Modern Physics

1. The fraction of the original number of nuclei of a radioactive atom having a mean life of 10 days, that decays during the 5^{th} day is **[NSEP-2017]**

(A) 0.15 (B) 0.30 (C) 0.045 (D) 0.064

Ans. (D)

Sol. $T_{av} = 10 \text{ days } = \frac{1}{\lambda}$

No. of decays during 5^{th} day $= N_0e^{-\lambda.4} - N_0e^{-\lambda 5}$

fraction decayed during 5^{th} day $= e^{-4\lambda} - e^{-5\lambda}$

$= e^{-4/10} - e^{-1/2}$

$= e^{-2/5} - e^{-1/2} = 0.0637 \simeq 0.064$

2. The photoelectric threshold wavelength of tungsten is 230 nm. The energy of electrons ejected from its surface by ultraviolet light of wavelength 180 nm is **[NSEP-2017]**

(A) 0.15 eV (B) 1.5 eV (C) 15 eV (D) 1.5 keV

Ans. (B)

Sol. $\frac{hc}{1800} - \frac{hc}{2300} = \frac{12400eV[500]}{1800 \times 2300} = 1.5eV$

3. The maximum wavelength that can ionize a hydrogen atom initially in the ground state is **[NSEP-2018]**

(A) 660.0 nm. (B) 364.5 nm. (C) 121.9 nm. (D) 91.4 nm.

Ans. (D)

Sol. Maximum wavelength $\Rightarrow$ minimum energy i.e transition takes place from n = 1 to n = ∞

$\Rightarrow \Delta E$ = 13.6 eV

$\Rightarrow \lambda$ = 12400 Å

= 914 Å = 91.4 nm

4. The wavelength of the waves associated with a proton and a photon are the same. Therefore, the two have equal. **[NSEP-2018]**

(A) mass. (B) velocity. (C) momentum. (D) kinetic energy.

Ans. (C)

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

$E_{photon} = \frac{h}{\lambda}$

$E_{proton} = \frac{P^2}{2m}$

only momentum can be equal

5. Which of the following sources emits light having highest degree of coherence? **[NSEP-2018]**

(A) Light Emitting Diode. (B) LASER diode.

(C) Neon lamp. (D) Incandescent lamp.

Ans. (B)

6. An electron in hydrogen atom jumps from a level n = 4 to n = 1. The momentum of the recoiled atom is **[NSEP-2018]**

(A) 6.8×10^{-27} kg-m/s
(B) 12.75×10^{-19} kg-m/s
(C) 13.6×10^{-19} kg-m/s
(D) zero.

Ans. (A)

Sol. $\Delta E = 13.6\left(1-\frac{1}{16}\right) = \frac{13.6\times 15}{16} = \frac{51}{4}$

$= 12.75\text{eV} = \frac{12.75\times 1.6\times 10^{-19}}{3\times 10^{8}}$

Photon will take away almost all of the energy

$\frac{hc}{\lambda} = 12.75\text{eV}$

$\Rightarrow \frac{h}{\lambda} = \left(\frac{12.75}{c}\right) = P_{\text{photon}} = P_{\text{revoled atom}}$

$= 6.8 \times 10^{-27}$ kg m/s

7. A stationary hydrogen atom emits photon corresponding to the first line (highest wave length) of Lyman series. If R is the Rydberg constant and M is the mass of the atom, the recoil velocity of the atom is: **[NSEP-2019]**

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

Ans. (C)

Sol. let λ is wavelength of first line of Lyman series

Then $\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$

$\Rightarrow \quad \frac{1}{\lambda} = R\left(\frac{3}{4}\right)$

From conservation of linear momentum of emitted photon = linear momentum of atom

$h/\lambda = Mv$

$\frac{3Rh}{4} = Mv$

8. A source emits photons of energy 5 eV which are incident on a metallic sphere of work function 3.0 eV. The radius of the sphere is $r = 8 \times 10^{-3}$ m. It is observed that after some time emission of photoelectrons from the metallic sphere is stopped. Charge on the sphere when the photoemission stops is. **[NSEP-2019]**

