NUCLEI

1. Two nuclei have mass numbers in the ratio 1:8. What is the ratio of their nuclear radii?

Solution. $\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{8}\right)^{1/3} = \frac{1}{2}$

2. A radioactive nucleus A under goes a series of decays according to the following scheme:

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

The mass number and atomic of A_4 are 172 and 69 respectively. What are these number of A?

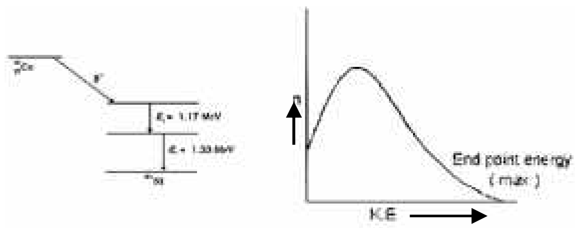
Solution. Let X = mass number =**180** &

Y = Atomic number = **72**,

3. (a)Draw the energy level diagram showing the emission of β-particles followed by γ-rays by a $^{6}_{2}$ Co nucleus.

(b) Plot the distribution of K.E of β-particles and state why the energy spectrum is continuous.

Solution.



4. A nucleus $^{2}_{1}$ Ne undergoes β-decay and becomes$^{2}_{1}$ Na. Calculate the maximum K.E of electrons emitted assuming that the daughter nucleus and anti-neutrino carry negligible

K.E. $\begin{cases} \text{mass of } ^{2}_{1}\text{ Ne} = 22.994466\text{u} \\ \text{mass of } ^{2}_{1}\text{ Na} = 22.989770\text{u} \\ 1\text{ u} = 931.5\text{MeV}/c^2 \end{cases}$

Solution.

Δm = mass of $^{2}_{1}$ Ne – (mass of$^{2}_{1}$ Na + mass of $_{-1}^{0}\beta$)

= 22.994466 − (22.989770 + negligible mass)

= **0.004696u** **E = Δm×c²** = 0.004696 × 931.5 **=4.37MeV.**

5. A neutron is absorbed by a $^{6}_{3}$Li nucleus with the subsequent emission of an ∝ particle. Write the corresponding nuclear reaction . Calculate the energy released in this reaction.

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$G \begin{cases} m(^{6}_{3}\text{Li}) = 6.015126\text{ u} \\ m(^{1}_{0}\text{n}) = 1.0086654\text{ u} \\ m(^{4}_{2}\text{He}) = 4.0026044\text{ u and } m(^{3}_{1}\text{H}) = 3.01\text{u} \end{cases}$

Solution. $^{6}_{3}\text{L} + ^{1}_{0}\text{n} \rightarrow ^{4}_{2}\text{H} + ^{3}_{1}\text{H}$

Mass of reactants = 6.015126 + 1.0086654

= 7.0237914 u

Mass of product = 4.0026044 + 3.01

=7.0126044 u

 Mass defect = Mass of reactance - Mass of product = 0.011187 u

Energy released = 0.011187×931.6

= **10.42MeV.**

6. The binding energy of deutron ($^{2}_{1}$H) and -particle($^{4}_{2}$He) and 1.25 and 7.2 MeV/nucleon respectively. Which nucleus is more stable? Calculate binding energy per nucleon of $^{5}_{2}$ Fe.

Given $\begin{cases} m(^{5}_{2}\text{ Fe}) = 55.934939\text{ u} \\ m(\text{proton}) = 1.007825\text{ u} \\ m(\text{neutron}) = 1.008665\text{ u} \end{cases}$ **Solution**.

-particle , have higher binding nucleon so it is more stable. $^{5}_{2}$ Fe nucleus contains 26 protons and (56 – 26) neutrons.

Mass of constituents of $^{5}_{2}$ Fe nucleus

= 26×1.007825 + 30×1.008665

= 56.4634 u

Mass defect (Δm) = 56.4634 – 55.934939 = 0.528461 u

Binding Energy(E) = 0.528461 × 931

= **491.997 MeV**.

7. Calculate the binding energy per nucleon of $^{4}_{2}$ Ca nucleus.

Given: $\begin{cases} m(^{4}_{2}\text{ Ca}) = 39.962589\text{ u} \\ m_n = 1.008665\text{ u} \\ m_p = 1.007825\text{ u} \end{cases}$

Solution. Mass of nucleons

= 20×1.008665 + 20 × 1.007825

= 40.3298 u

Δm = 40.3298 - 39.962589 = 0.367211 u

ΔE = 0.367211 × 931.5 = 342.05 MeV

Binding energy per nucleon = $\frac{\Delta E}{A} = \frac{3\quad .0}{4}$

=**8.55 MeV**.

8. Calculate the amount of energy released during the -decay of

$^{2}_{9}\text{ U} \rightarrow ^{2}_{9}\text{ Th} + ^{4}_{2}\text{He}$

Given : $\begin{cases} m(^{2}_{9}\text{ U}) = 238.05079\text{ u} \\ m(^{2}_{9}\text{ Th}) = 234.04363\text{ u} \\ m(^{4}_{2}\text{He}) = 4.00260\text{ u} \end{cases}$

1u = 931.5MeV/c².

Solution.

Δm = 238.05079 − 234.04363 − 4.00260 = 0.00456 u

ΔE = 0.00456×931.5 = **4.24764 MeV**.

