Å

(C) The power supplied by the accelerating voltage source is 10 watt

(D) The minimum wavelength of radiation coming from the tungsten target (collector) is 2.23 Å

23. Energy liberated in the de-excitation of hydrogen atom from 3rd level to 1st level falls on a photo-cathode. Later when the same photocathode is exposed to a spectrum of some unknown hydrogen like gas, excited to 2nd energy level, it is found that the de-Broglie wavelength of the fastest photoelectrons, now ejected has decreased by a factor of 3. For this new gas, difference of energies of 2nd Lyman line and 1st Balmer line is found to be 3 times the ionization potential of the hydrogen atom. Select the correct statement(s) :

(A) The gas is lithium

(B) The gas is helium

(C) The work function of photocathode is 8.5 eV

(D) The work function of photocathode is 5.5 eV

24. 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 Advanced-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 oribitals 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

Linked Comprehension Type (3 Para × 3Q. & 3 Para × 2 Q.) [3 M (-1)]
(Single Correct Answer Type)

Paragraph for Question 25 to 27

A mercury arc lamp provides 0.1 watt of ultra-violet radiation at a wavelength of λ = 2537 Å only. The photo tube (cathode of photo electric device) consists of potassium and has an effective area of 4 cm^2. The cathode is located at a distance of 1m from the radiation source. The work function for potassium is ϕ_0 = 2.22 eV.

25. According to classical theory, the radiation from arc lamp spreads out uniformly in space as spherical wave. What time of exposure to the radiation should be required for a potassium atom (radius 2Å) in the cathode to accumulate sufficient energy to eject a photo-electron ?

(A) 352 second (B) 176 second (C) 704 seconds (D) No time lag

26. To what saturation current does the flux of photons at the cathode corresponds if the photo conversion efficiency is 5%.

(A) 32.5 nA (B) 10.15 nA (C) 65 nA (D) 3.25 nA

27. What is the cut off potential V_0 ?

(A) 26.9 V (B) 2.69 V (C) 1.35 V (D) 5.33 V

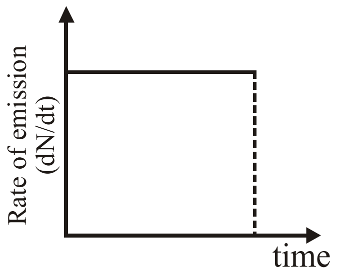
Paragraph for Questions no. 28 to 30

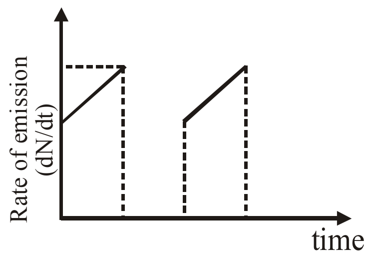
A light of wavelength λ is incident on a metal sheet of work function $\phi = 2$ eV. The wavelength λ varies with time as $\lambda = 3000 + 40t$, where λ is in Å and t is in second. The power incident on metal sheet is constant at 100 W. This signal is switched on and off for time intervals of 2 minutes and 1 minute respectively. Each time the signal is switched on, the λ start from initial value of 3000 Å. The metal plate is grounded and electron clouding is negligible. The efficiency of photoemission is 1%
(hc = 12400 eVÅ, 1eV = 1.6×10^{-19} J)

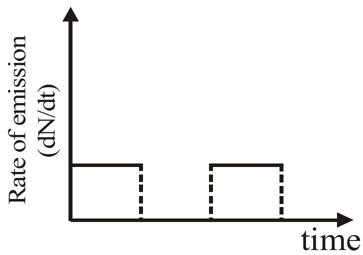
28. The time after which photoemission will stop is :-
(A) 120 s (B) 80 s (C) 60 s (D) 180 s

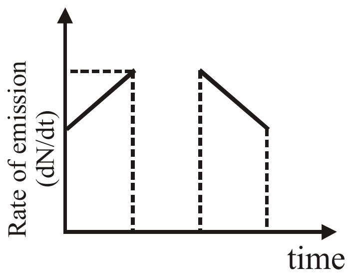
29. The total number of photoelectrons ejected in one hour is :-
(A) 3.71×10^{17} (B) 3.71×10^{21} (C) 3.71×10^{25} (D) 3.71×10^{7}

30. The variation of rate of emission vs time is :-

(A) 

(B) 

(C) 

(D) 

Paragraph for Question Nos. 31 to 33

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. **[JEE 2010]**

31. A diatomic molecule has moment of inertia I. By Bohr's quantization condition its rotational energy in the n^{th} 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) $n^2\left(\frac{h^2}{8\pi^2 I}\right)$

32. 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 $h = 2\pi \times 10^{-34}$ Js)
(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

33. 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

Paragraph for Questions 34 and 35

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. **[AIEEE-2010]**

34. The speed of daughter nuclei is :-

(A) $c\sqrt{\frac{\Delta m}{M+\Delta m}}$ (B) $c\frac{\Delta m}{M+\Delta m}$ (C) $c\sqrt{\frac{2\Delta m}{M}}$ (D) $c\sqrt{\frac{\Delta m}{M}}$

35. The binding energy per nucleon for the parent nucleus is E_1 an that for the daughter nuclei is E_2. Then:- **[AIEEE - 2010]**

(A) $E_1 = 2E_2$ (B) $E_2 = 2E_1$ (C) $E_1 > E_2$ (D) $E_2 > E_1$

Paragraph for Questions 36 and 37

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 a continuous spectrum. Considering a three-body decay process, i.e. $n \rightarrow p + e^- + \vec{v}_e$, around 1930, Pauli explained the observed electron energy spectrum. Assuming the anti-neutrino $\left(\vec{v}_e\right)$ 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.

36. 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? **[JEE 2012]**

(A) $0 \le K \le 0.8 \times 10^6 eV$ (B) $3.0eV \le K \le 0.8 \times 10^6 eV$

(C) $3.0eV \le K < 0.8 \times 10^6 eV$ (D) $0 \le K < 0.8 \times 10^6 eV$

37. What is the maximum energy of the anti-neutrino? **[JEE 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

Paragraph for Questions 38 and 39

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 :- **[JEE Advance-2013]**

${}^{1}_{1}H$	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)

38. 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

39. The correct statement is :-

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

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

(C) Deuteron and alpha particle can undergo complete fusion

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

Matching List Type (4 × 4) 1 Q. [3 M (–1)]

40. 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 Advance-2013]

	List I		List II
P.	Alpha decay	1.	${}_{8}^{15}O \to {}_{7}^{15}N + ...$
Q.	β^+ decay	2.	${}_{92}^{238}U \to {}_{90}^{234}Th + ...$
R.	Fission	3.	${}_{83}^{185}Bi \to {}_{82}^{184}Pb + ...$
S.	Proton emission	4.	${}_{94}^{239}Pu \to {}_{57}^{140}La + ...$

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

SECTION-II

Numerical Answer Type Question 1 Q. [3(0)]
(upto second decimal place)

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

SECTION-III

Numerical Grid Type (Ranging from 0 to 9) 9 Q. [4 M (0)]

1. Photons having energy equivalent to III line of lyman series of H atom can eject electrons from a metal. These electrons can excite H atoms upto n = 2 level. If the maximum work function of the metal in eV, is ϕ, find the integer next to ϕ.