(A) 1.77×10^{-16} C
(B) 1.77×10^{-12} C
(C) 1.11×10^{-12} C
(D) 1.11×10^{-10} C

Ans. (B)

Sol. Maximum energy of emitted photo-electron = 5eV – 3eV = 2eV

Emission of photoelectrons from metallic sphere is stopped.

when energy of photoelectron becomes zero $= -\frac{KQe}{R} + 2eV = 0$ (where Q is charge of sphere)

$-\frac{KQ}{R} + 2V = 0$

$$\frac{KQ}{R} = 2V$$

$$Q = \frac{2R}{K} = \frac{2 \times 8 \times 10^{-3}}{9 \times 10^{9}} = \frac{16}{9} \times 10^{-12} = 1.77 \times 10^{-12} C$$

9. In an experiment on photoelectric effect, the slope of straight line graph between the stopping potential and the frequency of incident radiation gives **[NSEP-2019]**

(A) Electron charge (e) (B) Planck constant (h)

(C) $\frac{h}{e}$ (D) Work function (W)

Ans. (C)

Sol. eV = hf – ϕ

$$V = \frac{h}{e} f - \phi$$

Slope = h/e

10. According to Bohr's theory the ionization energy of H atom is 13.6 eV. The energy needed to remove an electron from Helium ion (He^+) is: **[NSEP-2019]**

(A) 13.6 eV (B) 16.8 eV (C) 27.2 eV (D) 54.4 eV

Ans. (D)

Sol. According to Bohr's theory

Ionization energy = 13.6 Z^2

So, ionization energy of He^+ is 13.6 × 2^2 = 54.4 eV

11. The phenomenon inverse to photo electric effect is: **[NSEP-2019]**

(A) Compton effect (B) Pair production

(C) Raman effect (D) Production of X-rays in Coolidge tube

Ans. (D)

12. A stationary hydrogen atom emits a photon of wavelength 1025 Å. Its angular momentum changes by **[NSEP-2019]**

(A) $\frac{h}{\pi}$ (B) $\frac{2h}{\pi}$ (C) $\frac{h}{2\pi}$ (D) $\frac{3h}{2\pi}$

Ans. (A)

Sol. Energy of emitted photon $= \frac{hc}{\lambda} = \frac{12400 eV Å}{1025 Å}$

= 12.097 eV

which implies transition of e^- from 3rd orbit to 1st orbit

So, that change in angular momentum $= (3-1)\frac{h}{2\pi}$

$$= \frac{h}{\pi}$$

13. A number of identical absorbing plates are arranged in between a source of light and a photo cell. When there is no plate in between, the photo current is maximum. Under the circumstances let us focus on the two statements – **[NSEP-2019]**

(1) The photo current decreases with the increase in number of absorbing plates.

(2) The stopping potential increases with the increase in number of absorbing plates.

(A) Statements (1) and (2) are both true and (1) is the cause of (2).

(B) Statements (1) and (2) are both true but (1) and (2) are independent.

(C) Statement (1) is true while (2) is not true and (1) and (2) are independent.

(D) Statement (1) is true while (2) is not true and (2) is the effect of (1).

Ans. (C)

Sol. Due to the presence of absorbing plates the intensity of the light incident on ptotocell is reduced thereby decreasing the number of photons striking the photocell. So current is reduced Stopping potential (Vs) is independent of the intensity rather it depends on the frequency of light.

14. The mass of an electron can be expressed as **[NSEP-2019]**

(A) 0.512 MeV
(B) 8.19×10^{-14} J/c^2
(C) 9.1×10^{-31} kg
(D) 0.00055 amu

where c is speed of light in vacuum

Ans. (BCD)

Sol. m = 9.1×10^{-31} kg

E = mC^2

15. The Nucleus ${}^{23}_{10}\text{Ne}$ decays by $\beta-$ emission through the reaction ${}^{23}_{10}\text{Ne} \rightarrow {}^{23}_{11}\text{Na} + {}^{0}_{-1}\beta + \bar{\nu} +$ energy The atomic masses are ${}^{23}_{10}\text{Ne} = 22.994466\text{u}$ and ${}^{23}_{11}\text{Na} = 22.989770\text{u}$, ${}^{0}_{-1}\beta = 0.000549\text{u}$. The maximum kinetic energy that the emitted electron can ever have is **[NSEP-2020]**

