Unit VIII: Atoms and Nuclei **15 Periods**

Chapter–12: Atoms

Alpha-particle scattering experiment; Rutherford's model of atom; Bohr model, energy levels, hydrogen spectrum.

Chapter–13: Nuclei

Composition and size of nucleus, Radioactivity, alpha, beta and gamma particles/rays and their properties; radioactive decay law.

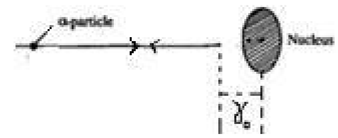
Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission, nuclear fusion.

801. Define the distance of closest approach. **CBSE (D)-2017**

[Ans. Distance of closest approach : The minimum distance up to which an α-particle can approach the nucleus just before retracing its path, is known as distance of closest approach

$$r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2Ze^2)}{E_K}$$

$= 2.5 \times 10^{-14}$ m



802. The K. E. of α –particle incident on gold foil is doubled. How does the distance of closest approach change? **CBSE (D)-2017,(AI)-2015,2012**

[Ans. $r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2Ze^2)}{E_K}$ ⇨ $r_0 \propto \frac{1}{E_K}$

hence, distance of closest approach will be halved when K.E. is doubled

803. In the Rutherford's scattering experiment the distance of closest approach for an α –particle is d_0. If α –particle is replaced by a proton, how much kinetic energy in comparison to α –particle will it require to have the same distance of closest approach d_0 ? **CBSE (F)-2009**

[Ans. $E_{K_\alpha} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{d_0}$ & $E_{K_p} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{d_0}$ ⇨ $E_{K_p} = \frac{1}{2}E_{K_\alpha}$

804. Determine the distance of closest approach when an alpha particle of kinetic energy 4.5 MeV strikes a nucleus of $Z = 80$, stops and reverses its direction. **CBSE (AI)-2015, 2012, (AIC)-2015**

[Ans. $r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2Ze^2)}{E_K} = 9 \times 10^9 \times \frac{2 \times 80 \times (1.6 \times 10^{-19})^2}{4.5 \times 10^6 \times 1.6 \times 10^{-19}}$ = 5.12 x 10^{-14} m

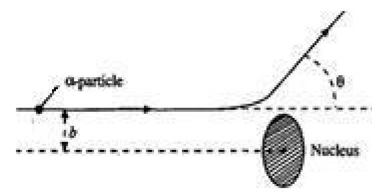
805. (i) What is Impact parameter ? **CBSE (AIC)-2015**

(ii) What is the significance of impact parameter ?

[Ans. (i) Impact parameter (b) :

It is the perpendicular distance of the initial velocity vector of the α-particle from the

(ii) Significance : It gives an estimate of size of nucleus



806. The trajectories, traced by different α –particles, in Geiger-Marsden experiment were observed as shown in figure. (a) What names are given to the symbols 'b' and 'θ' shown here ? **CBSE (DC)-2008**

(b) What can we say about values of b for (i) $\theta = 0^0$ (ii) $\theta = \pi$ radians ?

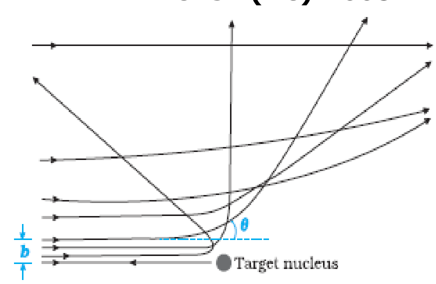
[Ans. (a) symbol **'b'** represents **impact parameter**

& **'θ'** represents **scattering angle**

(b) $b = \frac{Ze^2 \cot\theta/2}{4\pi\varepsilon_0 (\frac{1}{2} m u^2)}$

(i) **when $\theta = 0^0$**, **b** is maximum & represent the **atomic size**

(ii) **When $\theta = \pi$ radians, b** is minimum & represent **nuclear size**



807. State Bohr's quantization condition for defining stationary orbits. **CBSE (D)-2016,(D)-2012,(F)-2010**

[Ans. Bohr's quantization condition : electrons can revolve only in those orbits in which their angular momentum is an integral multiple of $\frac{h}{2\pi}$

i, e, $mvr = n\frac{h}{2\pi}$ where $n = 1,2,3, ———————$

These orbits are called stationary orbits and electrons do not radiate energy while revolving in these orbits

908. State Bohr postulate of hydrogen atom that gives the relationship for the frequency of emitted photon in a transition. **OR** **CBSE (F)-2016**

State Bohr's postulate of hydrogen atom which successfully explains emission lines in the spectrum of hydrogen atom.

[Ans. Bohr's postulate of transition : **CBSE (AI)-2015, (D)-2013**

When an electron makes a transition from higher (E_2) to lower energy level (E_1), a photon is emitted which have the energy equal to the energy difference of two levels.

i, e, $h\nu = E_2 - E_1$ This equation is called Bohr's frequency condition

809. The ground state energy of hydrogen atom is –13.6 eV. What are the kinetic and potential energies of electron in this state ? **CBSE (AI)-2014, 2011,(AIC)-2002**

[Ans. $E_K = +13.6\ eV$ & $P.E. = 2\ X\ (-13.6) = -27.2\ eV$

810. The total energy of an electron in the first excited state of hydrogen atom is $-3.4\ eV$. What is the kinetic and potential energy of the electron in this state ? **CBSE (DC)-2010,(D)-2001**

[Ans. $E_K = +3.4\ eV$ & $P.E. = 2\ X\ (-3.4) = -6.8\ eV$

811. Given the value of the ground state energy of hydrogen atom as –13.6 eV. Find out its kinetic and potential energy in the ground and second excited states. **CBSE (AI)-2015,2008**

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

For ground state $n = 1$, ⇨ $E_1 = -13.6\ eV$ ⇨ $E_K = +13.6\ eV$ & $P.E. = 2\,X\,(-13.6) = -27.2\ eV$

For II excited state $n = 3$, ⇨ $E_3 = -\frac{13.6}{3^2} = -1.51\ eV$ ⇨ $E_K = +1.51\ eV$ & $P.E. = 2\,X\,(-1.51) = -3.02\ eV$

812. The value of ground state energy of hydrogen atom is –13.6 eV. **CBSE (AI)-2008, 2001, (F)-2009**

(i) what does the negative sign signify ?

(ii) How much energy is required to take an electron in this atom from the ground state to the first excited state ?

[Ans. (i) Negative sign shows that electron is bound with the nucleus by electrostatic force

(ii) $E_n = -\frac{13.6}{n^2}$eV & For ground state n =1 and for first excited state n =2

⇨ $\Delta E = E_2 - E_1 = -\frac{13.6}{2^2} - \left(-\frac{13.6}{1^2}\right) = -3.4 + 13.6 = 10.2$ eV

813. In the ground state of hydrogen atom, its Bohr radius is given as 5.3 X $10^{-11}\,m$. The atom is excited such that the radius becomes 21.2X $10^{-11}\,m$. Find - **CBSE (AI)-2016**

(i) the value of principal quantum number and

(ii) the total energy of the atom in this excited state.

[Ans. (i) $r = n^2\,r_0$ ⇨ $n^2 = \frac{r}{r_0}$ ⇨ $n^2 = \frac{21.2\,X\,10^{-11}}{5.3\,X\,10^{-11}} = 4$ ⇨ $n = 2$

(ii) $E_n = -\frac{13.6}{n^2}$e ⇨ $E_2 = -\frac{13.6}{2^2}$eV $= -3.4$ eV

814. Calculate the de-Broglie wavelength of the electron orbiting in the $n = 2$ state of hydrogen atom.

[Ans. $E_k = \frac{13.6}{n^2}$eV $= \frac{13.6}{2^2}$eV $= \frac{13.6}{4}$eV $= 3.4$ eV $= 3.4$ X 10^{-19}J **CBSE (AI)-2016**

de-Broglie wavelength, $\lambda = \frac{h}{\sqrt{2mE_k}} = \frac{6.6\,X\,10^{-34}}{\sqrt{2X\,9.1\,X\,10^{-31}\,X3.4\,X\,1.6\,X10^{-19}}} = 0.6$ X $10^{-10}\,m$

815. What is the longest wavelength of photon that can ionize a hydrogen atom in its ground state ? Specify the type of radiation. **CBSE (D)-2007**

[Ans. $\Delta E = \frac{hc}{\lambda}$ ⇨ $\lambda = \frac{hc}{\Delta E} = \frac{6.6\,X\,10^{-34}\,X\,3\,X\,10^8}{13.6\,X\,1.6\,X\,10^{-19}} = 0.910\,X\,10^{-10}\,m$, Ultraviolet region

816. Write the expression for Bohr's radius in hydrogen atom. **CBSE (D)-2010**

[Ans. $r_0 = \frac{\varepsilon_0 h^2}{\pi m e^2} = 0.53\,A^0$

817. In hydrogen atom, if the electron is replaced by a particle which is 200 times heavier but have the same charge, How would its radius change ? **CBSE (F)-2008**

[Ans. radius will be 1/200 times, **Reason :** $r = \frac{\varepsilon_0\,n^2\,h^2}{\pi\,m\,Ze^2}$ ⇨ $r \propto \frac{1}{m}$