2. A potential difference of V volts is applied on two parallel electrodes separated by a distance of 4.0×10^{-2} m . The electrons of very low energy are injected into the region between the electrodes which contains argon at low pressure . The average distance the electrons travel between collisions with argon atoms is 8×10^{-5} m . The ionization energy of argon atom is 16 eV . Estimate the minimum value of V(in kV) such that the electrons will cause ionization in argon atoms by collision .

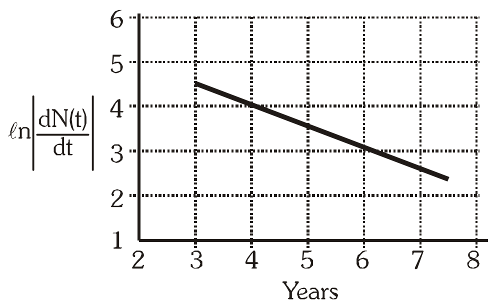
3. When 0.50 Å X-rays strike a material, the photoelectrons from the K shell are observed to move in a circle of radius 23 mm in a magnetic field of 2×10^{-2} T. The binding energy of K-shell electrons is $a^2 \times 100$ eV then write the value of a in your OMR sheet ?
(Take : mass of electron = 9.2×10^{-31} kg & hc = 12400 eV–Å)

4. Consider a universe in which the π-meson orbits around the nucleus instead of electron. Assuming a Bohr model for a π-meson of mass m_π and of the same charge as the electron is in a circular orbit of radius r about the nucleus with an orbital angular momentum $\frac{h}{2\pi}$. If the radius of a nucleus of atomic number Z is given by $R = 1.6 \times 10^{-15} Z^{1/3}$ m. The total number of elements in this universe that can exist bis given as 'N'. Fill $\left[\frac{N-1}{12}\right]$ in OMR sheet. [Given $\frac{\varepsilon_0 h^2}{\pi m_e e^2} = 0.53\mathring{A}$; $\frac{m_\pi}{m_e} = 265$; neglect any shielding effect for the havier atoms and assume non relativistic physics to be applicable and take $5^{1/4} \approx 1.5$]

5. A silver sphere of radius 1 cm and work function 4.7 eV is suspended from an insulating thread in free-space. 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 **[JEE 2011]**

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

7. To determine the half life of a radioactive element, a student plots a graph of $\ell n\left|\frac{dN(t)}{dt}\right|$ versus t. Here $\frac{dN(t)}{dt}$ 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 **[JEE-2010]**



8. Geiger counter reading of a radioactive sample is initially 6800 counts per min. The same sample gives a reading of 425 counts per min 10 hrs later. The sample's half life of α hr. Fill 2α in OMR sheet.

9. 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 ($^{12}_{6}C^*$) at 4.041 MeV above its ground state. If $^{12}_{5}B$ decays to $^{12}_{6}C^*$, the maximum kinetic energy of the β-particle in units of MeV is (1u = 931.5 MeV/c^2, where c is the speed of light in vacuum). **[JEE Advance-2016]**

Subjective Type **14 Q. [4 M (0)]**

1. A beam of light has three wavelengths 4144Å, 4972Å & 6216 Å with a total intensity of 3.6×10^{-3} W.m^{-2} equally distributed amongst the three wavelengths. The beam falls normally on an area 1.0 cm^2 of a clean metallic surface of work function 2.3 eV. Assume that there is no loss of light by reflection and that each energetically capable photon ejects one electron. Calculate the number of photoelectrons liberated in two seconds.

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

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

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

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

(d) Evaluate the time t.

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

4. A gas of identical hydrogen like atoms has some atoms in the lowest (ground) energy level A & some atoms in a particular upper (excited) energy level B & there are no atoms in any other energy level. The atoms of the gas make transition to a higher energy level by the absorbing monochromatic light of photon energy 2.55eV. Subsequently, the atoms emit radiation of only six different photon energies. Some of the emitted photons have energy 2.55 eV. Some have energy more and some have less than 2.55 eV.

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

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

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

5. A neutron of kinetic energy 65 eV collides inelastically with a singly ionized helium atom at rest . It is scattered at an angle of 90° with respect of its original direction. (Given : Mass of he atom = 4×(mass of neutron), ionization energy of H atom =13.6 eV)

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

(ii) If the atom gets de-excited subsequently by emitting radiation, find the frequencies of the emitted radiation.

6. A beam of ultraviolet light of wavelength 100 nm – 200 nm is passed through a box filled with hydrogen gas in ground state. The light coming out of the box is split into two beams 'A' and 'B'. A contains unabsorbed light from the incident light and B contains the emitted light by hydrogen atoms. The beam A is incident on the emitter in a photoelectric tube. The stopping potential in this case is 5 volts. Find the work function of the emitter. In the second case the beam B is incident on the same emitter. Find the stopping potential in this case. You can assume that the transition to higher energy states are not permitted from the excited states. Use hc = 12400 eVÅ.

7. In an X-ray tube the accelerating voltage is 20 KV. Two targets A and B are used one by one. For 'A' the wavelength of the K_α line is 62 pm. For 'B' the wavelength of the L_α line is 124 pm. The energy of the 'B' ion with vacancy in 'L' shell is 15.5 KeV higher than the atom of B. [Take hc = 12400 eVÅ]

(i) Find λ_{min} in Å.

(ii) Can K_α – photon be emitted by 'A'? Explain with reason.

(iii) Can L – photons be emitted by 'B'? What is the minimum wavelength (in Å) of the characteristic X-ray that will be emitted by 'B'.

8. Suppose that the Sun consists entirely of hydrogen atom and releases the energy by the nuclear reaction, $4\,{}_1^1H \longrightarrow {}_2^4He$ with 26 MeV of energy released. If the total output power of the Sun is assumed to remain constant at 3.9×10^{26} W, find the time it will take to burn all the hydrogen. Take the mass of the Sun as 1.7×10^{30} kg.

9. U^{238} and U^{235} occur in nature in an atomic ratio 140 : 1. Assuming that at the time of earth's formation the two isotopes were present in equal amounts. Calculate the age of the earth.