(A) 4.374MeV
(B) 3.862MeV
(C) 2.187MeV
(D) 1.931MeV

Ans. (A)

Sol. The mass defect $\Delta m=$ (mass of ${}^{23}_{10}\text{Ne}$ - mass of 10 electrons) - (mass of ${}^{23}_{11}\text{Na}$ - mass of 11 electrons) - mass of one electron

Or $\Delta m = \left(\text{mass of } {}^{23}_{10}\text{Ne}\right) - \left(\text{mass of } {}^{23}_{11}\text{Na}\right) = (22.994466) - (22.989770) = 0.004696\text{amu}$ Thereby $\Delta E = 0.004696 \times 931.5 = 4.374\text{MeV}$ This energy is shared between the electron and the neutrino. In an extreme situation the electron can take the whole of this energy so the maximum energy the electron can have is 4.374MeV

16. Even the radiation of highest wave length in the ultraviolet region of hydrogen spectrum is just able to eject photoelectrons from a metal. The value of threshold frequency for the given metal is **[NSEP-2020]**

(A) 3.83×10^{15} Hz
(B) 4.33×10^{14} Hz
(C) 2.46×10^{15} Hz
(D) 7.83×10^{14} Hz

Ans. (C)

Sol. Lymen series of hydrogen spectrum falls in ultra violet region. Minimum energy photon of Lymen series is emitted for transition from $n = 2$ to $n = 1$ and has an energy $13.6\left(\frac{1}{1^2} - \frac{1}{2^2}\right)\text{eV} = 10.2\text{eV}$.

All other spectral lines will be of higher energies and so the frequencies. Therefore if this 10.2eV photon can eject photo electron then other will definitely. So required threshold frequency ν is $\nu = \frac{10.2 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} \text{Hz} = 2.46 \times 10^{15} \text{Hz}$

17. Positronium is a short-lived $\left(\approx 10^{-9}\,\text{s}\right)$ bound state of an electron and a positron (a positively charged particle with mass and charge equal (in magnitude) to an electron) revolving round their common centre of mass. If E_0, v_0 and a_0 are respectively the ground state energy, the orbital speed of electron in first orbit and the radius of the first $(n = 1)$ Bohr orbit for Hydrogen atom, the corresponding quantities E, v and a for the positronium are **[NSEP-2021]**

(A) $E = \frac{E_0}{2}$ (B) $a = a_0$ (C) $a = 2a_0$ (D) $E = E_0, v = v_0, a = a_0$

Ans. (ac)

Sol. According to Bohr theory, in an hydrogen atom an electron revolves round the proton, the centripetal force being provided by electrostatic attraction. Such that

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e \cdot e}{r^2} \quad \text{or } mv^2 r = Ke^2 \qquad ....(1)$$

where v and r are the velocity of electron and the radius of the orbit and $K = \frac{1}{4\pi\varepsilon_0}$

According to Bohr quantum condition (second postulate)

$$mvr = n\frac{h}{2\pi} \quad \text{or } mvr = n\hbar \qquad ......(2)$$

Dividing eq (1) by eq (2) $v = \frac{Ke^2}{n\hbar} \Rightarrow v$ does not depend on mass. Now substituting v in equation (2)

$$m\left(\frac{Ke^2}{n\hbar}\right)r = n\hbar \Rightarrow r = \frac{n^2\hbar^2}{Kme^2} \quad \text{showing that } r \propto \frac{1}{m}$$

The total energy E = KE + PE

$$= \frac{1}{2}mv^2 - \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r} = \frac{1}{2}m\left(\frac{Ke^2}{n\hbar}\right)^2 - \frac{Ke^2}{r}$$

$$E = \frac{1}{2}\frac{mK^2e^4}{n^2\hbar^2} - \frac{Ke^2}{n^2\hbar^2}Kme^2 E_n = -\frac{1}{2}\frac{mK^2e^4}{n^2\hbar^2} \Rightarrow E \propto m$$

To understand the situation more specifically, one replaces the mass of electron by the effective mass i.e. the reduced mass (μ) which for the case of hydrogen atom is