818. What is the ratio of radii of the orbits corresponding to first excited state and ground state in a hydrogen atom ?

[Ans. 4:1 as $r \propto n^2$ **CBSE (D)-2010**

819.The radius of innermost electron orbit of a hydrogen atom is 5.3 X 10^{-11} m. What is the radius of orbit in the second excited state ? **CBSE (D)-2010**

[Ans. For II excited state $n = 3$ $r = n^2\,r_0 = 3^2$ X 5.3 X $10^{-11} = 47.7$ X $10^{-11}\,m$

820. Find out the wavelength of the electron orbiting in the ground state of hydrogen atom. **CBSE (D)-2017**

[Ans. $r_0 = 0.53\,A^0$ & For ground state $n = 1$

By the de-Broglie relation,

$2\pi r = n\,\lambda$ ⇨ $2\ X\ 3.14\ X\ 0.53\,X\,10^{-10} = 1\,X\,\lambda$ ⇨ $\lambda = 3.32\,X\,10^{-10}\,m = 3.32\,A^0$

821. Use Bohr model of hydrogen atom to calculate the speed of the electron in the first excited state.
[Ans. For first excited state, n = 2 **CBSE (AI)-2016**

$v_n = \frac{1}{137}\frac{c}{n}$ ⇨ $v_2 = \frac{1}{137} X \frac{3 X 10^8}{2} = 1.09 X 10^6$ m/s

822. Use Rydberg formula to determine the wavelength of H_α line. (Given : Rydberg's constant R =1.03 X 10^7 m^{-1})
[Ans. For H_α line, n_1=2 and n_2=3 **CBSE (AI)-2015, (D)-2012**

⇨ $\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$ ⇨ $\lambda = \frac{36}{5R} = \frac{36}{5 X 1.03 X 10^7} = 6990\ A^0$

823. When H_α line in the emission spectrum of hydrogen atom obtained ? Calculate the frequency of photon emitted during this transition. **CBSE (AI)-2016**
[Ans. for H_α line/first line in Balmer series transition is from $n = 3$ to $n = 2$

$\frac{1}{\lambda_{max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$

⇨ $\nu = \frac{c}{\lambda} = c X \frac{5R}{36} = \frac{3X10^8 X\ 5\ X\ 1.09\ X\ 10^7}{36} = 4.7 X 10^{14}$ Hz

824. Calculate the shortest wavelength of the spectral lines emitted in Balmer series. (Rydberg constant, $R = 10^7 m^{-1}$)
[Ans. $\frac{1}{\lambda_{min}} = R\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right] = R\left[\frac{1}{4} - 0\right] = \frac{R}{4}$ ⇨ $\lambda_{min} = \frac{4}{R} = \frac{4}{10^7}$ m = 4000 A^0 **CBSE (AI)-2016**

825. Calculate the wavelength of radiation emitted when electron in a hydrogen atom jumps from $n = \infty$ to $n = 1$.
[Ans. $\frac{1}{\lambda} = R\left[\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right] = R\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right] = R\ [1 - 0] = R$ **CBSE (AI)-2016**

⇨ $\lambda = \frac{1}{R} = \frac{1}{1.09\ X\ 10^7} m = 912\ A^0$

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826. (i) Write the relation between mass number and radius of a nucleus. **CBSE (F)-2012,(AI)-2011**
(ii) Show that nuclear density in a given nucleus is independent of mass number A. **CBSE (D)-2015,2013,2012**
[Ans. (i) $R = R_0\ A^{1/3}$ where R_0 is constant

(ii) nuclear density $\rho = \frac{M}{V} = \frac{A}{\frac{4}{3}\pi r^3} = \frac{A}{\frac{4}{3}\pi(\ R_0 A^{1/3}\ )^3} = \frac{3}{4\ \pi R_0^3}$

827. Compare the radii of two nuclei with mass numbers 1 and 27 respectively. **CBSE (AI)-2012,2010,(D)-2011**
[Ans. $R \propto A^{1/3}$ ⇨ $\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{27}\right)^{1/3} = \frac{1}{3}$

828. What is the nuclear radius of ^{125}Fe, if that of ^{27}Al is 3.6 Fermi ? **CBSE (AI)-2008**
[Ans. $R \propto A^{1/3}$ ⇨ $\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{125}{27}\right)^{1/3} = \frac{5}{3}$

⇨ $R_1 = R_2 X \frac{5}{3} = 3.6 X \frac{5}{3} = 6$ Fermi

829. Two nuclei have mass numbers in the ratio 1:2. What is the ratio of their nuclear densities ? **CBSE (D)-2009**
[Ans. 1:1 as nuclear density does not depend on mass number

830. What are nuclear forces ? State any two characteristic properties of nuclear forces.
CBSE (AIC)-2017,(AI)-2015,2012,2011,2008,2007
[Ans. Nuclear Forces ; Very short range strongest attractive forces, which firmly hold the nucleons together inside a nucleus, are called nuclear forces.

Properties: (i) very short range, strongest attractive forces.
(ii) charge independent.
(iii) non-central forces
(iv) do not obey inverse square law

831. Define the term mass defect. **CBSE (AIC)-2014,2001**
[Ans. Mass defect (Δm): The difference in mass of a nucleus and its constituents, is called the mass defect.

$\Delta m = [\ Zm_p + (A - Z)\ m_n\ ] - M_N$

832. Define binding energy of a nucleus. **CBSE (AIC)-2002**

[Ans. Binding Energy (BE) **:** It is defined as the minimum energy required to separate its nucleons and place them at rest at infinite distance apart

It is the equivalent energy of mass defect, i,e, $BE = \Delta m \text{ X } c^2$

833. What is meant by the term binding energy per nucleon **CBSE (DC)-2010**

[Ans. Binding Energy per nucleon (E_{bn}) **:** It is the average energy per nucleon needed to separate a nucleus in to its individual nucleons

$$E_{bn} = \frac{E_b}{A} = \frac{\Delta m\, c^2}{A}$$

834. The binding energies of deuteron $({}_1^2\text{H})$ and $\alpha - particle$ $({}_2^4\text{He})$ are 1.25 and 7.2 MeV/ nucleon respectively. Which nucleus is more stable ? **CBSE (AIC)-2001**

[Ans. $\alpha - particle$ $({}_2^4\text{He})$ is more stable as BE per nucleon of ${}_2^4\text{He}$ is more than that of ${}_1^2\text{H}$

835. Which out of two nuclei ${}_3^7X$ & ${}_3^4Y$ is more stable ? **CBSE (AI)-2004**

[Ans. Nucleus ${}_3^7X$ is more stable because n/p ratio for ${}_3^7X$ is more than that for ${}_3^4Y$

Reason : A nucleus is more stable if, it has -(a) high value of B.E./A (b) greater n/p ratio, or (c) even-even nucleus.

836. Why is mass of a nucleus is always less than the sum of the masses of its constituent, neutrons & protons ? **CBSE (AI)-2004**

[Ans. When nucleons approach each other to form a nucleus, they strongly attract each other. Hence their potential energy decreases and becomes negative. This decrease in P.E. results in the decrease in the mass of the nucleons

837. If the nucleons of a nucleus are separated far apart from each other, the sum of the masses of all these nucleons is larger than the mass of the nucleus. Why ? **CBSE (AIC)-2003**

[Ans. For the separation of nucleons to a distance far apart from each other, an energy equal to B.E. of the nucleus is given to these nucleons. From E = Δm c^2, thus mass difference comes

838. If the total number of neutrons & protons in a nuclear reaction is conserved, how is then the energy is absorbed or evolved in the reaction ? **CBSE (AI)-2015**

OR

In a nuclear reaction,

$${}_2^3\text{He} + {}_2^3\text{He} \longrightarrow {}_2^4\text{He} + {}_1^1\text{H} + 12.86 \text{ MeV}$$ **CBSE (D)-2013**

though the number of nucleons is conserved on both sides of the reaction, yet the energy is released. How ? Explain.