(Half life of $u^{238} = 4.5 \times 10^9$ yrs & that of $U^{235} = 7.13 \times 10^8$ yrs)

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

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

12. The element Curium ${}_{96}^{248}Cm$ has a mean life of 10^{13} seconds. Its primary decay modes are spontaneous fission and α decay, the former with a probability of 8% and the latter with a probability of 92%. Each fission releases 200 MeV of energy. The masses involved in α decay are as follows :

${}_{96}^{248}Cm = 248.072220u, {}_{94}^{244}Pu = 244.064100u \,\&\, {}_2^4He = 4.002603u.$

Calculate the power output from a sample of 10^{20} Cm atoms. (1 u = 931 MeV/c^2)

13. A π^+ meson of negligible initial velocity decays to a μ^+ (muon) and a neutrino. With what kinetic energy (in eV) does the muon move? (The rest mass of neutrino can be considered zero. The rest mass of the π^+ meson is 150 MeV and the rest mass of the muon is 100 MeV.) Take neutrino to behave like a photon. Take $\sqrt{2} = 1.41$.

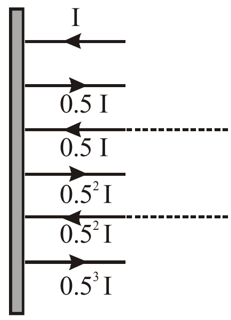
14. A radioactive sample emits n β-particles in 2 sec. In next 2 sec it emits 0.75 n β-particles, what is the mean life of the sample? **[JEE 2003]**

SOLUTIONS
SECTION-I

Single Correct Answer Type **20 Q. [3 M (–1)]**

1. Ans. (D)

Sol. The force experienced by A is due to infinite number of incidence and reflection. The situation is shown in the diagram.



$$F = \frac{I}{c} + \frac{0.5\,I}{c} \times 2 + \frac{0.5^2\,I}{c} \times 2 + \frac{0.5^2\,I}{c} \times 2 + ...$$

$$= \frac{I}{c} + \frac{2I}{c}\left[\frac{1}{2} + \frac{1}{2^2} + \frac{1}{2^3} + ...\right]$$

$$= \frac{I}{c} + \frac{2I}{c} \times \left[\frac{1/2}{1-1/2}\right] = \frac{3I}{c}$$

2. Ans. (A)

Sol. $p = \frac{h}{\lambda}$

$$K.E. = \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$$

If entire K.E. of electron is converted into photon then

$$\frac{h^2}{2m\lambda^2} = \frac{hc}{\lambda_0}$$

$$\lambda_0 = \frac{2mc\lambda^2}{h}$$

3. Ans. (D)

Sol. Transition from n = 3 to 2 (first line OF Balmer Series corresponds to longest wavelength), photon emitted with momentum

$$P_{photon} = \frac{h}{\lambda} = Rh\left(\frac{1}{3^2} - \frac{1}{2^2}\right) = \frac{5Rh}{36}$$

Apply Momentum Conservation

$$P_{photon} = P_{atom}$$

$$\frac{5Rh}{36} = MV$$

$$V = \frac{5Rh}{36M}$$

4. Ans. (D)

Sol. From Moseley's law, $\sqrt{\nu} = a\,(Z - b)$

$$\frac{1}{\lambda} \propto k\,(Z - b)^2 \qquad \{k \text{ is a constant}\}$$

For K_α : b = 1

$$\frac{\frac{1}{\lambda_{K_{\alpha\,copper}}}}{\frac{1}{\lambda_{K_{\alpha\,impurity}}}}=\left(\frac{Z_{Cu}-b}{Z_{imp}-b}\right)^2 \Rightarrow \frac{\lambda_{K_{\alpha\,impurity}}}{\lambda_{K_{\alpha\,copper}}}=\left(\frac{Z_{Cu}-b}{Z_{imp}-b}\right)^2 \qquad \text{so } Z_{imp}=26$$

5. Ans. (D)

Sol. Energy of $E = h\theta = E_0 z^2\left[\frac{1}{(n-1)^2}-\frac{1}{n^2}\right]$

$$= E_0 z^2\left[\frac{2n-1}{n^2(n-1)^2}\right]$$

$$h\theta \approx E_0 z^2\left[\frac{2n}{n^4}\right] \Rightarrow v \propto \frac{1}{n^3}$$

6. Ans. (B)

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

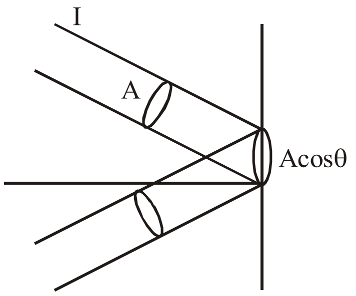
Cut off wavelength depends on the energy of the accelerated electrons and is independent of nature of target.

$$\lambda_{K\alpha} \propto \frac{1}{(z-b)^2}$$

characteristic wavelength depend on atomic no and cut off wavelength depend on energy of e^-.

7. Ans. (A)

Sol.



$$\left(\frac{dp}{dt}\right)_{incident}=\frac{I}{C}A\cos^2\theta$$

$$\left(\frac{dp}{dt}\right)_{reflected}=\frac{-I}{C}A\,0.5\cos^2\theta$$

$$F=\frac{3}{2}\frac{I}{C}A\cos^2\theta$$

$$\frac{F}{A}=P=\frac{3I}{2C}\cos^2\theta=\frac{3I}{4C}$$

8. Ans. (A)

Sol. According to photo electric effect equation :

$$KE_{max} = \frac{hc}{\lambda} - \phi_0$$

$$\frac{p^2}{2m} = \frac{hc}{\lambda} - \phi_0$$

$$\frac{(h/\lambda_d)^2}{2m} = \frac{hc}{\lambda} - \phi_0$$

Assuming small changes, differentiating both sides,

$$\frac{h^2}{2m}\left(-\frac{2d\lambda_d}{\lambda_d^3}\right) = -\frac{hc}{\lambda^2}d\lambda$$

$$\frac{d\lambda_d}{d\lambda} \propto \frac{\lambda_d^3}{\lambda^2}$$

9. **Ans. (C)**

Sol. $Y \rightarrow 2Z$

Reactant R = 60 × 8.5 = 10 meV

Product P = 2 × 30 × 5 = 300 meV

$\Delta E = -210$ meV

Therefore Endothermic

If it was C

$W \rightarrow 2Y$

R = 120 × 75 = 900 meV

P = 2 × 60 × 8.5 = 1020 meV

$\Delta E = 120$ meV

Therefore Exothermic

If it was D

$X \rightarrow Y + Z$

R = 90 × 8 = 720 meV

P = 60 × 8.5 + 30 × 5 = 66.0 meV

$\Delta E = -60$ meV

Therefore Endothermic

10. **Ans. (B)**

Sol. $\frac{\ell n 2}{1620} \times t = \ell n\left(\frac{5gm}{W_2}\right)$

$$W_2 = 5e^{\frac{-\ell n 2 \times 5}{1620 \times 365 \times 24}}$$

$$N_2 = -\frac{5}{223} \times 6.022 \times 10^{23} \times 2^{\frac{5}{1620 \times 365 \times 24}} + \frac{5}{223} \times N_A$$

$$N_2 = \frac{5}{223} \times 6.022 \times 10^{23}\left(1 - \frac{0.1}{2^{5/1620 \times 365 \times 24}}\right)$$

