toppr

Download Toppr - India's best learning app for classes 5th to 12th

360° learning with our adaptive platform

Online Classes
Learn for free with short videos and live classes

Adaptive Practice
Practice smart with questions created for your unique needs

Mock Tests
Be exam ready by solving all India tests and previous years' papers

Live Doubts
Chat with tutors and get your doubts resolved instantly, 24x7

Live Classes
Learn concepts and get tips from the best teachers with free Live Classes

Learn for free with the best videos

Polish your basics with fun games

Practice smart with personalised questions

Get your doubts cleared instantly, 24x7

Download the app for FREE now

GET A 5-DAY FREE TRIAL

9,184,321
HAPPY STUDENTS
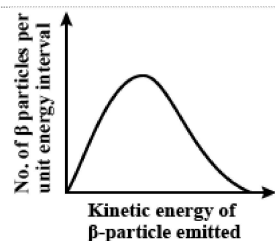
492,461,127
QUESTIONS ATTEMPTED

3,986,828
TESTS TAKEN

8,017,171
DOUBTS ANSWERED

NCERT Solutions for Class 12 Subject-wise

- Class 12 Mathematics

- Class 12 Physics

- Class 12 Chemistry

- Class 12 Biology

- Class 12 Accountancy

- Class 12 Business Studies

- Class 12 English

#419871
Topic: Change in Nucleus due to Radioactive decay

Kinetic energy of
β-particle emitted

Consider the decay of a free neutron at rest : $n \rightarrow p + e^-$

Show that the two-body decay of this type must necessarily give an electron of fixed energy and, therefore, cannot account for the observed continuous energy distribution in the β - decay of a neutron or a nucleus (Fig. 6.19).

[Note: The simple result of this exercise was one among the several arguments advanced by W. Pauli to predict the existence of a third particle in the decay products of β-decay. This particle is known as neutrino. We now know that it is a particle of intrinsic spin 1/2 (like e^- p or n), but is neutral, and either massless or having an extremely small mass(compared to the mass of electron) and which interacts very weakly with matter. The correct decay process of neutron is : $n \rightarrow p + e^- + v$]

Solution

The decay process of free neutron at rest is given as:

n $p + e^-$

From Einsteins mass-energy relation, we have the energy of electron as mc^2

Where,

m = Mass defect = Mass of neutron (Mass of proton + Mass of electron)

c = Speed of light

m and c are constants. Hence, the given two-body decay is unable to explain the continuous energy distribution in the β-decay of a neutron or a nucleus. The presence of neutrino on the LHS of the decay correctly explains the continuous energy distribution.

#421785
Topic: First Order Radioactive Decay

A radioactive isotope has a half-life of T years. How long will it take the activity to reduce to (a) 3.125% (b) 1% of its original value?

Solution

(a) Let the half-life be T years.

original amount of isotope is N_o

after decay, the remaining amount is N

now as per given values, N/N_o = 3.125% = 1/32

also, $N/N_o = e^{-\lambda t}$

where λ is decay constant

also $\lambda = 0.693/T$

so, $t = 3.4657/\lambda = 5T$ years.

(b) Let the half-life be T years.

original amount of isotope is N_o

after decay, the remaining amount is N

now as per given values, N/N_o = 1% = 1/100

also, $N/N_o = e^{-\lambda t}$

where λ is decay constant

also $\lambda = 0.693/T$

so, $t = 4.6052/\lambda = 6.645T$ years.

#421789
Topic: First Order Radioactive Decay

Obtain the amount of $^{60}_{27}Co$ necessary to provide a radioactive source of 8.0 mCi strength. The half-life of $^{60}_{27}Co$ is 5.3 years.

Solution

Strength of radioactive source is given as,

$dN/dt = 8\ mCi = 29.6 \times 10^7\ decay/s$

T=half life, or 5.3 years $= 1.67 \times 10^8\ s$

N is required number of atom.

$dN/dt = \lambda N, \lambda = 0.693/T$

$N = 7.133 \times 10^{16}\ atoms$

Using avogardo number, $7.133 \times 10^{16}\ atoms = 7.106 \times 10^{-6}g$ of cobalt.

#421793

Topic: Nuclear Structure

Obtain approximately the ratio of the nuclear radii of the gold isotope $^{197}_{79}Au$ and the silver isotope $^{107}_{47}Ag$.

Solution

$R_1/R_2 = \sqrt[3]{m_1/m_2} = (197/107)^{1/3} = 1.2256$

#421804

Topic: Change in Nucleus due to Radioactive decay

Find the Q-value and the kinetic energy of the emitted α- Particle in the α-decay of (a) $^{220}_{86}Rn$ and (b) $^{226}_{88}Ra$.