[Ans. Since certain mass disappears in the formation of a nucleus (mass defect), it appears in the form of energy E = Δmc^2. Thus the difference of B.E. of the two sides appear as energy released or absorbed in a nuclear reaction

839. A nucleus with mass number A = 240 and BE/A = 7.6 MeV breaks in to two fragments each of A = 120 with BE/A = 8.5 MeV. Calculate the energy released. **CBSE (D)-2016**

[Ans. Energy released = BE of two fragments − BE of nucleus

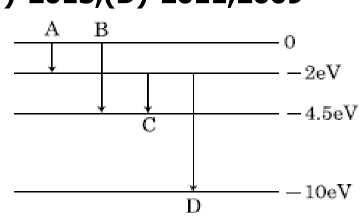
= 2 X 120 X 8.5 − 240 X 7.6 = 240 (8.5 − 7.6) = 240 X 0.9 = 216 MeV

840. Calculate the energy released in the fusion reaction : **CBSE (D)-2016**

$${}_1^2\text{H} + {}_1^2\text{H} \longrightarrow {}_2^3\text{He} + n,$$ where BE of ${}_1^2\text{H} = 2.23\ MeV$ and of ${}_2^3\text{He} = 7.73\ MeV$

[Ans. Energy released $= BE$ of ${}_2^3\text{He} - BE$ of $({}_1^2\text{H} + {}_1^2\text{H}) = 7.73 - (2.23 + 2.23) = 3.73$ MeV

841. The energy levels of a hypothetical atom are shown below. Which of the shown transitions will result in the emission of photon of wavelength 275 nm ? **[Ans.** B] **CBSE (F)-2013,(D)-2011,2009**



[Ans. $\lambda = 275 \text{ nm} = 275 \text{ X } 10^{-9}\ m$

$$\Delta E = \frac{hc}{\lambda} = \frac{6.6\ X\ 10^{-34}\ X\ 3\ X\ 10^{8}}{2.75 \text{ X } 10^{-7} \text{ X } 1.6\text{X } 10^{-19}} = 4.5 \text{ eV}$$

For transition B

$\Delta E = 0 - (-4.5) = 4.5$ eV

842. Calculate the binding energy per nucleon of ${}_{20}^{40}Ca$ nucleus. **CBSE (AI)-2007,2004,2002,(D)-2002**

(Given, Mass of ${}_{20}^{40}Ca$ = 39.962589 u, Mass of proton= 1.007825 u, Mass of neutron =1.008665 u & 1u= 931 MeV/c^2)

[Ans. mass defect, Δm = [Zm_p + (A − Z) m_n] $-M_N$ = [20(1.007825) + 20(1.008665)]−39.962589 =0.367211

⇨ B.E. = 0.367211 X 931 = 341.87 MeV ⇨ B.E. per nucleon = $\frac{341.87}{40}$ = 8.547 MeV

843. What is radioactivity ? **CBSE (AIC)-2001**

[**Ans**. **Radioactivity** : The phenomenon of spontaneous and continuous emission of radiations such as α or β and γ –rays from the nucleus of heavy elements is called radioactivity

844. When a radioactive radiation is placed in an electric or magnetic field it divides in to three parts. Why ? **CBSE (AIC)-2014**

[**Ans**. Radioactive decay occurs in series where daughter product give rise to grand daughter product and so on. Some of them emit α –particles while others emit β –particles. If after α- emission or β- emission, nucleus is left in the excited state it may emit γ –rays. Therefore radioactive sample give out α –particle, β –particles and γ –rays together

845. Why do α –particles have high ionising power ? **CBSE (F)-2010**

[**Ans**. Because of their large mass & large nuclear cross section α –particles have highest ionizing power

846. Which of the following radiations α-rays, β-rays, γ-rays **CBSE (AI)-2001**

(i) are similar to X-rays
(ii) are easily absorbed by the matter
(iii) travel with greatest speed
(iv) are similar in nature to cathode rays.

[**Ans**. (i) $\gamma - rays$ (ii) α-rays (iii) γ-rays (iv) β-rays

847. What is the difference between an electron and a $\beta - particle$? **CBSE (AIC)-2001**

[**Ans**. Both are essentially the same. In fact an electron of nuclear origin is called $\beta - particle$

848. A nucleus contains no electrons, yet it ejects them. How ? **CBSE (AIC)-2003**

[**Ans**. A neutron in a nucleus decays in to a proton and an antineutrino. It is this electron which is emitted as $\beta - particle$

$$n \longrightarrow p + {}_{-1}^{0}e + \overline{\nu}$$

849. A nucleus undergoes $\boldsymbol{\beta}^{-}decay$. How does its (i) mass number (ii) atomic number change ? **CBSE (D)-2011**

[**Ans**. During $\boldsymbol{\beta}^{-}decay$ (i) mass number remains same (ii) atomic number increases by one

850. What is β-decay ? **CBSE (F)-2002**

[**Ans**. $\boldsymbol{\beta - decay}$: The process of spontaneous emission of β –particle from a radioactive nucleus is called β –decay

851. (i) Write the nuclear decay process of β-decay ${}_{15}^{32}P$ **CBSE (AI)-2010,2004,(D)-2004**

(ii) Write the β –decay of tritium in symbolic form. **CBSE (F) -2015,(AI)-2013**

[**Ans**. (i) ${}_{15}^{32}P \longrightarrow {}_{16}^{32}\mathrm{S} + {}_{-1}^{0}e + \overline{\nu}$

(ii) ${}_{1}^{3}\mathrm{H} \longrightarrow {}_{2}^{3}\mathrm{He} + {}_{-1}^{0}e + \overline{\nu}$

852. Write the basic nuclear process involved in the emission of (a) β^{-} decay and (b) β^{+} decay in a symbolic form, by a radioactive nucleus. **CBSE (D)-2017,(AI)-2016,2013,(F)-2015,(AIC)-2015**

[**Ans**. (a) β^{-} decay, $n \longrightarrow p + {}_{-1}^{0}e + \overline{\nu}$

(b) β^{+} decay, $p \longrightarrow n + {}_{+1}^{0}e + \nu$

853. Why is the detection of neutrinos found very difficult ? **CBSE (AI)-2016,2013,(F)-2015,(AIC)-2015**

[**Ans**. Because neutrinos have no charge, almost no mass and their interaction with matter is very weak

854. Why the mass number of a nuclide undergoing β-decay does not change? **CBSE (DC)-2003**

OR

In both β-decay process, the mass number of the nucleus remains same, whereas the atomic number Z increases by one in β^{-}decay and decreases by one in β^{+}decay. Explain giving reason. **CBSE (F)-2014**

[**Ans**. In both β-decay process, the conversion of neutron to proton or proton to neutron inside the nuleus. These nucleons have nearly equal masses. Hence mass number does not change and

In $\boldsymbol{\beta}^{-}$ decay $n \longrightarrow p + {}_{-1}^{0}e + \overline{\nu}$

or ${}_{Z}^{A}\mathrm{X} \longrightarrow {}_{Z+1}^{A}\mathrm{Y} + {}_{-1}^{0}e + \overline{\nu}$

In $\boldsymbol{\beta}^{+}$ decay $p \longrightarrow n + {}_{+1}^{0}e + \nu$

or ${}_{Z}^{A}\mathrm{X} \longrightarrow {}_{Z+1}^{A}\mathrm{Y} + {}_{+1}^{0}e + \nu$

855. Write the nuclear reactions for the following- **CBSE (DC)-2005**

(i) α-decay of ${}^{242}_{94}Pu$ (ii) β-decay of ${}^{32}_{15}P$ (iii) β^{+}decay of ${}^{11}_{6}\text{C}$ (iv) α-decay of ${}^{226}_{88}Ra$

[Ans. (i) ${}^{242}_{94}Pu \longrightarrow {}^{238}_{92}U + {}^{4}_{2}\text{He}$

(ii) ${}^{32}_{15}P \longrightarrow {}^{32}_{16}\text{S} + {}^{0}_{-1}e + \overline{\nu}$

(iii) ${}^{11}_{6}\text{C} \longrightarrow {}^{11}_{5}\text{C} + {}^{0}_{+1}e + \nu$

(iv) ${}^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^{4}_{2}\text{He}$

856. In the reactions given below, find the values of x, y & z and a, b & c. **CBSE (AI)-2016**

(a) ${}^{12}_{6}\text{C} \longrightarrow {}^{y}_{z}\text{B} + x + \nu$ **[Ans.** (a) x = ${}^{0}_{+1}e$, y =5, z =11 (b) a=10, b=2, c= 4]

(b) ${}^{12}_{6}\text{C} + {}^{12}_{6}\text{C} \longrightarrow {}^{20}_{a}\text{Ne} + {}^{c}_{b}\text{He}$

857. In the following nuclear reaction assign the value of Z and A. **[Ans.** (a) Z = 56, A = 89] **CBSE (AI)-2015**

$$n + {}^{235}_{92}U \longrightarrow {}^{144}_{Z}Ba + {}^{A}_{36}X + 3\,n$$

858. Identify the nature of the radioactive radiations emitted in each step of the decay process given below:

${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y \longrightarrow {}^{A-4}_{Z-1}W$ **CBSE (AI)-2015**

[Ans. ${}^{A}_{Z}X \xrightarrow{\alpha} {}^{A-4}_{Z-2}Y \xrightarrow{\beta^-} {}^{A-4}_{Z-1}W$

859. Give the mass number and atomic number of elements on the right hand side of the decay process. **CBSE (D)-2004**

$${}^{220}_{86}Ru \longrightarrow Po + \text{He}$$

[Ans. ${}^{220}_{86}Ru \longrightarrow {}^{216}_{84}Po + {}^{4}_{2}\text{He}$

==

860. A radioactive nucleus 'A' undergoes series of decays shown in the following scheme : **CBSE (AI)-2015**

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\gamma} A_3$$

If mass number and atomiv number of A_3 are 176 and 69 respectively, find the mass number and atomic number of A

[Ans. ${}^{180}_{70}A \xrightarrow{\alpha} {}^{176}_{68}A_1 \xrightarrow{\beta} {}^{176}_{69}A_2 \xrightarrow{\gamma} {}^{176}_{69}A_3$

861. A radioactive nucleus 'A' undergoes a series of decays according to the following scheme- **CBSE (D)-2017,(D)-2009,(AIC)-2002**

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

If the mass number and atomic number of A are 180 & 72 respectively, What are these numbers for A_4?