11. **Ans. (B)**

Sol. $F \propto \frac{1}{r^2}$ [Electrostatic force]

$r \propto n^2$

$F \propto \frac{1}{n^4}$

12. Ans. (D)

Sol. ${}_1^2H \rightarrow n + p$

$E_{adsorbed} = 939 + 940 - 1876$

$= 3$ MeV

13. Ans. (B)

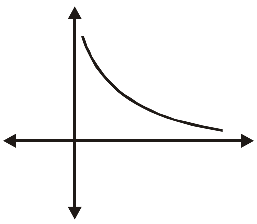
Sol. $t = \frac{\ell n2}{45} = \ell n\left(\frac{8}{1}\right)$

T = 135 years

14. Ans. (E)

Sol. $X \rightarrow Y$

$\frac{dN}{dt} = \lambda N_0 e^{-\lambda t}$



15. Ans. (B)

Sol. $\text{time} = \frac{3200 \times 10^3}{2000} = 1600\,\text{sec}$

$N = 10^8 e^{-\frac{\ell n2}{800}1600}$

$N = \frac{10^8}{4} = 25 \times 10^6$ neutrons

16. Ans. (C)

Sol. Potential $= \frac{KQ}{R}$

$1 = \frac{9 \times 10^9}{1.6 \times 10^{-3}}\left(6.25 \times 10^{10}\right) \times 1.6 \times 10^{-19} t$

$t = \frac{(1000)^{-1}}{9 \times 6.25}$

t = 18 μ second

17. Ans. (D)

Sol. By energy conservation

$7.7 \times 10^{-14} = \frac{3}{2} \times 1.38 \times 10^{-23} \times T \times 2$

$T = 10^9$ K

18. Ans. (C)

Sol. Statement-1 : Energy of β^- particle from 0 to maximum so $E_1 - E_2$ is the continuous energy spectrum.

Statement-2 : For energy conservation and momentum at least three particle daughter nucleus $+\beta^{-1}$ and antineutron.

19. Ans. (D)

Sol. $\lambda_n = \frac{h}{mu} = \frac{h}{\sqrt{2mk_n}}$

$\Rightarrow k_n = \frac{h^2}{2m\lambda_n^2}$; $k_g = \frac{h^2}{2m\lambda_g^2}$

$\Rightarrow k_g - k_n = \frac{h^2}{2m}\left[\frac{1}{\lambda_g^2} - \frac{1}{\lambda_n^2}\right]$

$E_n = -k_n$

for emitted photon

$$\frac{hc}{\Lambda_n} = E_n - E_g = K_g - K_n$$

$$\frac{1}{\Lambda_n} = \frac{K_g - K_n}{hc}$$

$$\Lambda_n = \frac{hc}{K_g - K_n} \Rightarrow \Lambda_n = \frac{hc}{\frac{h^2}{2m}\left[\frac{1}{\lambda_g^2} - \frac{1}{\lambda_n^2}\right]}$$

$$\Lambda_n = \frac{2mc}{h\left(\frac{\lambda_n^2 - \lambda_g^2}{\lambda_g^2\lambda_n^2}\right)}$$

$$\Lambda_n = \frac{2mc\lambda_g^2\lambda_n^2}{h\left(\lambda_n^2 - \lambda_g^2\right)}$$

as $\lambda_n \propto n$

$\lambda_n >> \lambda_g$

$$\Lambda_n = \frac{2mc\lambda_g^2}{h}\left[1 - \left(\frac{\lambda_g}{\lambda_n}\right)^2\right]^{-1}$$

$$\Lambda_n = \frac{2mc\lambda_g^2}{h}\left[1 + \left(\frac{\lambda_g}{\lambda_n}\right)^2 + \text{higher powers of } \frac{\lambda_g}{\lambda_n}\right]$$

$$\Lambda_n \approx A + \frac{B}{\lambda_n^2}$$

where $A = \frac{2mc\lambda_g^2}{h}$

& $B = \frac{2mc\lambda_g^4}{h}$

20. Ans. (C)

Sol. Electrostatic energy = $BE_N - BE_O$

$= [[7M_H + 8M_n - M_N] - [8M_H + 7M_n - M_O]] \times C^2$

$= [-M_H + M_n + M_O - M_N]C^2$

$= [-1.007825 + 1.008665 + 15.003065 - 15.000109] \times 931.5$

$= + 3.5359$ MeV

$$\Delta E = \frac{3}{5} \times \frac{1.44 \times 8 \times 7}{R} - \frac{3}{5} \times \frac{1.44 \times 7 \times 6}{R} = 3.5359$$

$$R = \frac{3 \times 1.44 \times 14}{5 \times 3.5359} = 3.42\text{fm}$$

Multiple Correct Answer Type 4 Q. [4 M (–1)]

21. Ans. (A,B,D)

Sol. Higher binding energy per nucleon means the nucleus is more stable and binding energy is the energy released by nucleus and is always positive

22. Ans. (A,B)

Sol. $P = V\, i_s$ where V = accelerating voltage ; i_s = saturation photocurrent

$$i_s = \frac{\text{Power of source of light } \times \text{ Quantum efficiency } \times \lambda(\text{in Å})}{12400} = \frac{100 \times .01 \times 124}{12400} = 0.1 \text{ A}$$

$\therefore$ Power = 100 watt

Maximum energy of incoming electron = $\frac{hc}{\lambda} - \phi + eV = \left(\frac{12400}{124} - 10 + 10{,}000\right)$ eV = 10,090 eV

$$\lambda_{min} = \frac{12400}{10090} = 1.23 \text{ Å}$$

Power provided by accelerating potential = 100 W

23. Ans. (B, C)

Sol. $E_0 z^2\left(1 - \frac{1}{9}\right) - E_0 z^2\left(\frac{1}{4} - \frac{1}{9}\right) = 3E_0$