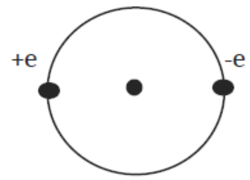
$$\mu = \frac{m \times 1836m}{m + 1836m} \approx m(\text{electron mass}) \text{ thus for hydrogen atom the}$$

Radius of first orbit $r = a_0 = \frac{\hbar^2}{Kme^2}$ we have substitute n = 1

Velocity of electron in first orbit $v = v_0 = \frac{Ke^2}{\hbar}$

Energy of electron in first orbit E = $E_0 = -\frac{1}{2}\frac{mK^2e^4}{\hbar^2} \Rightarrow E \propto m$

A positronium is a short lived atomic entity in which a negatively charged electron is said to revolve round a positron (a positive particle having charge and mass equal to an electron even sometimes known as a positive electron) Since the particles have equal mass, the rotation takes place around the centre of mass which lies midway between the two.



In case of positronium the reduced mass is $\mu = \frac{mm}{m+m} = \frac{m}{2}$

Thereby the radius becomes $r = a = \frac{\hbar^2}{K(m/2)e^2} = \frac{2\hbar^2}{Kme^2} = 2a_0$

And energy becomes $E = -\frac{1}{2}\frac{(m/2)K^2e^4}{n^2\hbar^2} \Rightarrow E = -\frac{1}{4}\frac{mK^2e^4}{n^2\hbar^2} = \frac{E_0}{2}$

18. When a sample of atoms is irradiated by neutrons, radioactive atoms are produced at a constant rate R, which decay with decay constant λ. The number of radioactive atoms accumulated after an irradiation time t is given by **[NSEP-2022]**

(A) $N(t) = Rte^{-lt}$ (B) $N(t) = \frac{R}{\lambda}e^{-\lambda t}$ (C) $N(t) = \frac{R}{\lambda}\left(1-e^{-\lambda t}\right)$ (D) $N(t) = Rt(1-e^{-\lambda t})$

Ans. (C)

Sol. $A \to B \to C$

Accumulation:

$dN = Rdt - \lambda N dt$

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

$$\int_0^B \frac{dN}{R-\lambda N} = \int_{t=0}^{t} dt$$

$$\left.\frac{\ln\ln\left(R-\lambda N\right)}{-\lambda}\right]_0^N = t$$

$\ln(R - \lambda N) - \ln r = -\lambda t$

$$\ln\left(\frac{R-\lambda N}{R}\right) = -\lambda t$$

$$\frac{R-\lambda N}{R} = e^{-\lambda t}$$

$R - \lambda N = Re^{-\lambda t}$

$\lambda N = R(1-e^{-\lambda t})$

$$N = \frac{R}{\lambda}(1-e^{-\lambda t})$$

19. A hydrogen atom is in ground state $(n=1)$. The magnetic field produced by revolving electron, at centre of atom is B_0. Atom is excited to state $_{n=4}$. According to Bohr model, the correct alternative(s) is/are **[NSEP-2022]**

(A) Magnetic field at centre of atom for $(n=4)$ becomes $B_4 = \frac{B_0}{64}$

(B) Energy absorbed by atom in going from $(n=1)$ to $(n=4)$ is $12.75eV$

(C) Change in magnitude of angular momentum of electron is $\frac{3h}{2\pi}$

(D) Assume that this excited atom $(n = 4)$ is at rest and it makes transition to ground state $(n = 1)$ in a single quantum jump of an electron, (Take mass of atom $M_H = 1.67 \times 10^{-27}$ Kg) the recoil speed of atom will be nearly $v = 4.1 ms^{-1}$.