[Ans. ${}^{180}_{72}A \xrightarrow{\alpha} {}^{176}_{70}A_1 \xrightarrow{\beta} {}^{176}_{71}A_2 \xrightarrow{\alpha} {}^{172}_{69}A_3 \xrightarrow{\gamma} {}^{172}_{69}A_4$

862. A radioactive isotope D decays according to the sequence - **CBSE (AI)-2002**

$$D \xrightarrow{{}^{1}_{0}n} D_1 \xrightarrow{\alpha} D_2$$

If the mass number & atomic number for D_2 are 176 & 71 respectively, find the mass number and atomic number of D

[Ans. ${}^{181}_{69}D \xrightarrow{{}^{1}_{0}n} {}^{180}_{69}D_1 \xrightarrow{\alpha} {}^{176}_{67}D_2$]

863. The sequence of stepwise decays of a radioactive nucleus is - **CBSE (D)-2010**

$$D \xrightarrow{\alpha} D_1 \xrightarrow{\beta^-} D_2$$

If the atomic number and mass number of D_2 are 71 & 176 respectively, What are their corresponding values for D ?

[Ans. ${}^{180}_{72}D \xrightarrow{\alpha} {}^{176}_{70}D_1 \xrightarrow{\beta^-} {}^{176}_{71}D_2$

864. (a) Write two important limitations of Rutherford nuclear model of the atom. **CBSE (D)-2017,(AIC)-2015**
(b) How these were explained in Bohr's model of hydrogen atom ? **CBSE (AIC)-2015**

[Ans. (a) Limitations of Rutherford nuclear model of the atom :

(i) Electron moving in a circular orbit around the nucleus would get accelerated. Therefore it looses its energy and hence it would spiral into the nucleus

(ii) Due to continuously changing radii of orbits, electron will emit em waves of all frequencies. Hence atom should emit continuous spectrum

(b) Explanation according to Bohr's model of hydrogen atom :

(i) Electron in an atom can revolve in certain stable orbits without the emission of radiant energy, in which

$$m\,v\,r = n\frac{h}{2\pi} \qquad \text{Where} \quad n = 1,2,3,\text{--------}$$

(ii) Energy is released/ absorbed only, when an electron jumps from one stable orbit to another stable orbit. This results in a discrete spectrum

865. How does de-Broglie explain the stationary orbits for revolution of electrons using Bohr's quantization condition ?

[Ans. de-Broglie's explanation of Stationary orbits **CBSE (D)-2016,(D)-2012,(F)-2010**

According to de- Broglie hypothesis,

$$\lambda = \frac{h}{p} \quad \Rightarrow \quad p = \frac{h}{\lambda}$$

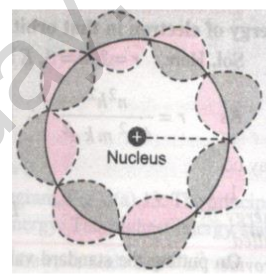
But for circular orbits,

$L = m\,v\,r = r_n\,p$ where r_n is the radius of quantized orbits

⇨ $n\,\frac{h}{2\pi} = r_n\,\frac{h}{\lambda}$ $[\because L = n\frac{h}{2\pi}]$

⇨ $2\,\pi\,r_n = n\,\lambda$

⇨ Circumference of permitted orbits are integer multiples of wavelength λ



866. Derive the Bohr's quantization condition for angular momentum of the orbiting of electron in hydrogen atom, Using de-Broglie's hypothesis. **CBSE (AIC)-2017,(AI)-2016,2015,2011**

[Ans. de-Broglie wavelength

$$\lambda = \frac{h}{mv}$$

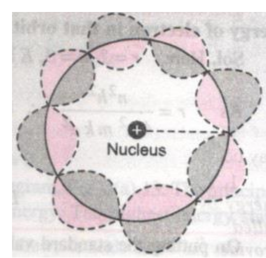
For electron moving in n^{th} orbit,

$$2\pi r = n\,\lambda$$

⇨ $2\pi r = n\frac{h}{mv}$

⇨ $m\,v\,r = n\,\frac{h}{2\pi}$

This is Bohr's postulate of quantization of angular momentum



867. Use de-Broglie's hypothesis to write the relation for the n^{th} radius of Bohr orbit interms of Bohr's quantization condition of orbital angular momentum. **CBSE (F)-2016**

[Ans. de Broglie Wavelength associated with electron in its orbit

$$\lambda = \frac{h}{p} = \frac{h}{m\,v_n}$$

Only those waves survive which form standing waves. For electron moving in n^{th} circular orbit of radius r_n

$2\pi r_n = n\,\lambda$ where n = 1,2,3,-------------

⇨ $2\pi r_n = n\frac{h}{m\,v_n}$

⇨ $r_n = n\frac{n\,h}{2\,\pi\,m\,v_n}$

868. (i) Define Ionization energy. What is its value for hydrogen atom ? **CBSE (AI)-2016,2010**
(ii) How would the ionization energy change when electron in hydrogen atom is replaced by a particle of mass 200 times that of the electron but having the same charge ?

[Ans. (i) **Ionization Energy** : It is the minimum energy required to just remove an electron from the atom

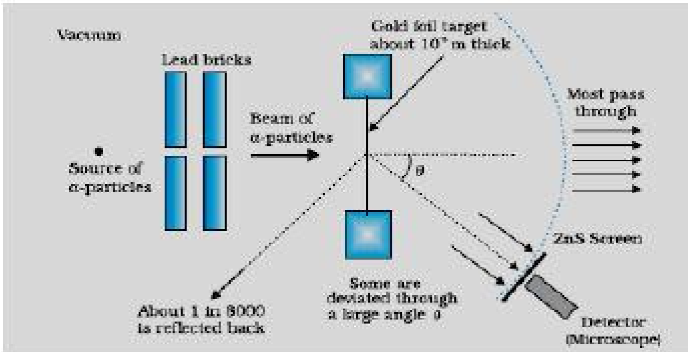
for H- atom ionization energy is $E_0 = \frac{m\,e^4}{8\,\varepsilon_0^2 h^2} = 13.6$ eV

(ii) As $E \propto m$, hence ionization energy becomes 200 times

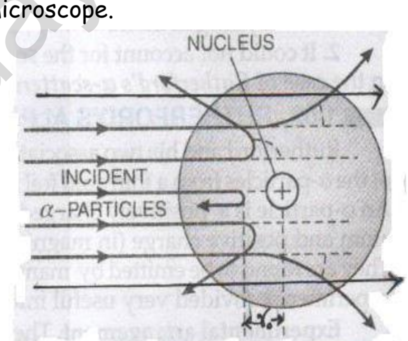
869. Draw a schematic arrangement of the Geiger – Marsden experiment for studying α –particle scattering by a thin foil of gold. Describe briefly, by drawing trajectories of the scattered α –particles, how this study can be used to estimate the size of the nucleus ? Draw a plot showing the number of particles scattered versus scattering angle θ.

CBSE (F)-2013,2010,2008,2003 (AI)-2009,(D)-2005

[Ans. <u>Geiger-Marsden experiment</u> (Rutherford's α–Particle scattering experiment) :



High energetic collimated beam of α–Particles is allowed to fall on a very thin gold foil as shown. The scattered α-particles are observed through a rotating detector consisting of ZnS screen and microscope.



<u>**Observations and Conclusions**</u> :

(i) most of the α–Particles passed un deflected through the foil.

It indicates that most of the space in an atom is empty.

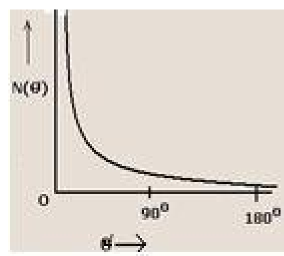
(ii) some α–Particles were deflected through small angles and only a few (1 in 8000) were deflected through large angles (> 90^0) to return back

It concludes that whole of the positive charge and almost whole mass is concentrated in a tiny central core known as nucleus.

(iii)The number of α–Particles at a scattering angle θ is

$$N(\theta) \propto \frac{1}{sin^4(\theta/2)}$$

It is due to the fact that, scattering of α-particles is in accordance with Coulomb's force.