$z = 2$

$\lambda_1/\lambda_2 = 3$

$$KE_1 = E_0\left(1 - \frac{1}{9}\right) - \phi$$

$$KE_2 = E_0 z^2\left(1 - \frac{1}{4}\right) - \phi$$

$$KE \propto \frac{1}{\lambda^2} = 8.5\text{eV}$$

24. Ans. (A, B, D)

Sol. As radius $r \propto \frac{n^2}{z}$

$$\Rightarrow \frac{\Delta r}{r} = \frac{\left(\frac{n+1}{z}\right)^2 - \left(\frac{n}{z}\right)^2}{\left(\frac{n}{z}\right)^2} = \frac{2n+1}{n^2} \approx \frac{2}{n} \propto \frac{1}{n}$$

as energy $E \propto \frac{z^2}{n^2}$

$$\Rightarrow \frac{\Delta E}{E} = \frac{\frac{z^2}{n^2} - \frac{z^2}{(n+1)^2}}{\frac{z^2}{(n+1)^2}} = \frac{(n+1)^2 - n^2}{n^2.(n+1)^2}.(n+1)^2$$

$$\Rightarrow \frac{\Delta E}{E} = \frac{2n+1}{n^2} \simeq \frac{2n}{n^2} \propto \frac{1}{n}$$

as angular momentum $L = \frac{nh}{2\pi}$

$$\Rightarrow \frac{\Delta L}{L} = \frac{\frac{(n+1)h}{2\pi} - \frac{nh}{2\pi}}{\frac{nh}{2\pi}} = \frac{1}{n} \propto \frac{1}{n}$$

$$1.6\times10^{-19}\times2 = \frac{h\times3\times10^8}{3000\times10^{-10}} - \frac{h\times3\times10^8}{4000\times10^{-10}} + 1.6\times10^{-19}$$

$$1.6\times10^{-19} = \frac{h\times3\times10^8}{10^{-7}}\left(\frac{1}{3}-\frac{1}{4}\right) = \frac{h\times3\times10^8}{10^{-7}}\left[\frac{4-3}{12}\right]$$

$$1.6\times10^{-19} = \frac{h\times3\times10^8}{10^{-7}}\times\frac{1}{12}$$

$$1.6\times4\times\frac{10^{-19}\times10^{-7}}{10^8} = h$$

6.4×10^{-34} Js = h

Linked Comprehension Type (3 Para × 3Q. & 3 Para × 2 Q.) [3 M (-1)]
(Single Correct Answer Type)

25. Ans. (A)

Sol. UV energy flux at a distance of $1\text{m} = \frac{0.1}{4\pi\times1^2}$

cross section (effective area) of atom = $\pi \times (2 \times 10^{-10})^2 = 4\pi \times 10^{-20}$ m^2

Energy required to eject a photoelectron from potassium = 2.2 eV $\equiv$ 2.2 1.6 10^{-19} J.

$$\Rightarrow \text{Exposure time} = \frac{2.2 \times 1.6 \times 10^{-19}}{\left(\frac{0.1}{4\pi \times 1^2}\right)\left(4\pi \times 10^{-20}\right)} = 352 \text{ s}$$

26. Ans. (A)

Sol. Flux of photon at the cathode = $\left(\frac{0.1}{4\pi \times 1^2}\right)\left(\frac{1}{\text{photon energy}}\right)$ = 1.015×10^{16} photons/ sec m^2

Saturation current = (photon flux × effective area of cathode) × 5/100 × 1.6 × 10^{-19} = 3.25 × 10^{-8} A.

27. Ans. (B)

Sol. Cut off potential = $\frac{(4.897 - 2.22)\text{eV}}{e}$ = 2.69 volts.

28. Ans. (B)

Sol. $\frac{hc}{\lambda_0} = \phi_{wf} \Rightarrow \lambda_0 = 6200\,\mathring{A}$

for emission $\lambda < \lambda_0 \Rightarrow 3000 + 40t = 6200 \Rightarrow t = 80$ sec

29. Ans. (B)

Sol. $\frac{P}{100} = \frac{dN}{dt}\frac{hc}{\lambda}$ for 3 minute $\Rightarrow \frac{dN}{dt} = \frac{\lambda}{hc} \times 1 \Rightarrow dN = \int_0^{80} \frac{\lambda}{hc} dt$; $N' = \frac{3.71 \times 10^{21}}{20}$

for one hour $N = N' \times 20 = 3.71 \times 10^{21}$

30. Ans. (B)

Sol. $\left(\frac{dN}{dt}\right) = \frac{P\lambda}{hc} = \frac{100}{hc}(3000 + 40t)$

31. Ans. (D)

Sol. $I\omega = \frac{nh}{2\pi}$

Rotational kinetic energy = $\frac{1}{2}I\omega^2 = \frac{1}{2}\frac{n^2h^2}{4\pi^2 I} = \frac{n^2h^2}{8\pi^2 I}$

32. Ans. (B)

Sol. Bohr's quantization condition is $L = I\omega = \frac{nh}{2\pi}$

Rotational KE = $\frac{1}{2}I\omega^2 = \frac{1}{2}I\left(\frac{nh}{2\pi I}\right)^2 = \frac{n^2h^2}{8\pi^2 I}$

From n = 2 to n = 1 we have

$$\Delta KE = \frac{h^2}{8\pi^2 I}\left(2^2 - 1^2\right) = \frac{3h^2}{8\pi^2 I}$$

This is the excitation energy which is equal to hv

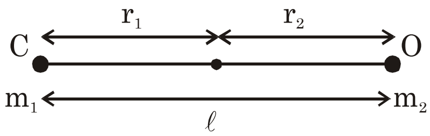
Thus we get, $h\nu = \frac{3h^2}{8\pi^2 I}$

$$I = \frac{3h}{8\pi^2 \nu}$$

Substituting the respective values we get the moment of inertia as 1.87×10^{-46} kgm^2

33. Ans. (C)

Sol.



$m_1r_1 = m_2r_2$
$12r_1 = 16\ r_2$

$\frac{r_1}{r_2} = \frac{4}{3} \Rightarrow \frac{r_1}{\ell} = \frac{4}{7}$

$r_1 = \frac{4}{7}$

Now, $m_1r_1^2 + m_2r_2^2$

$= m_1r_1\ (r_1 + r_2)$

$= m_1\left(\frac{4}{7}\ell\right)\ell$

$I = \left(\frac{4m_1}{7}\right)\ell^2 \Rightarrow \ell = \sqrt{\frac{7I}{4m_1}}$

$\ell = \sqrt{\frac{7 \times 1.87 \times 10^{-46}}{4 \times 12 \times \frac{5}{3} \times 10^{-27}}}$

$= 0.128 \times 10^{-9}$ m
$= 1.28 \times 10^{-10}$ m

34. Ans. (C)

Sol. $Q = \Delta mc^2 = \frac{1}{2} \times \left(\frac{M}{2}\right)v^2 + \frac{1}{2} \times \left(\frac{M}{2}\right)v^2$

$\Delta mc^2 = \frac{1}{2} \times Mv^2 \qquad v = c\sqrt{\frac{2\Delta m}{M}}$

35. Ans. (D)

Sol. Energy is released

$\therefore\ (B.E.)_{product} > (B.E.)_{Reactant}$

36. Ans. (D)

Sol. KE_{max} of β^{-1}.