Ans. (BCD)

Sol. $B = \frac{\mu_0 ef}{2r} = \frac{\mu_0 ev}{2r.2\pi r}$

$v \propto \frac{1}{n}$

$r \propto n^2$

$\Rightarrow B \propto \frac{1}{n^5}$

$\Rightarrow \frac{B(n=4)}{B_0} = \frac{1}{4^5}$

$\therefore$(A) is incorrect

Energy of n^{th} state of Hydrogen atom is given by,

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

$\Rightarrow \Delta E = 13.6\left[1 - \frac{1}{4^2}\right] eV = 13.6 \times \frac{15}{16} = 12.75 eV$

$\Rightarrow$(B) is correct

Angular momentum of an electron in the n^{th} state is given by,

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

$\Rightarrow \Delta |L| = \frac{4h}{2\pi} - \frac{h}{2\pi} = \frac{3h}{2\pi}$

$\therefore$(C) is correct

Using Conservation of linear momentum,

$|p_{atom}| = |p_{photon}|$

$\Rightarrow Mv = \frac{h}{\lambda}$

Rydberg's formula is given by,

$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$\Rightarrow Mv = Rh\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$\Rightarrow Mv = Rh\left(1 - \frac{1}{4^2}\right) = \frac{15}{16} Rh$

$\Rightarrow v = \frac{15}{16} \times \frac{1.097 \times 10^7 \times 6.6 \times 10^{-34}}{1.67 \times 10^{-27}}$

$\Rightarrow v = 4.1 ms^{-1}$

$\therefore$ (D) is correct

20. In an experimental set up to study the photoelectric effect a point source of light of power 3.2mW is used. The source emits mono energetic photons of energy 5eV and is located at a distance $d = 0.8\text{m}$ from centre of a stationary metallic sphere of work function $W = 3.0\text{eV}$. The radius of the sphere is $R = 8\text{mm}$. Assume that the sphere is isolated and photo electrons are instantly swept away after emission. Also assume that the efficiency off photoelectric emission is one for every 10^6 photons. In the present set up **[NSEP-2022]**

(A) The de Broglie wavelength of fastest moving photoelectron is nearly 8.7Å

(B) It is observed that after some time emission of photoelectrons from the surface of metal sphere is stopped, the charge on sphere just when the electron emission stops is $64\pi\epsilon_0 \times 10^{-3}\text{C}$

(C) Time after which photo electric emission stops is nearly 111s

(D) The light source emits 4×10^{15} photons per second.

Ans. (ABCD)

Sol. $K_{max} = E - \phi$ According to Einstein's photoelectric equation,

$$\Rightarrow K_{max} = 5\text{eV} - 3\text{eV} = 2\text{eV} = \frac{p_{max}^2}{2m}$$

De Broglie wavelength is given by,

$$\lambda_{db} = \frac{h}{p_{max}}$$

$$\lambda_{db} = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 2 \times 1.6 \times 10^{-19}}}$$

$$\lambda_{db} = \frac{6.63 \times 10}{7.63}\text{Å} = 8.7\text{Å}$$

(A) is correct

Photoelectric emission will stop when,

$eV_0 = 2\text{eV} \Rightarrow V_0 = 2\text{V}$ (V_0 : Potential of sphere)

The charge when potential of sphere is V_0 is

$$2 = \frac{1}{4\pi\epsilon_0} \cdot \frac{Q}{r} \Rightarrow Q = 8\pi\epsilon_0 \left(8 \times 10^{-3}\right) = 64\pi\epsilon_0 \times 10^{-3}\text{C}$$

(B) is correct

Total photoelectrons emitted = $\dfrac{64\pi\epsilon_0 \times 10^{-3}\text{C}}{1.6 \times 10^{-19}}$

Let No. of photons incident in sphere is N

As the efficiency of photoelectric emission is 1 in 10^6 photons

$$\Rightarrow N = 10^6 \cdot \frac{64\pi\epsilon_0 10^{-3}}{1.6 \times 10^{-19}} = 40\pi\epsilon_0 \times 10^{22}$$

Let n = No. of photons emitted be second by the source,

P = nE

$$\Rightarrow 3.2 \times 10^{-3} = n \times 5 \times 1.6 \times 10^{-19}$$

$$\Rightarrow n = \frac{2}{5} \times 10^{16} = 4 \times 10^{15}$$

Calculating the time for N photons to incident in sphere

$$\Rightarrow \frac{n}{4\pi d^2}\pi R^2 \cdot t = N \Rightarrow t = \frac{N4d^2}{\eta R^2} = \frac{40\pi\epsilon_0 \times 10^{22} \times 4 \times (0.8)^2}{4 \times 10^{15} \times \left(8 \times 10^{-3}\right)^2}$$

$$\Rightarrow t = 4\pi\epsilon_0 \times 10^8 \times 10^4 = \frac{10^{12}}{9 \times 10^9} = 111s$$