Size of nucleus : It can be estimated by distance of closest approach

$$\frac{1}{2}\text{m}\,v^2 = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{r_0}$$

$$\Rightarrow \quad r_0 = \frac{1}{4\pi\varepsilon_0}\frac{(2Ze^2)}{\frac{1}{2}\text{m}\,v^2} = 2.5 \times 10^{-14} \text{ m}$$]

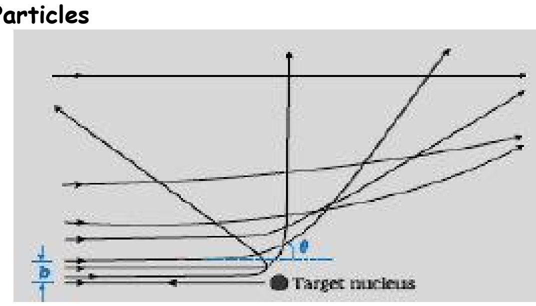
==

870. In Geiger- Marsden experiment, why is the most of the α–Particles go straight through the foil and only a small fraction gets scattered at large angles ? **CBSE (AIC)-2015**

[Ans. for most of the α–Particles, impact parameter is large, hence they suffer very small repulsion due to nucleus and go straight (right) through the foil

871. In Geiger-Marsden experiment, draw the trajectories traced by α–Particles in the Coulomb's field of target.

[Ans. Trajectories traced by α–Particles **CBSE (AIC)-2015**



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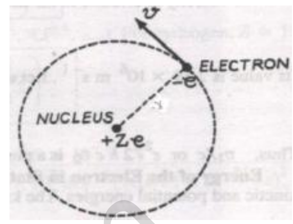
872. Using Bohr's postulates, derive the expression for the total energy of the electron in the stationary states of the hydrogen atom. Hence, derive the expression for the orbital velocity and orbital period of the electron moving in the n^{th} orbit of hydrogen atom. **CBSE (F)-2017,2014,2012,2011,(AI)-2015,2014,2013,(D)-2013**

[Ans. Bohr's theory of H-atom :

As the electrostatic force of attraction between electron and nucleus provides the necessary centripetal force



i,e, $\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{r^2}$

⇨ $mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}$ ------------(1)

According to Bohr's quantum condition

$m\,v\,r = n\frac{h}{2\pi}$ -----------(2)

on squaring eqn (2) and dividing by eqn (1) we get

$$\frac{m^2v^2r^2}{m\,v^2} = \frac{n^2h^2/\,4\pi^2}{\frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}}$$

⇨ $\boldsymbol{r = \frac{\varepsilon_0\, n^2\, h^2}{\pi\, m\, Ze^2}}$ ⇨ $\boldsymbol{r_n \propto n^2}$

For H-atom $Z = 1$ & for innermost orbit $n = 1$,

⇨ $r_0 = \frac{\varepsilon_0 h^2}{\pi\, m\, e^2}$ = 0.53 A^0. This is called **Bohr's orbit**

<u>Energy of electron in stationary orbits</u>

K.E. of electron, $E_K = \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}\right)$ $\left[\because mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}\right]$

& P.E. $U = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(-e)}{r} = -\frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{r}$

⇨ total energy of electron $E = E_K + U = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r}\right) - \frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{r} = -\frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{r}$

⇨ $E_n = -\frac{1}{2}\frac{1}{4\pi\varepsilon_0}\frac{(Z\,e^2)}{\frac{\varepsilon_0\, n^2\, h^2}{\pi\, m\, Z\, e^2}} = -\frac{m\,Z^2e^4}{8\,\varepsilon_0^2\,h^2}\left(\frac{1}{n^2}\right)$

⇨ $E_n = -\frac{m\,Z^2e^4}{8\,\varepsilon_0^2\,h^2}\left(\frac{1}{n^2}\right) \times \frac{ch}{ch} = -\frac{m\,Z^2e^4}{8\,\varepsilon_0^2\,c\,h^3}\left(\frac{ch}{n^2}\right) = -\frac{\boldsymbol{Z^2Rch}}{\boldsymbol{n^2}}$

For H- atom $Z = 1$

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

Where, $R = \frac{m\,e^4}{8\varepsilon_0^2\,ch^3}$ = 1.097 X 10^7 m^{-1} and is called Rydberg's constant.

<u>Orbital velocity & time period of electron in stationary orbits</u>

dividing by eqn (1) by (2)

$$\frac{m\,v^2}{m\,v\,r} = \frac{1}{4\pi\varepsilon_0}\frac{Z\,e^2}{r} \times \frac{2\pi}{nh}$$

⇨ $v = \frac{Ze^2}{(2\,\varepsilon_0)n\,h} = \frac{Ze^2}{(2\,\varepsilon_0)c\,h} \times \frac{c}{n} = \alpha\,\frac{c}{n} = \frac{1}{137}\frac{c}{n}$ ⇨ $\boldsymbol{v \propto \frac{1}{n}}$

where $\alpha = \frac{Ze^2}{(2\,\varepsilon_0)c\,h} = \frac{1}{137}$ and is called fine structure constant

Orbital period of electron in H-atom :

$$T = \frac{2\pi r}{v} = \frac{2\pi(mvr)}{mv^2} = \frac{2\pi\left(\frac{nh}{2\pi}\right)}{m\left(\frac{e^2}{2\varepsilon_0 n\,h}\right)^2}$$

⇨ $T = \frac{4\varepsilon_0^2\,n^3h^3}{me^4}$

873. (a) Explain the origin of spectral series/ lines of hydrogen atom using Bohr's atomic model.
(b) Draw the energy level diagram showing how the line spectra corresponding to Lyman/Balmer series occur due to transition between energy levels in a hydrogen atom. **CBSE (AI)-2015,(D)-2013**

[Ans. (a) Spectral series of hydrogen atom :

According to Bohr's frequency condition, if an electron makes a transition from higher energy level E_2 to lower energy level E_1, then

$$h\frac{c}{\lambda} = E_2 - E_1 = -\frac{Rch}{n_2^2} - \left[-\frac{Rch}{n_1^2}\right] = Rch\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

⇨ $\bar{\nu} = \frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ where $\bar{\nu}$ is called wave number

Where $\bar{\nu}$ is called wave number (number of waves per unit distance), & R is the Rydberg's constant ($R = 1.097 \times 10^7\ m^{-1}$)

(i) Lyman Series

When an electron jumps from any higher energy level to the first level, we get Lyman series.
This series lies in ultraviolet region ($912 - 1215\ A^0$) and hence not visible. It is given by

$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{n_2^2}\right]$ where $n_2 = 2,3,4,5,$---------

(ii) Balmer Series

When an electron jumps from any higher energy level to the second level, we get Balmer series.
This series lies in visible region ($3646 - 6563\ A^0$) and is given by

$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n_2^2}\right]$ where $n_2 = 3,4,5,6,$---------

(iii) Paschen Series

When an electron jumps from any higher energy level to the third level, we get Paschen series.
This series lies in infrared region, ($8204 - 18752\ A^0$) hence not visible and is given by

$\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n_2^2}\right]$ where $n_2 = 4,5,6,7,$---------

(iv) Brackett Series

When an electron jumps from any higher energy level to the fourth level, we get Brackett series.
This series lies in infrared region, ($14576 - 40589\ A^0$) hence not visible & is given by

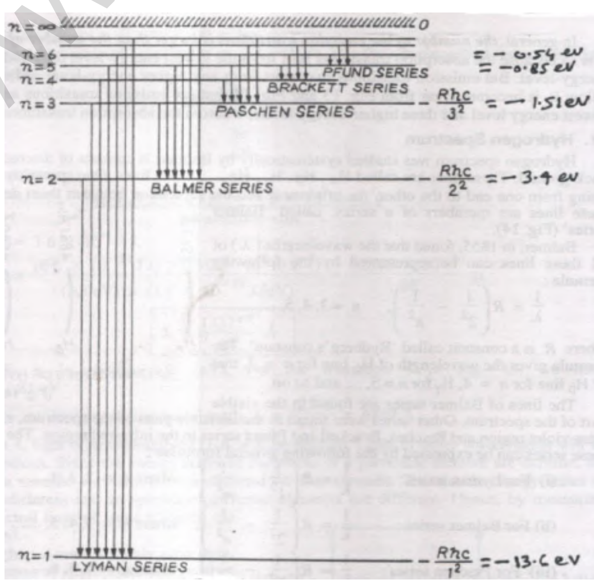
$\frac{1}{\lambda} = R\left[\frac{1}{4^2} - \frac{1}{n_2^2}\right]$ where $n_2 = 5,6,7,8,$--------

(v) Pfund Series

When an electron jumps from any higher energy level to the fifth level, we get Pfund series.
This series also lies in infrared region, ($22775 - 74536\ A^0$) hence not visible & is given by

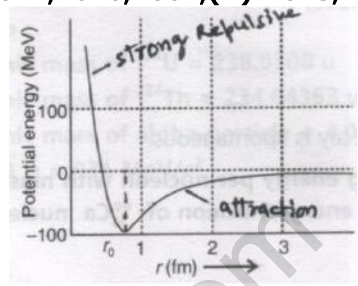
$\frac{1}{\lambda} = R\left[\frac{1}{5^2} - \frac{1}{n_2^2}\right]$ where $n_2 = 6,7,8,9,$--------

(b) Hydrogen spectrum :



874. Draw a plot of potential energy of a pair of nucleons as a function of their separations.
(i) Write two important conclusions that can be drawn from the graph.
(ii) What is the significance of negative potential energy in the graph drawn ?