$Q = 0.8 \times 10^6$ eV

$KE_P + KE_{\beta^-} + KE_{\bar{\nu}} = Q$

KE_P is almost zero

When $KE_\beta = 0$

Then, $KE_{\bar{\nu}} = Q - KE_P$

$\cong Q$

37. Ans. (C)

Sol. $0 \le KE_{\beta^-} \le Q - KE_P - KE_{\bar{\nu}}$

$0 \le KE_{\beta^-} < Q$

38. **Ans. (A)**

Sol. ${}^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}He + Q$

Total energy released = $(M_{Po} - M_{Pb} - M_{He})C^2$

= [(209.982876) – (205.974455 + 4.002603)] × 932 MeV

= [0.005818] × 932 MeV = 5.422376 MeV

Kinetic energy of α particle = $\left(\frac{A-4}{A}\right)Q = \left(\frac{206}{210}\right)5.422376\text{ MeV}$ = 5.319 MeV = 5319 KeV

39. **Ans. (C)**

Sol. Only in option (C); sum of the masses of product is less than sum of the masses of reactant for reaction ${}^{2}_{1}H + {}^{4}_{2}He \rightarrow {}^{6}_{3}Li$

$$M_{Li} < M_{Deutron} + M_{alpha}$$

Matching List Type (4 × 4) — 1 Q. [3 M (–1)]

40. **Ans. (C)**

Sol. Completing reaction in list II

(1) ${}^{15}_{8}O \rightarrow {}^{15}_{7}N + {}_{1}^{0}e$ (β^+ decay Q)

(2) ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}_{2}^{4}He$ (Alpha decay P)

(3) ${}^{185}_{83}Bi \rightarrow {}^{184}_{82}Pb + {}_{1}^{1}H$ (Proton emission S)

(4) ${}^{239}_{94}Pu \rightarrow {}^{140}_{57}La + ...$ (Fission R)

SECTION-II

Numerical Answer Type Question (upto second decimal place) — 1 Q. [3(0)]

1. **Ans.** 5196 yrs

Sol. $\lambda t = \ell n\left(\frac{A_0}{A_t}\right)$

$t = \frac{1}{\lambda} \times \ell n\left(\frac{12 \times 50}{320}\right)$

$t = \frac{5730}{\ell n 2} \times \ell n\left(\frac{15}{8}\right)$

t = 5196 years

SECTION-III

Numerical Grid Type (Ranging from 0 to 9) — 9 Q. [4 M (0)]

1. **Ans. 3**

Sol. $\phi = 13.6\left[\frac{1}{2^2} - \frac{1}{4^2}\right]$

2. **Ans. 8**

Sol. Given distance between electrode = 4×10^{-2}m

Average distance travelled by electrons between successive collision = 8×10^{-5} m.

Thus, $\frac{eV}{4 \times 10^{-2}} \times 8 \times 10^{-5} = 16eV \Rightarrow V = 8keV$

3. Ans. 8

Sol. As we know,

$$F = qvB = m\frac{v^2}{R} \Rightarrow v = \frac{q}{m}BR$$

The kinetic energy of the photoelectron

$$\frac{1}{2}mv^2 = \frac{1}{2}\frac{e^2B^2R^2}{m}$$

$$= \frac{1}{2}\frac{\left(1.6\times10^{-19}\right)^2\left(2\times10^{-2}\right)^2\left(23\times10^{-3}\right)^2}{\left(9.1\times10^{-31}\right)}$$

$= 2.97 \times 10^{-15}$ J

$$= \frac{2.97\times10^{-15}}{1.6\times10^{-19}} = 18.4\,\text{KeV}$$

Energy of the incident photon = $\frac{hc}{\lambda}$

$$= \frac{12.4}{0.50} = 24.8\text{keV}$$

Therefore binding energy = 24.8 – 18.4 = 6.4 KeV = 6400 eV

4. **Ans. 3**

Sol. Atom will exist if size of nucleus is less than the orbit of π-meson

$$\therefore 1.6\times10^{-15}Z^{1/3} < \frac{0.53}{265Z} \Rightarrow Z < 37.5$$

$$r = \frac{n^2h}{4\pi^2Kzem_\pi}$$

$$r = \frac{\varepsilon_0h^2}{\pi m\pi e^2}\times\frac{n^2}{z} \Rightarrow \left(1^{st}\ \text{orbit}\right) \qquad r = \frac{0.53}{265}\times\frac{1}{Z}$$

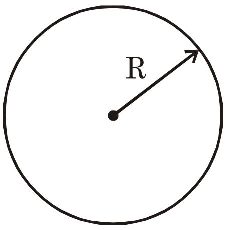
Atom will exist if size of nucleus is less than the orbit of π-meson

$$\therefore\ 1.6 \times 10^{-15}\ Z^{1/3} < \frac{0.53}{265Z} \Rightarrow Z < 37.5$$

$\therefore Z_{max} = 37$

5. **Ans. 7**

Sol.



R = 1 cm

ϕ = 4.7 eV

$$\frac{hc}{\lambda} = \phi - eV$$

$$\frac{1240(\text{ev})(\text{nm})}{200(\text{nm})} = 4.7(\text{eV}) + \text{eV}$$

$$\frac{1240}{200}\text{e} = 4.7\text{eV} + \text{eV}$$

$6.2 - 4.7 = V$ $\quad\quad\quad$ $\therefore$ V = 1.5 volt

$$\frac{1}{4\pi\epsilon_0}\frac{Q}{R} = 1.5$$

$$\left(9\times10^9\right)\frac{Ne}{\frac{1}{100}} = 1.5$$

9×10^{11} Ne = 1.5; $\quad\quad$ $N = \dfrac{1.5}{9\times10^{11}\times1.6\times10^{-19}} = \dfrac{15}{16}\times\dfrac{1}{9}\times10^8$

$$= \frac{5}{3\times16}\times10^8 = \frac{50}{48}\times10^7$$

Z = 7

6. **Ans.** 6 litre

Sol. $5\times\dfrac{\ell n2}{15} = \ell n\left(\dfrac{3.7\times10^4}{296\times v}\right)$

$$2^{1/3} = \frac{3.7\times10^4}{296\times v}\times60$$

v = 6000 cm^3

v = 6 litre

7. **Ans. 8**

Sol. $\left|\dfrac{dN}{dt}\right| = \lambda N_0 e^{-\lambda t}$ $\therefore \ell n\left|\dfrac{dN}{dt}\right| = \ell n(N_0\lambda) - \lambda t$ $\therefore \ell n\left|\dfrac{dN}{dt}\right| = \ell n(N_0\lambda) - \lambda t \Rightarrow -\lambda = \text{slope} = -\dfrac{1}{2}\text{year}^{-1} \Rightarrow \lambda = \dfrac{1}{2}\text{yr}^{-1}$

$\therefore t_{1/2} = \dfrac{0.693}{\lambda} = 1.386$ given time is 3 times of $t_{1/2}$ $\therefore$ value of p is 8.