$\therefore$ (C) and (D) are correct

21. A target of ^7Li is bombarded with a proton beam of current 10^{-4} ampere for 1 hour to produce ^7Be of activity 1.8×10^8 disintegrations per second. Assuming that bombarding of 1000 protons produces one ^7Be radioactive nucleus, the half-life of ^7Be is estimated to be approximately **[NSEP-2023]**

(A) 6887 hour (B) 4332 hour (C) 2407 hour (D) 2195 hour

Ans. **(C)**

Sol.

$$i = \frac{ne}{t}$$

$$n = \frac{it}{e}$$

$$\frac{dN}{dt} = \lambda N \times 10^{-3}$$

$$\lambda = \frac{dN}{dt \cdot N} \times 10^3$$

$$\lambda = \frac{dN}{dt \cdot N} \times 10^3 = \frac{dN}{dt}\frac{e \times 10^3}{it}$$

$$\lambda = \frac{1 \cdot 8 \times 10^{11} \times e}{it}$$

$$t_{112} = \frac{\ln 2 \times i \times t}{1 \cdot 8 \times 10^{11} \times e}$$

$$t_{112} = \frac{0.693 \times 10^{-4} \times 3600}{1.8 \times 10^{11} \times 1.6 \times 10^{-19}} \text{sec}$$

$$t_{112} = \frac{0.693 \times 10^{-4}}{1.8 \times 10^{18} \times 1.6 \times 10^{19}}$$

$$= \frac{6932 \times 10^{-8}}{1.8 \times 1.6 \times 10^{-8}}$$

$$= \frac{6932}{1.8 \times 1.6} = 2406.9 \simeq 2407 \text{ hour}$$

22. Two nuclides A and B are isotopes. The nuclides B and C are isobars. All the three nuclides A, B and C are radioactive. You may then conclude that **[NSEP-2023]**

(A) the nuclides A, B and C must belong to the same element

(B) the nuclides A, B and C may belong to the same element

(C) it is possible that A may change to B through a radioactive decay process

(D) it is possible that B may change to C through a radioactive decay process

Ans. **(D)**

Sol. ${}^{A}_{Z}X$ ${}^{A_1}_{Z_1}Y$ ${}^{A_1}_{Z}X$ ${}^{A_1}_{Z_1}X$

$A = {}^{A}_{Z}X$ $B = {}^{A_1}_{Z}X$ $C = {}^{A_1}_{Z_1}Y$

$${}^{A_1}_{Z}X \xrightarrow[-\beta\,\text{decay}]{} {}^{A_1}_{Z}y + {}^{0}_{-1}\beta + \bar{\nu}$$

23. Heavy stable nuclei have more neutrons than protons. This is because of the fact that **[NSEP-2023]**

(A) neutrons are heavier than protons
(B) the electrostatic forces between protons are repulsive
(C) neutrons decay into protons through beta decay
(D) the nuclear forces between neutrons are weaker than those between protons

Ans. **(B)**

Sol. Because between P – P elector -state forces are repulsive.

24. During the processes of annihilation of a stationary electron of mass m_0 with a stationary positron of equal mass, a radiation is emitted. The wavelength of the resulting radiation is **[NSEP-2023]**

(A) $\frac{h}{m_0c}$ (B) $\frac{2h}{m_0c}$ (C) $\frac{m_0}{hc}$ (D) $\frac{m_0c}{h}$

Ans. **(A)**

Sol. In the annihilation process, two photons will be emitted in opposite direction to conserve the momentum.