[Ans. Graph : **CBSE (AIC)-2017,(AI)-2015,2012,2010,2007,(D)-2013,2007**



(i) Conclusions :

(a) For $r < r_0$, P.E. increases rapidly with the decrease in r.
This indicates strong repulsion between the nucleons

(b) For $r > r_0$, P.E. is negative which falls to zero for a separation more than a few Fermi. It indicates attractive force between the nucleons

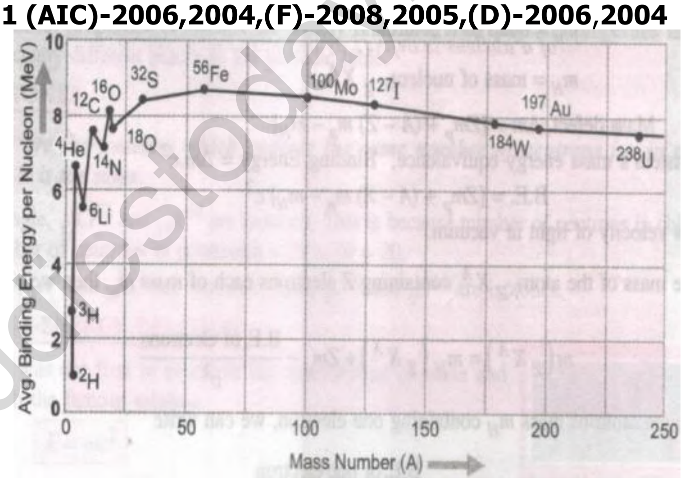
(ii) Significance :

Negative potential energy shows that binding force between the nucleons is strong.

875. Draw a plot of binding energy per nucleon (B.E/A) as a function of mass number A.
(a) Write salient features of this curve.
(b) Write two important conclusions that can be drawn regarding the nature of nuclear force.
(c) Use this graph to explain the release of energy in both the processes of nuclear fission and fusion.

CBSE (AI)-2016,2013,2011,2009,2004,2001 (AIC)-2006,2004,(F)-2008,2005,(D)-2006,2004

[Ans. Binding energy curve :



(a) Salient features :

(i) BE per nucleon (E_{bn}) is practically constant (independent of A) for the nuclei of middle mass number (30 <A<170).

Maximum E_{bn} is about 8.75 MeV for $A = 56$, thus Fe^{56} is most stable.

For A = 238 E_{bn} drops to 7.6 MeV.

(ii) Average B.E. per nucleon is very small for both light nuclei ($A < 30$) and heavy nuclei($A > 170$), so these nuclei are less stable.

(b) Conclusions/Importance of BE curve :

(i) Nuclear force is attractive and sufficiently strong to produce BE of a few MeV per nucleon

(ii) Constancy of BE curve in the range 30 <A <170 is a due to the fact that nuclear force is short – ranged.

(c) Release of energy in fission & fusion :

(i) When a heavy nucleus undergoes nuclear fission, the BE per nucleon of product nuclei is more than that of the original nucleus. This means that the nucleons get more tightly bound. Hence, there is release of energy.

(ii) When two very light nuclei (A ≤10) undergoes nuclear fusion, the BE per nucleon of product nucleus becomes more than that of the original lighter nuclei. This means that the nucleons in the final nucleus get more tightly bound. Hence, there is release of energy.

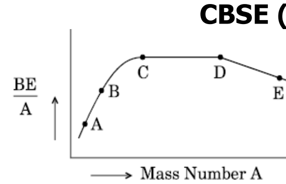
876. What characteristic property of nuclear force explains the consistency of binding energy per nucleon (BE/A) in the range of mass number 'A' lying 30< A< 170 ? **CBSE (AI)-2015**

[Ans. Nuclear force is short ranged or saturated

877. Give the reason for the decrease of binding energy per nucleon for nuclei with high numbers.

[Ans. This is due to increase in Coulomb repulsive force between protons **CBSE (DC)-2006,(D)-2004**

878. The figure shows the plot of binding energy (BE) per nucleon as a function of mass number A. Point out, giving reasons, the two processes (in terms of A,B,C,D and E) , one of which can occur due to nuclear fission and the other due to nuclear fusion. **CBSE (AI)-2015**



[Ans. (i) Nuclear fission of E in to D and C,
as there is increase in binding energy per nucleon

(ii) Nuclear fusion of A and B in to C,
as there is an increase in binding energy per nucleon

879. State the law of radioactive decay.

(i) Derive the mathematical expression for law of radioactive decay for a sample of radioactive nucleus.

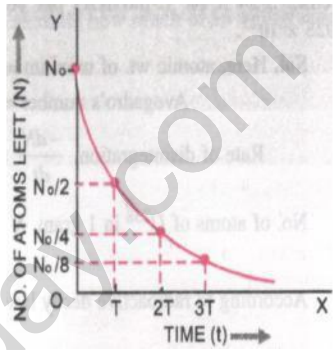
(ii) Plot a graph showing the number (N) of undecayed nuclei as a function of time (t) for a given radioactive sample having half-life T. **CBSE (AI) -2016, 2015, 2006, 2004, (D)-2014, 2011,2005, CBSE (F)-2013,2007**

[**Ans. Law of radioactive decay** : The rate of decay of a given radioactive sample is directly proportional to the total number of undecayed nuclei present in the sample

i,e, $-\frac{dN}{dt} \propto N$

⇨ $\frac{dN}{dt} = -\lambda N$

⇨ $\frac{dN}{N} = -\lambda\, dt$ -----------(1)



Where λ is constant of proportionality & is called decay constant

Let, when $t = 0,\ N = N_0$, Integrating (1) on both sides

$$\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_0^t dt$$

$$[\log_e N]_{N_0}^{N} = -\lambda\, [t]_0^t$$

$$\log_e N - \log_e N_0 = -\lambda\,(t - 0)$$

$$\log_e \frac{N}{N_0} = -\lambda\, t$$

⇨ $\frac{N}{N_0} = e^{-\lambda t}$

⇨ $\mathbf{N = N_0\, e^{-\lambda t}}$

==

880. Define the terms half-life period & decay constant of a radioactive substance. Write their S.I. units. Establish the relation between them. **CBSE (AI)-2015,2006,2004,(F)-2007,(D)-2005,2001**

[Ans. Half-life (T) : It is defined as the time taken to decay one-half of the initial number of nuclei present in a radioactive sample

Its S.I. unit is second (s)

Decay constant (λ) : It is defined as the reciprocal of the time in which the number of nuclei left undecayed reduces to $\frac{1}{e}$ times of its initial value

Its S.I. unit is second (s^{-1})

Relation : We have, $N = N_0 e^{-\lambda t}$

But when $t = T, N = \frac{N_0}{2}$

⇨ $\frac{N_0}{2} = N_0 e^{-\lambda T}$

$\frac{1}{2} = e^{-\lambda T}$

⇨ $2 = e^{\lambda T}$

$\lambda T = \log_e 2$

$$\lambda = \frac{\log_e 2}{T} = \frac{0.6931}{T}$$

==

881. Define the term **mean life** of a radioactive nuclide. How is the mean life of a given radioactive nucleus related to the decay constant and Half-life ? **CBSE (AI) -2016, 2015, (F)-2014**

[Ans. Average or Mean life (τ) : mean life of a radioactive substance is defined as the sum of life time of all the nuclei divided by the number of all nuclei

i,e, Mean life (τ) = $\frac{sum\ of\ life\ time\ of\ all\ the\ nuclei}{total\ number\ of\ nuclei} = \frac{\int_0^{N_0} t\, dN}{N_0} = \frac{1}{\lambda}$

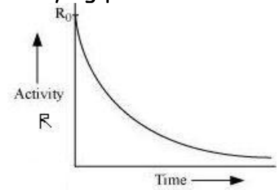
Relation : $\boldsymbol{\tau = \frac{1}{\lambda} = \frac{T}{0.6931} = 1.44\ T}$

882. Define activity of a radioactive substance and write its S.I. unit. Plot a graph showing variation of activity of a given radioactive sample with time **CBSE (F)-2016,(AI)-2015,2009,(D)-2010,2005,(F)-2008**

[Ans. **Activity (R)** : It is defined as the number of radioactive nuclei decaying per second at any time

i,e, $R = -\frac{dN}{dt}$

S.I. unit of Activity is Becquerel (Bq)



883. Show that the decay rate 'R' of a sample of a radioactive nuclide is related to the number of radioactive nuclei 'N' at the same instant by the expression $R = \lambda N$ & $\frac{dR}{dt} \propto \frac{1}{T^2}$ **CBSE (AIC)-2010**

[Ans. $R = -\frac{dN}{dt} = -\frac{d}{dt}\left(N_0 e^{-\lambda t}\right) = -N_0\left(-\lambda e^{-\lambda t}\right) = \lambda\left(N_0 e^{-\lambda t}\right) = \lambda N \Rightarrow R = \lambda N$

Now, $R = \lambda N$

$\Rightarrow \frac{dR}{dt} = \frac{d}{dt}(\lambda N) = \lambda\frac{dN}{dt} = \lambda(R) = \lambda(\lambda N) = \lambda^2 N = \left[\frac{\log_e 2}{T}\right]^2 N$

$\Rightarrow \frac{dR}{dt} \propto \frac{1}{T^2}$

884. A radioactive sample having N nuclei has activity R. Write down an expression for its half-life in terms of R and N **CBSE (AIC)-2011**

[Ans. Activity $R = \lambda N \Rightarrow \lambda = \frac{R}{N}$

Half-life, $T = \frac{0.6931}{\lambda} = \frac{0.6931\, N}{R}$

===

885. What is nuclear fission and fusion ? Give one representative equation of each. **CBSE (AIC)-2005**

[Ans. <u>Nuclear fission</u> : When a heavy nucleus is bombarded with slow neutrons it splits in to two or more light nuclei and a very large amount of energy is released. This phenomenon is called nuclear fission

$${}^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{236}_{92}U \longrightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3\,{}^{1}_{0}n + Q$$