8. **Ans. 5**

Sol. $A = \dfrac{A_0}{2^n} \Rightarrow 2^n = \dfrac{6800}{425}$; n = No. of half life

$2^n = 16 = 2^4$

$\Rightarrow n = 4$

$\Rightarrow 4 \times t_{1/2} = 10$

$\Rightarrow t_{1/2} = 2.5h$

9. **Ans. 9**

Sol. ${}^{12}_{5}B \to {}^{12}_{6}C + {}^{0}_{-1}e + \bar{v}$

Mass defect = (12.014 – 12) u

$\therefore$ Released energy = 13.041 MeV

Energy used for excitation of ${}^{12}_{6}C$ = 4.041 MeV

$\therefore$ Energy converted to KE of electron

= 13.041 – 4.041 = 9 MeV

Subjective Type **14 Q. [4 M (0)]**

1. **Ans.** 1.1×10^{12}

Sol. $\lambda_1 = 4144$ Å

$$E_1 = \frac{12400}{4144} eV, E_1 = 3 \text{ eV}$$

$\lambda_2 = 4972$ Å

$$E_2 = \frac{12400}{4972} = 2.5\, eV$$

$\lambda_3 = 6216$

$$E_3 = \frac{12400}{6216} = 2\, eV$$

number of photo electron emitted in 2 second

$$= 2 \times \left(\frac{1.2 \times 10^{-3}}{3 \times 1.6 \times 10^{-19}} + \frac{1.2 \times 10^{-3}}{2.5 \times 1.6 \times 10^{-19}} \right) \times 10^{-4}$$

$$= 2 \times 10^{16} \left(\frac{1.2}{4.8} + \frac{1.2}{400} \right) \times 10^{-4}$$

$= 1.1 \times 10^{12}$

2. **Ans.** (a) $10^5\ s^{-1}$; (b) 286.18; (d) 111 s

Sol. (a) number of phto electron emitted per second

$$= \frac{3.2 \times 10^{-3}}{5 \times 1.6 \times 10^{-19}} \times \frac{1}{4\pi(0.5)^2} \times \pi \times \frac{8 \times 10^{-4}}{10^6}$$

$= 10^5$ electron/sec

(b) $K.E_{max} = 2$ eV

$$\lambda_{electron} = \sqrt{75}\text{Å}$$

$$\lambda_{photon} = \frac{12400}{5} = 2480\text{Å}$$

$$\frac{\lambda_{electron}}{\lambda_{photon}} = \frac{5\sqrt{3}}{2480} = \frac{\sqrt{3}}{496} = \frac{1}{286.36}$$

(c) because +ve charge would go on accumulating on sphere & it's work function would increase & all the free elecrtron can be removed

$$\frac{2 \times 1.6 \times 10^{-19}}{1.6 \times 10^{-19}} = \frac{KQ}{R} = \frac{9 \times 10^9 \times 10^5 \times 1.6 \times 10^{-19}}{8 \times 10^{-2}} t$$

$$t = \frac{10^{-2} \times 10^{19}}{9 \times 10^{14}}$$

$$t = \frac{1000}{9} = 111.11 \sec$$

3. **Ans.** KE $\cong$ 151 eV, $d_{least} = 0.5$ Å

Sol. $\therefore$ if d is multiple of 0.5 Å then standing waves would be fomred

$$\text{Energy} = \frac{p^2}{2M}$$

$$=\frac{h^2}{2\lambda^2 m_\alpha}$$

$$=\frac{\left(6.63\times10^{-34}\right)^2}{2\times\left(0.5\times10^{-10}\right)^2\times9.11\times10^{-31}}$$

$$=\frac{9.65\times10^{-17}}{4}=2.412\times10^{-17}=151\text{eV}$$

4. **Ans.** (i) 2 ; (ii) 13.6 eV ; (iii) 12.75 eV, 0.66 eV

Sol. Electron is present in 4th energy level

$E_1 = -13.6\ z^2$ initially electron was present in 2nd state

$E_2 = -3.4\ z^2$

$E_3 = -1.51\ z^2$

$E_4 = -0.85\ z^2$

(ii) Ionisation energy = 13.6 ev

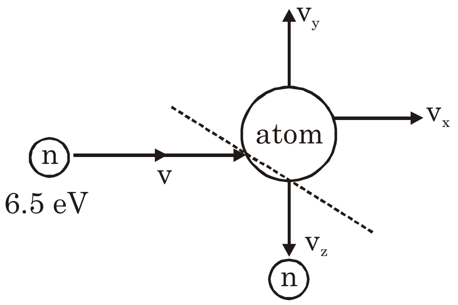
(iii) Maximum energy $n = 4 \rightarrow n = 1$ & minimum $n = 4 \rightarrow n = 3$

5. **Ans.** (i) Allowed values of energy of neutron = 6.36 eV and 0.312 eV ; Allowed values of energy of He atom = 17.84 eV and 16.328 eV ,

(ii) 18.23×10^{14} Hz , 9.846×10^{15} Hz ,

11.6×10^{15} Hz

Sol. He^+



$m_{He}v_y = m_n v_z \Rightarrow 4v_y = v_z$

$m_n v = m_{He}\ v_x \qquad v_x = \frac{v}{4}$

$$\frac{1}{2}m_n v^2 = 65\text{ev}$$

$$\frac{1}{2}m_n v^2 = \frac{1}{2}m_{He}v_x^2 + \frac{1}{2}m_{He}v_y^2 + \frac{1}{2}m_n v_z^2 + \text{energy in excitation}$$

$$65\text{ev} = \frac{65\text{ev}}{4} + \frac{1}{2}4m_0 v_y^2 + \frac{1}{2}m_0 v_z^2 + \text{energy in excitation}$$

$$65\times\frac{3}{4} = m_0\left(2v_y^2 + 8v_y^2\right) + \text{energy in excitation}$$

$$65\times\frac{3}{4} = 10m_0 v_y^2 + \text{energy in excitation}$$

$$\text{K.E}_{\text{possible}} \text{ for neutron} = \left(48.75 - 40.8\right)\times\frac{16}{20} = 6.36$$

or $\left(48.75-12.09\right)\times\dfrac{16}{20}=0.312$

$$\text{K.E}_{\text{atom}}=\frac{65}{4}+\frac{6.36}{4}\text{or}\frac{65}{4}+\frac{0.312}{4}$$

= 17.84 or 16.328

(ii) The frequency of emitted radiation

40.8 eV = hν or

12.09 × 4 = hν

or 7.56 = hν

$$\nu_1=\frac{40.8\times1.6\times10^{-19}}{6.63\times10^{-34}}=9.84\times10^{15}\,\text{Hz}$$

$$\nu_2=\frac{48.36\times1.6\times10^{-19}}{6.63\times10^{-34}}=11.6\times10^{15}\,\text{Hz}$$

$$\nu_3=\frac{7.56\times1.6\times10^{-19}}{6.63\times10^{-34}}=18.24\times10^{14}\,\text{Hz}$$