So, from energy conservation,

$$2\frac{hc}{\lambda} = 2m_0c^2$$

$$\therefore\ \lambda = \frac{h}{m_0c}$$

25. In an X ray tube the electrons are expected to strike the target with a velocity that is 10% of the velocity of light. The applied voltage should be **[NSEP-2017]**

(A) 517.6 V (B) 1052 V (C) 2.559 kV (D) 5.680 kV

Ans. (C)

Sol. $v_e = 0.1C = 0.3 \times 10^8$ m/s

Assuming non-relatioistic case :

$$v = \frac{9.1 \times 9 \times 10^{-17}}{2 \times 1.6 \times 10^{-19}} = \frac{81.9}{3.2} \times 100$$

= 2559 volt

= 2.559 kv

26. In and atom an electron excites to the fourth orbit. When it jumps back to the energy levels a spectrum is formed. Total number of spectral lines in this spectrum would be **[NSEP-2017]**

(A) 3 (B) 4 (C) 5 (D) 6

Ans. (A)

Sol. Since there is only one atom, so number of line will be 3

27. The energy of the characteristic X-ray photon in a Coolidge tube comes from **[NSEP-2018]**

(A) the kinetic energy of striking electron.

(B) the kinetic energy of the free electrons of the target.

(C) the kinetic energy of the ions of the target.

(D) the electronic transition of the target atom.

Ans. (D)

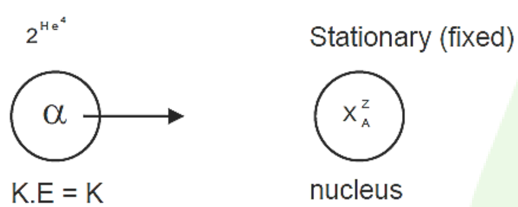
Sol. Energy of x-rays in characteristic x-ray photon comes from electronic transition of in the target atom

28. An alpha particle with kinetic energy K approaches a stationary nucleus having atomic number Z. The distance of closest approach is b. Therefore, the distance of closest approach for a nucleus of atomic number 2Z is **[NSEP-2018]**

(A) b/2. (B) $\sqrt{2}$ b. (C) 2 b. (D) 4 b.

Ans. (C)

Sol.



$$K = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{r}$$

$$r = \frac{2ze^2}{4\pi\varepsilon_0 K} \Rightarrow r = \frac{2Ze^2}{4\pi\varepsilon_0 K} = b$$

$$K = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(2Ze)}{r_{min}}$$

$$r_{min} = \frac{4Ze^2}{4\pi\varepsilon_0 K}$$

$\Rightarrow r_{min} = 2b$

29. In a nuclear reaction, two photons each of energy 0.51 MeV are produced by electron-positron annihilation. The wavelength associated with each photon is: **[NSEP-2019]**

(A) 2.44×10^{-12} m
(B) 2.44×10^{-8} m
(C) 1.46×10^{-12} m
(D) 3.44×10^{-10} m

Ans. (A)

Sol. $\lambda = \frac{1240 \times 10^{-9}}{0.51 \times 10^{6}} m$

$= 2431.3 \times 10^{-15}$ m

$= 2.44 \times 10^{-12}$ m

30. Natural Uranium is a mixture of $^{238}_{92}U$ and $^{235}_{92}U$ with a relative mass abundance of 140 :1. The ratio of radioactivity contributed by the two isotopes of natural uranium, if their half-lives are 4.5×10^{9} years and 7.0×10^{8} years respectively is **[NSEP-2020]**

(A) 99.3: 0.7
(B) 50.3: 49.7
(C) 95.6: 04.4
(D) cannot be estimated

Ans. (C)

Sol. In a sample of uranium of mass M, the masses of the two isotopes are

$M_1 = \frac{140}{141} M$ and $M_2 = \frac{1}{141} M$ The number of atoms of the two isotopes are

$N_1 = \frac{140}{141} M \frac{N_A}{238}$ and $N_2 = \frac{1}{141} M \frac{N_A}{235}$ Knowing further that $N = N_0 e^{-\lambda t}$ gives the Activity

As $A_1 = -\frac{dN_1}{dt} = \lambda N_1 = \frac{\ln 2}{T_1} \frac{140}{141} M \frac{N_A}{238}$ and $A_2 = -\frac{dN_2}{dt} = \lambda N_2 = \frac{\ln 2}{T_2} \frac{1}{141} M \frac{N_A}{235}$ The

relative contribution of Activity thus turns out to be $\frac{A_1}{A_1 + A_2} : \frac{A_2}{A_1 + A_2} \Rightarrow \frac{1}{4.5} \times \frac{140}{238} : \frac{1}{0.7} \times \frac{1}{235}$