Nuclear reactor and atom bomb are based on nuclear fission

Nuclear fusion : When two light nuclei are combined to form a heavy nucleus, a tremendous amount of energy is released. This phenomenon is called nuclear fission

$${}^{2}_{1}H + {}^{2}_{1}H \longrightarrow {}^{3}_{2}He + {}^{1}_{0}n + 3.27\text{ MeV}$$

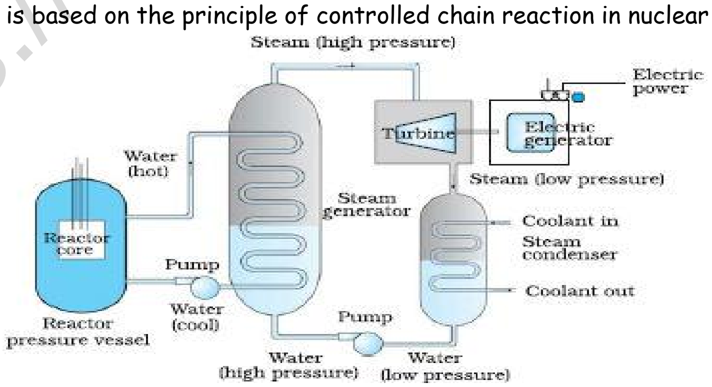
Source of energy in Sun is nuclear fusion. Hydrogen bomb is based on nuclear fusion

===

886. What is nuclear reactor ? Draw a labelled diagram of a nuclear reactor. Write its principle and explain its working.

[Ans. <u>Nuclear Reactor</u> : It is device used to convert nuclear energy it to electric energy.

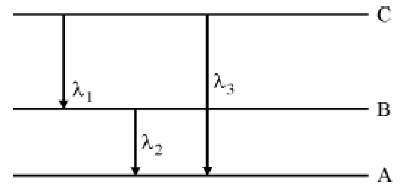
Principle : It is based on the principle of controlled chain reaction in nuclear fission.



Working : In a nuclear reactor, ${}^{235}_{92}U$ is used as a fuel, cadmium rods are used as control rods and graphite or heavy water as moderator. The entire set up is shielded with a heavy thick lead sheets and then with a thick concrete walls. The energy obtained from fission is used to heat up the water to produce steam. This steam is then used to rotate the turbines to produce electricity

887. Find the relation between the three wavelengths λ_1, λ_2 and λ_3 from the energy level diagram shown below.

CBSE (D)-2016



[Ans. $E_c - E_B = \frac{hc}{\lambda_1}$ ------(1)

$E_B - E_A = \frac{hc}{\lambda_2}$ ------(2)

$E_c - E_A = \frac{hc}{\lambda_3}$ ------(3)

Adding (1) and (2)

$E_c - E_A = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$

⇨ $\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$ ⇨ $\frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$

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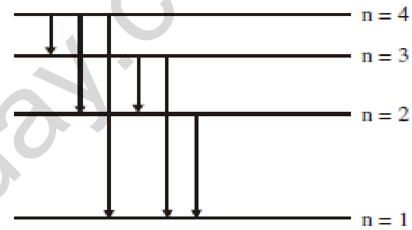
888 . The figure shows energy level diagram of hydrogen atom. **CBSE (AIC)-2015**

(i) Find out the transition which results in the emission of a photon of wavelength $496\ nm$

(ii) Which transition corresponds to the emission of radiation of maximum wavelength ? Justify your answer.



[Ans. (i) $\lambda = 496$ nm $= 496 \times 10^{-9}\ m$

$$\Delta E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{4.96 \times 10^{-7} \times 1.6 \times 10^{-19}} \text{ eV} \cong 2.5 \text{ eV}$$

For hydrogen atom, $E_n = -\frac{13.6}{n^2}$eV

⇨ $E_1 = -13.6$, $E_2 = -3.4$, $E_3 = -1.51$, $E_4 = -0.85$ eV

$E_4 - E_2 \cong 2.5$ eV hence transition n= 4 to n=1 will give radiation of wavelength 496 nm

(ii) $\Delta E = \frac{hc}{\lambda}$ ⇨ $\lambda \propto \frac{1}{\Delta E}$ for transition n= 4 to n=3 ΔE is minimum hence λ will be maximum

889. A hydrogen atom initially in its ground state absorbs a photon and is in the excited state with energy 12.5 eV. Calculate the longest wavelength of the radiation emitted and identify the series to which it belongs . (Rydberg constant, $R = 1.1 \times 10^7 m^{-1}$) **CBSE (AI)-2016**

[Ans. $\Delta E = -13.6 + 12.5 = -1.1$ eV

$E_n = -\frac{13.6}{n^2}$eV ⇨ $-1.1 = -\frac{13.6}{n^2}$ ⇨ n = 3

⇨ $\frac{1}{\lambda_{max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$ ⇨ $\lambda_{max} = \frac{36}{5R} = \frac{36}{5 \times 1.1 \times 10^7} = 6563\ A^0$ It belongs to Balmer series

890 . Using Rydberg's formula, calculate the longest wavelengths belonging to Lyman and Balmer series. In which region f hydrogen spectrum do these transmission lie ? (Given, $R = 1.1 \times 10^7 m^{-1}$) **CBSE (F)-2015**

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

For Lyman series, $\frac{1}{\lambda_{max}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = R\left[1 - \frac{1}{4}\right] = \frac{3R}{4}$

⇨ $\lambda_{max} = \frac{4}{3R} = \frac{4}{3 \times 1.1 \times 10^7} = 1210\ A^0$. It lies in Ultraviolet region

For Balmer series $\frac{1}{\lambda_{max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$

⇨ $\lambda_{max} = \frac{36}{5R} = \frac{36}{5 \times 1.1 \times 10^7} = 6563\ A^0$. It lies in visible region

891. The ground state energy of hydrogen atom is -13.6 eV. **CBSE (AI)-2008**

(i) what is the kinetic energy of an electron in the 2nd excited state ?

(ii) If the electron jumps to the ground state from 2nd excited state, calculate the wavelength of the spectral line emitted.

[Ans. (i) $E_{kn} = \frac{13.6}{n^2}$ eV & $U_n = -2 \times \frac{13.6}{n^2}$ eV

For ground state n =1 and for second excited state n = 3,

$E_{k3} = \frac{13.6}{3^2} = \frac{13.6}{9} = 1.51$ eV & $U_3 = -2 \times \frac{13.6}{3^2} = -\frac{27.2}{9} = 3.02$ eV

(ii) $\Delta E = E_3 - E_1 = -\frac{13.6}{3^2} - \left(-\frac{13.6}{1^2}\right) = -1.51 + 13.6 = 12.09$ eV $= 12.09 \times 1.6 \times 10^{-19}$ J

⇨ $\frac{hc}{\lambda} = \Delta E$ ⇨ $\lambda = \frac{hc}{\Delta E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{12.09 \times 1.6 \times 10^{-19}} = 1.02 \times 10^{-7}$ m

892. Two different radioactive elements with half lives T_1 and T_2 have N_1 and N_2 undecayed atoms respectively present at a given instant. Derive an expression for the ratio of their activities at this instant in terms of N_1 & N_2

[Ans. $R = -\frac{dN}{dt} = -\frac{d}{dt}\left(N_0 e^{-\lambda t}\right) = -N_0\ \left(-\lambda\, e^{-\lambda t}\right) = \lambda\left(N_0\, e^{-\lambda t}\right) = \lambda\, N$ **CBSE (DC)-2012**

⇨ $R = \lambda\, N$ ⇨ $R_1 = \lambda_1 N_1 = \frac{0.6931}{T_1} N_1$ & $R_2 = \lambda_2 N_2 = \frac{0.6931}{T_2} N_2$

⇨ $\frac{R_1}{R_2} = \frac{N_1}{N_2} X \frac{T_2}{T_1}$

893. Half life of ${}^{238}_{92}U$ against $\alpha -decay$ is 4.5 X 10^9 years. Calculate the activity of 1 g sample of ${}^{238}_{92}U$.
(Given Avogadro's number = 6 X 10^{26} atoms/ Kmol) **CBSE (AI) E-2016,(F)-2006, (D)-2005**

[Ans. Half-life T = 4.5 X 10^9 years = $4.5\ X\ 10^9\ X\ 365\ X\ 24\ X\ 60\ X\ 60$ s = 1.42 X 10^{17} s

Number of atoms present in 1 g sample of ${}^{238}_{92}U$, $N = \frac{6\ X\ 10^{23}}{238}$

Activity, $R = \lambda N = \frac{0.6931}{T} X\ N = \frac{0.6931}{1.42\ X\ 10^{17}} X \frac{6\ X\ 10^{23}}{238}$ = 1.23 X 10^4 Bq

894. A radioactive sample contains 2.2 mg of pure ${}^{11}_{6}$C which has half-life period of 1224 seconds. Calculate :
(i) the number of atoms present initially. **CBSE (AI)-2005**
(ii) the activity when 5 μg of the sample will be left.