6. Ans. 7.4 eV, 4.7 Volts

Sol. 5 eV = hν – ϕ

5 eV = hν – ϕ

ϕ = 7.4 ev

Energy = 6.2 – 12.4 ev

$E_{3\to1}$ = 13.6 – 1.51 = 12.09 ev

$E_{4\to1}$ = 13.6 – 0.85 = 12.75 ev

V = 10.2 – 7.4 + 1.89

V = 4.7 volt

7. Ans. (i) 0.62Å, (ii) No, (iii) Yes 0.8 Å

Sol. $\text{Energy}_{\text{min}}=\dfrac{12400}{62\times10^{-3}}=20\text{KeV}$

No because maximum energy available for collision is 20 KeV & b6 momentum conservation law & energy conservation law K. $E_p > 0$

∴ 20 Kev energy would not be available for excitation

λ_{min} = 0.62 Å

E = 10 Kev

$$\lambda_{\text{min}}=\frac{12400}{1500}=0.8\text{Å}$$

8. Ans. $8/3\times10^{18}$ sec

Sol. $4\,{}_1^1\text{H}\rightarrow{}_2^4\text{He}$

number of ${}_1^1\text{H}$ converting into ${}_1^4\text{He}$ in 1 sec $=\dfrac{3.9\times10^{26}\times4}{26\times10^{6}\times1.6\times10^{-19}}$

Mass of H^+ burning in 1 sec = $\dfrac{3.9\times4\times10^{26}}{26\times1.6}\times10^{13}\times1.7\times10^{-24}$

Time = $\dfrac{1.7\times10^{30}\times10^{3}\times8}{3\times10^{39}\times1.7\times10^{-24}}$

Time = $\dfrac{8}{3}\times10^{18}$ sec

9. Ans. 6.04×10^9 yrs

Sol. $N = N_0 e^{-\frac{\ell n2}{4.5\times10^9}t}$

$N' = N_0 e^{-\frac{\ell n2}{7.13\times10^8}t}$

$\frac{N}{N'} = e^{\ell n2t\left(-\frac{1}{4.5\times10^9}+\frac{1}{7.13\times10^8}\right)}$

$140 = 2^{\frac{t}{10^8}\left(\frac{1}{7.13}-\frac{1}{4.5}\right)}$

$t = 6.04 \times 10^9$ years

10. **Ans.** $t = \left(\frac{ln 5}{ln 2}\right)\tau$

Sol. $\frac{\ell n2}{\tau} \times t = \ell n\left(\frac{100}{20}\right)$

$t = \tau\frac{\ell n(5)}{\ell n(2)}$

11. **Ans.** $\Delta T = \frac{0.2E_0\left[\alpha t - \frac{\alpha}{\lambda}(1-e^{-\lambda t})\right]}{mS}$

Sol. $\frac{dN}{dt} = \alpha - \lambda N$

$\frac{dN}{\alpha - \lambda N} = dt$

$\ell n\left(\frac{(\alpha - \lambda N)}{(\alpha - \lambda N_0)}\right) = -t\lambda$

$\alpha - \lambda N = (\alpha - \lambda N_0)\, e^{-\lambda t}$

$\alpha = (\alpha - \lambda N_0)\, e^{-\lambda t} + \lambda N$

$N = \frac{1}{\lambda}\left(\alpha\left(1 - e^{-\lambda t}\right) + \lambda N_0 e^{-\lambda t}\right)$

$\frac{dN}{dt} = \alpha - \left(\alpha\left(1 - e^{-\lambda t}\right) + \lambda N_0 e^{-\lambda t}\right)$

$\frac{dN}{dt} = e^{-\lambda t}\left(\alpha - N_0\lambda\right)$

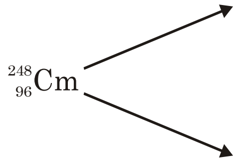
$\frac{E_0}{5}\left(N_0\lambda - \alpha\right)e^{-\lambda t} = ms\frac{dT}{dt} \quad \Rightarrow \quad \frac{dT}{dt} = \frac{E_0}{5}\left(N_0\lambda - \alpha\right)e^{-\lambda t} \times \frac{1}{ms}$

$\Delta T = \frac{E_0}{5ms}\frac{\left(N_0\lambda - \alpha\right)}{\lambda}e^{-\lambda t}\Big|_t^0 \quad \Rightarrow \quad \Delta T = \frac{E_0}{5ms}\left(N_0\left(1 - e^{-\lambda t}\right) - \frac{\alpha}{\lambda}\left(1 - e^{-\lambda t}\right)\right)$

$ms\Delta T = \frac{E_0}{5} \times \left(\alpha t - \frac{\alpha}{\lambda}\left(1 - e^{-\lambda t}\right)\right) \quad \delta \quad \Delta T = \frac{E_0}{5ms} \times \left(\alpha t - \frac{\alpha}{\lambda}\left(1 - e^{-\lambda t}\right)\right)$

12. **Ans.** $\cong 33.298\ \mu W$

Sol. $\lambda = 10^{-13} = \dfrac{1}{T_{mean}}$



E = 200 MeV

$^{244}_{94}Pu + ^{4}_{2}He$

Energy = 5.136 MeV

Energy output = $N_e e^{-\lambda t} \times \dfrac{8}{100} \times 200 + N_0 e^{-\lambda t} \dfrac{92}{100} \times 5.131$

Power = $\left(8 \times 2 + \dfrac{92 \times 5.136}{100}\right) N_0 e^{-\lambda t} \times \lambda$

$= 3.316 \times 10^{-6}$ watt

13. **Ans.** 9.00×10^6

Sol. $\pi^+ \to \mu^+ + v$

$$Pc + \frac{p^2}{2m} = 50 MeV$$

$$Pc + \frac{p^2c^2}{2 \times 100} = 50 MeV$$

$200\ x + x^2 = 50^2 \times 4$

$x^2 + 200\ x - (100)^2 = 0$

$$x = \frac{-200 + 200\sqrt{2}}{2}$$

pc = 41 MeV

E_p = 41 MeV

$E_{\mu^+} = 9 MeV$

14. **Ans.** $1.75n = N_0(1 - e^{-4\lambda})$, 6.95 sec, $\dfrac{2}{ln\left(\frac{4}{3}\right)}$

Sol. $N = N_0 e^{-\lambda t}$

$N_2 = N_0 e^{-2\lambda}$

and $N_4 = N_0 e^{-4\lambda}$

$\therefore$ $n = N_0 - N_2 = N_0 (1 - e^{-2\lambda})$

and $0.75\ n = N_0 (e^{-2\lambda} - e^{-4\lambda})$

Solving we get,

$\lambda = 0.145\ s^{-1}$

Average life = $\dfrac{1}{\lambda}$ = 6.896 second