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9. A sample of radioactive substance has 10^6 radioactive nuclei. Its half-life time is 20s. How many nuclei will remain after 10s? **Solution**.

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

$n = \frac{\text{ti} \quad \text{a d}}{\text{H} \quad \text{li}} = \frac{1}{2} = \frac{1}{2}$

$N = 10^6 \left(\frac{1}{2}\right)^{1/2} = \frac{1\ ^6}{\sqrt{2}} = 7.0\ \ \times 1\ \ ^5$

10. The half-life of radium is 1600 years. After how many years 25% radium block remains un decayed?

Solution. N = 25% of $N_0 = \frac{N_0}{4}$

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

 $n = 2, \frac{t}{T} = 2$ or $t = 2T = 2 \times 1600$

= 3200 years

11. Express 16mg mass into equivalent energy in electron volt.

Solution. m = 16mg = 16×10^{-3}g

$= 16 \times 10^{-6}$kg ,

$E = mc^2 = 16 \times 10^{-6} \times (3 \times 10^8)^2$

$= 1.44 \times 10^{1}\ \text{J} = \frac{1.4\ \times 1\ ^1}{1.6 \times 1\ ^{-1}}\ \text{eV} = 9 \times 10^{-3}\ \text{eV}$

12. The half-life period of a radioactive substance is 30 days. What is the time taken for 3/4th of its original mass to disintegrate? **Solution.** Here

$\frac{N_0 - N}{N_0} = \frac{3}{4}$ o $\frac{N}{N_0} = \frac{1}{4}$ $\quad \frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T}$ or $\left(\frac{1}{4}\right) = \left(\frac{1}{2}\right)^{t/3}$

 $\frac{t}{3} = 2$ or $t = 6\ \ d$

13. A radioactive substance decays to 1/32th its initial activity in 25 days. Calculate its half life.

Solution. $\frac{R}{R_0} = \left(\frac{1}{2}\right)^{t/T}$ or $\frac{1}{3} = \left(\frac{1}{2}\right)^{2\ \ /T}$

 $\left(\frac{1}{2}\right)^5 = \left(\frac{1}{2}\right)^{2\ \ /T}$ or $T = \frac{2}{5} = 5\ d$.

14. The half-life of U^2 against alpha decay is 1.42×10^{1} s. How many disintegrations per second occur in 1g of U^2 ? Avogadro number = 6.02×10^{23} mol-1.

Solution. T= 1.42×10^{-1} s

No of U^2 atoms in 1g. $N = \frac{A \qquad N}{A\ .m}$

$= \frac{6.0\ \times 1\ \ 2}{2} = 2.53 \times 10^2$

But $\lambda = \frac{0.6}{T} = \frac{0.6}{1.4\ \times 1\ ^{-1}}$

$= 4.88 \times 10^{-1}\ s^{-1}$

$\frac{d}{d} = \lambda N = 4.88 \times 10^{-1} \times 2.53 \times 10^2$

$= 1.235 \times 1\ ^4 s^{-1}$

PROPERTIES OF α,β AND γ-RAYS

FEATURE	α-particle	β- particle	γ- particle
Identity	Helium nucleus or doubly ionized helium atom ($^4_2$He)	ast moving ectron (β^0orβ^-)	Photon (E.M.W)
Charge	+2e	-e	zero
Mass	$4m_p$	m_e	Mass less
Speed	$\approx 10^7$m/s	1% to 99% of speed of light	Speed of light
Penetration power	1 (stopped by a paper)	100 (100 times of α)	10000 (100 times of β up to 30cm of iron (or Pb) sheet)
Ionisation power	10000	100	1
Effect of electric and magnetic field.	Deflected	Deflected	Not deflected
Energy spectrum	Line and discrete	Continuous	Line and discrete
Mutual interaction with matter	Produced heat	Produced heat	Produced photo electric effect, Compton effect, Pair production
Equation of decay	$^A_Z X \xrightarrow{\alpha - decay} {}^{A-4}_{Z-2}Y + {}^4_2He$	$^A_Z X \xrightarrow{\beta - decay} {}^{A}_{Z+1}Y + {}^0_{-1}e + \bar{\nu}$	$^A_Z X \xrightarrow{\gamma - decay} {}^A_Z Y + \gamma$

UNITS OF RADIOACTIVITY : The activity of a radioactive sample is generally expressed in terms of its rate of decay. In other words, the activity of a radioactive sample is expressed in terms of the number of disintegration per unit time. The radioactivity is measured in the following three units.

(i) The curie (Ci) : This was originally defined as the activity of 1g of radium in equilibrium with its by-products. But it is now defined as under : *The activity of a radioactive substance is said to be* one curie *if undergoes* 3.7×10^{1} *disintegrations per second.*

1 curie = 3.7×10^{1} disintegrations/s

(ii) The Rutherford (Rd) : *The activity of a radioactive substance is said to be one rutherford if it undergoes* 10^6 *disintegrations per second.*

1rutherford = 10^6 disintegrations / s

(iii) The Becquerel (Bq) : *The activity of a substance is said to be one becquerel if it undergoes 1 disintegration per second.* 1becquerel = 1 disintegration/s

1	$= 3.7 \times 1\ ^4$r	$= 3.7 \times 1\ ^1$ B

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