[Ans. Given $T = 1224$ s

(i) Number of atoms present initially in 2.2 mg of ${}^{11}_{6}$C

$N_0 = \frac{6\ X\ 10^{23}\ X\ 2.2\ X\ 10^{-3}}{11}$ = 1.2 X 10^{20}

(ii) Number of atoms present in 5 μg of ${}^{11}_{6}$C

$N = \frac{6\ X\ 10^{23}\ X\ 5\ X\ 10^{-6}}{11}$ = 2.74 X 10^{17}

$R = \lambda N = \frac{0.6931}{T} X\ N = \frac{0.6931}{1224}$ X 2.74 X 10^{17} = 1.55 X 10^{14} Bq

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895. The half life of a certain radioactive material against α –decay is 100 days. After how much time, will the Undecayed fraction of the material be 6.25 % ? **CBSE (AI)-2015**

[Ans. Given : $T = 100$ days & $\frac{N}{N_0}$ = 6.25 % $= \frac{6.25}{100} = \frac{1}{16}$

$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$ ⇨ $\frac{1}{16} = \left(\frac{1}{2}\right)^n$ ⇨ $n = 4$

⇨ $t = n\,T$ = 4 X 100 = 400 days

896. The half life of radioactive substance is 20s. calculate- **CBSE (F)-2009**
(i) The decay constant, and
(ii) time taken for the sample to decay 7/8th of the initial value.

[Ans. Given $T = 20$ s & $\frac{N}{N_0} = 1 - \frac{7}{8} = \frac{1}{8}$

(i) $\lambda = \frac{0.6931}{T} = \frac{0.6931}{20} = 0.0346\ s^{-1}$

(ii) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$ ⇨ $\frac{1}{8} = \left(\frac{1}{2}\right)^n$ ⇨ $n = 3$

⇨ $t = n\,T$ = 3 X 20 = 60 s

897. The activity of a radioactive element drops to $\frac{1}{16}$th of its initial value in 32 Years. Find the mean life of the sample.

[Ans. Given, $\frac{R}{R_0} = \frac{1}{16}$ & $t = 32$ years **CBSE (AIC)-2010**

$\frac{R}{R_0} = \left(\frac{1}{2}\right)^n$ ⇨ $\frac{1}{16} = \left(\frac{1}{2}\right)^n$ ⇨ $n = 4$ & $T = \frac{t}{n} = \frac{32}{4}$ = 8 years

⇨ = 1.44 T = 1.44 x 8 = 11.52 yrs

898. Calculate the energy release in MeV in the deuterium-tritium fusion reaction **CBSE (D)-2015,2010, (AI)-2009,(DC)-2008,2003**

$${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \longrightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$$

Given $m({}^{2}_{1}\mathrm{H})$ = 2.014102 u, $m({}^{3}_{1}\mathrm{H})$ = 3.016049 u, $m({}^{4}_{2}\mathrm{He})$ = 4.002603 u, m_n = 1.008665 u & 1u = 931.5 MeV/c²

[**Ans**. $\Delta m = [m({}^{2}_{1}\mathrm{H}) + m({}^{3}_{1}\mathrm{H}) - \{ m({}^{4}_{2}\mathrm{He}) + m_n\}]$ = [2.014102 + 3.016049 –{ 4.002603 +1.008665 }]

⇨ $\Delta m = 0.018883\ u$ ⇨ Q = 0.018883 X 931.5 = 17.59 MeV

899. Calculate the energy released if, U^{238} , emits an α-particle. **CBSE (AI)-2007**

OR

Calculate the energy released in MeV in the following nuclear reaction. **CBSE (AI)-2008,(D)-2007**

$${}^{238}_{92}\mathrm{U} \longrightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He} + Q$$

[**Ans**. 4.25

[Given, mass of ${}^{238}_{92}\mathrm{U}$ = 238.05079 u, mass of ${}^{234}_{90}\mathrm{Th}$ = 234.043630 u, mass of ${}^{4}_{2}\mathrm{He}$ =4.002600 u & 1u = 931.5 MeV/c²]

[**Ans.** $\Delta m = [m({}^{238}_{92}\mathrm{U}) - \{m({}^{234}_{90}\mathrm{Th}) + m({}^{4}_{2}\mathrm{He})\}]$= [238.05079 –{234.043630+ 4.002600}]

⇨ $\Delta m = 0.0456\ u$ ⇨ Q = 0.0456 X 931.5 = 4.25 MeV

899a. A neutron is absorbed by a ${}^{6}_{3}\mathrm{Li}$ nucleus with the subsequent emission of an alpha particle. Write the corresponding nuclear reaction. Calculate the energy released in this nuclear reaction. **CBSE (AI)-2006,(D)-2005**

OR

Calculate the energy released in the following nuclear reaction **CBSE (AI)-2006,2002,(D)-2005,2003**

$${}^{6}_{3}\mathrm{Li} + {}^{1}_{0}\mathrm{n} \longrightarrow {}^{4}_{2}\mathrm{He} + {}^{3}_{1}\mathrm{H} + Q$$

[**Ans**. 4.78 MeV]

[mass of ${}^{1}_{0}\mathrm{n}$ = 1.008665 u, mass of ${}^{6}_{3}\mathrm{Li}$ = 6.015126 u, mass of ${}^{4}_{2}\mathrm{He}$= 4.002603 u, mass of ${}^{3}_{1}\mathrm{H}$ = 3.016049 u]

[**Ans.** $\Delta m = [m({}^{6}_{3}\mathrm{Li}) + m({}^{1}_{0}\mathrm{n}) - \{m({}^{4}_{2}\mathrm{He}) + ({}^{3}_{1}\mathrm{H})\}]$= [6.015126 + 1.008665 – {4.002603 + 3.016049}]

⇨ $\Delta m = 0.005138\ u$

⇨ Q = 0.005138 X 931 = 4.78 MeV

899b. (i) Write symbolically the nuclear β^{+} decay process of ${}^{11}_{6}\mathrm{C}$. Is the decayed product X an isotope or isobar of ${}^{11}_{6}\mathrm{C}$?
(ii) Given tha mass value of $m({}^{11}_{6}\mathrm{C})$ = 11.011434 u and $m(X)$ = 11.00935 u. Estimate the Q value in this process.

[**Ans**. (i) ${}^{11}_{6}\mathrm{C} \longrightarrow {}^{11}_{5}\mathrm{C} + {}^{0}_{+1}e + \nu$, X is an isobar **CBSE (AI)-2015**

(ii) $\Delta m = [m({}^{11}_{6}\mathrm{C}) - m(X)]$ = [11.011434– 11.00935] = 0.002129 u

⇨ Q = 0.002129 X 931.5 = 1.98 MeV

899c. A nucleus ${}^{23}_{10}\mathrm{Ne}$, β-decays to give the nucleus of ${}^{23}_{11}\mathrm{Na}$. Write down the β-decay equation. Calculate the kinetic energy of electron emitted. (Rest mass of electron may be ignored.) **CBSE (D)-2008,(AI)-2004**

(Given, $m({}^{23}_{10}\mathrm{Ne}) = 22.994466\ u$ & $m({}^{23}_{11}\mathrm{Na}) = 22.989770\ u$)

[**Ans.** ${}^{23}_{10}\mathrm{Ne} \longrightarrow {}^{23}_{11}\mathrm{Na} + {}^{0}_{-1}e + \overline{\nu}$

⇨ $\Delta m = [m({}^{23}_{10}\mathrm{Ne}) - \{m({}^{23}_{11}\mathrm{Na})] = [22.994466 - 22.989770] = 0.004696$ u

⇨ Energy released or the K.E. of emitted electron Q = Δm X c^2 = 0.004696 X 931.5 = 4.374 MeV

899d. When a deuteron of mass $2.0141\ u$ and negligible kinetic energy is absorbed by a Lithium (${}^{6}_{3}\mathrm{Li}$) nucleus of mass $6.0155\ u$, the compound nucleus disintegrates spontaneously in to two alpha particles each of mass $4.0026\ u$. Calculate the energy in Joules carried by each alpha particle. $(1\ u = 1.66\ X\ 10^{-27}\ \mathrm{Kg})$ **CBSE (AI)-2004**

[**Ans.** ${}^{6}_{3}\mathrm{Li} + {}^{2}_{1}\mathrm{H} \longrightarrow {}^{4}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He} + Q$

⇨ $\Delta m = [m({}^{6}_{3}\mathrm{Li}) + m({}^{2}_{1}\mathrm{H}) - 2\ X\ m({}^{4}_{2}\mathrm{He})]$ = [6.0155 + 2.0141 – $4\ X$ 4.0026] = 8.0296 –8.0052

⇨ $\Delta m = 0.0244\ u = 0.0244$ X $1.66\ X\ 10^{-27}$ Kg

⇨ Q = Δm X c^2 = 0.0244 X $1.66\ X\ 10^{-27}$X $(3\ X\ 10^{8})^2$ = 3.645 X 10^{-12} J

Hence energy carried by each alpha particle = 3.645 X 10^{-12}/2 = 1.8225 X 10^{-12} J

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