$\Rightarrow 0.1307 : 0.0060 :: \frac{0.1307}{0.1367} \times 100 : \frac{0.0061}{0.1367} \times 100 \Rightarrow 95.6\%$ and 4.4%

31. If the specific activity of C^{14} nuclide in a certain ancient wooden toy is known to be $\frac{3}{5}$ of that in a recently fallen tree of the same class, the age of the ancient wooden toy is (The half life of C^{14} is 5570 years) **[NSEP-2021]**

(A) 5570 years
(B) 4105 years
(C) 3342 years
(D) 2785 years

Ans. (B)

Sol. According to the law of radioactive disintegration $N = N_0 e^{-\lambda t}$ The activity therefore is

$-\frac{dN}{dt} = \lambda N_0 e^{-\lambda t}$ Given that at certain time t the activity of the sample is

$$\left(-\frac{dN}{dt}\right)_t = \frac{3}{5}\left(-\frac{dN}{dt}\right)_{t=0} = \frac{3}{5}\lambda N_0$$

So $e^{-\lambda t} = \frac{3}{5} \Rightarrow \lambda t = \ln\left(\frac{5}{3}\right)$

or $\quad \dfrac{\ln 2}{T} \times t = \ln\left(\dfrac{5}{3}\right) \Rightarrow t = \dfrac{T \times \ln(5/3)}{\ln 2} = \dfrac{5570 \times 0.5108}{0.693} = 4105$ years

32. Fission of one nucleus of. ^{235}U releases 200 MeV energy in average. Minimum amount of. ^{235}U required to run 1000 MW reactor per year of continuous operation (assuming 30% efficiency) is **[NSEP-2022]**

(A) 1280 ton (B) 1.28 ton (C) 1.1 ton (D) 1.1×10^5ton

Ans. (B)

Sol. $\because$ Amount of energy required in a day

= 1000 × 24 × 3600 MJ

$\rightarrow$ no of nuclie required per day = $\dfrac{24 \times 36 \times 10^5 \text{MJ}}{200 \times 1.6 \times 10^{-19} \times (0.3)\text{MJ}}$

= 9×10^{24} (at 30% efficiency)

$\rightarrow$ no. of moles required per day = $\dfrac{\text{Number of nuclei}}{6 \times 10^{23}} = \dfrac{9 \times 10^{24}}{6 \times 10^{23}} = 15$

$\rightarrow$ no. of moles required per year = 15 × 365 = 5475

$\rightarrow$ mass required = (5475 × 0.235) kg $\cong$ 1.28 ton

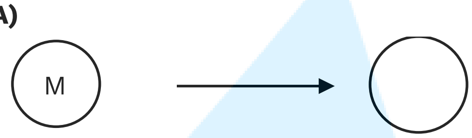
33. A hydrogen atom $\left(M_H = 1.67 \times 10^{-27}\text{kg}\right)$, initially at rest, emits a photon and goes from the excited state $n = 5$ to the ground state. The recoil speed of the atom is nearly **[NSEP-2023]**

(A) 4.2ms^{-1} (B) $4 \times 10^{-4}\text{ms}^{-1}$

(C) $2 \times 10^{-2}\text{ms}^{-1}$ (D) $8 \times 10^{2}\text{ms}^{-1}$

Ans. **(A)**

Sol.



1.67×10^{-27}

34. Continuous and Characteristic X - rays are produced when electron beam accelerated by a high potential difference of V volt (say) is made to hit the metallic target such as Molybdenum in a modern Coolidge tube. Let λ_{min} be the smallest possible wavelength of continuous X - rays and $\lambda_{L\alpha}$ be the maximum wavelength of the characteristic X - rays. Then **[NSEP-2023]**

(A) $\lambda_{L\alpha}$ increases with increase in V (B) $\lambda_{l,\alpha}$ decreases with increase in V

(C) λ_{min} increases with increase in V (D) λ_{min} decreases with increase in V

Ans. (D)

Sol. Since $\lambda_{L\alpha}$ does not depends on voltage & $\lambda_{min} = \dfrac{hc}{ev}$