Given:

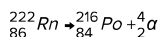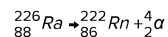$m(^{226}_{88}Ra) = 226.02540\ u,$

$m(^{222}_{86}Rn) = 222.01750\ u,$

$m(^{216}_{84}Po) = 216.00189\ u$

Solution

(a)

$^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^{4}_{2}\alpha$

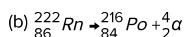$^{222}_{86}Rn \rightarrow ^{216}_{84}Po + ^{4}_{2}\alpha$

$Q = \Delta m \times 931 MeV$

$\Delta m = 226.02540 - 222.01750 - 4.002603 = 0.005297$

Q = 4.93 MeV,

$E_\alpha = 4.85 MeV$

Kinetic energy $= \dfrac{Mass\ no.\ after\ decay}{Mass\ no.\ before\ decay} \times Q$

$K.E = \dfrac{222}{226} \times 4.93 = 4.85 MeV$

(b) $^{222}_{86}Rn \rightarrow ^{216}_{84}Po + ^{4}_{2}\alpha$

$Q = \Delta m \times 931 MeV$

$\Delta m = 220.01137 - 216.00189 - 4.002603 = 0.006877$

Q = 6.4 MeV,

$E_\alpha = 6.29 MeV$

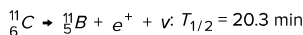Kinetic energy $= \dfrac{Mass\ no.\ after\ decay}{Mass\ no.\ before\ decay} \times Q$

$K.E = \dfrac{216}{222} \times 6.4 = 6.29 MeV$

#421830

Topic: Change in Nucleus due to Radioactive decay
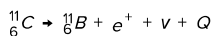

The radio nuclide ^{11}C decays according to,

$^{11}_{6}C \rightarrow {^{11}_{5}B} + e^{+} + v: T_{1/2} = 20.3$ min

The maximum energy of the emitted positron is 0.960 MeV.

Given the mass values:

$m(^{11}_{6}C) = 11.011434\ u$ and $m(^{11}_{6}B) = 11.009305\ u$

Calculate Q and compare it with the maximum energy of the positron emitted.

Solution

$^{11}_{6}C \rightarrow {^{11}_{6}B} + e^{+} + v + Q$

$Q = \left[m_N \left(^{11}_{6}C \right) - m_N \left(^{11}_{6}B \right) - m_e \right] c^2$

Where, the masses used are those of nuclei and not of atoms. If we use atomic masses, we have to add $6 m_e$ in case of ^{11}C and $5 m_e$ in case of ^{11}B. Hence,

$Q = \left[m \left(^{11}_{6}C \right) - m \left(^{11}_{6}B \right) - 2 m_e \right] c^2$ (Note m_e has been doubled)

Using given masses, Q = 0.961 MeV.

$Q = E_d + E_e + E_v$

The daughter nucleus is too heavy compared to e^+ and v, so it carries negligible energy ($E_d = 0$). If the kinetic energy (E_v) carried by the neutrino is minimum (i.e., zero), the positron carries maximum energy, and this is practically all energy Q, hence, maximum $E^e = Q$.

#421895
Topic: Nuclear Fusion

The fission properties of $^{239}_{94}Pu$ are very similar to those of $^{235}_{92}U$. The average energy released per fission is 180 MeV. How much energy, in MeV, is released if all the atoms in 1 kg of pure $^{239}_{94}Pu$ undergo fission?

Solution

Number of atoms in 1 kg of pure Pu = $\dfrac{6.023 \times 10^{23}}{239} \times 1000 = 2.52 \times 10^{24}$

As average energy released in fission is 180 MeV, the total energy released is $2.52 \times 10^{24} \times 180 MeV = 4.53 \times 10^{26} MeV$.

#421901
Topic: Nuclear Fission

A 1000 MW fission reactor consumes half of its fuel in 5.00 y. How much $^{235}_{92}U$ did it contain initially? Assume that the reactor operates 80% of the time, that all the energy generated arises from the fission of $^{235}_{92}U$ and that this nuclide is consumed only by the fission process.

Solution

Energy generated per gram of $^{235}_{92}U = \dfrac{6 \times 10^{23} \times 200 \times 1.6 \times 10^{-13}}{235}\ Jg^{-1}$
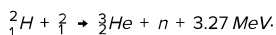
The amount of $^{235}_{92}U$ consumed in 5y with 80% on-times $= \dfrac{5 \times 0.8 \times 3.154 \times 10^{16} \times 235}{1.2 \times 1.6 \times 10^{13}}\ g = 1544\ kg$

The initial amount of $^{235}_{92}U = 3088\ kg$

#421902
Topic: Binding Energy

How long can an electric lamp of 100 W be kept glowing by fusion of 2.0 kg of deuterium? Take the fusion reaction as :

$^{2}_{1}H + {^{2}_{1}} \rightarrow {^{3}_{2}He} + n + 3.27\ MeV.$

Solution

Number of atoms in 2 kg deuterium $= \dfrac{6.023 \times 10^{23} \times 2000}{2} = 6.023 \times 10^{26}$

Energy released when 2 atoms fuse $= 3.27 MeV$

Thus, total energy released $= \dfrac{3.27}{2} \times 6.023 \times 10^{26} MeV = 15.75 \times 10^{13} J.$

Energy consumed by bulb per second = $100 J.$

Thus, time for which the bulb glows $= \dfrac{15.75 \times 10^{13}}{100} s = 15.75 \times 10^{11} s = 4.99 \times 10^{7} years.$

#421912
Topic: Nuclear Structure

From the relation R = $R_0 A^{\frac{1}{3}}$, where R_0 is a constant and A is the mass number of a nucleus, show that the nuclear matter density is nearly constant (i.e. independent of A).
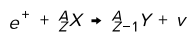
Solution

Density of nuclear matter = Mass of nucleus/Volume of nucleus

$$= \frac{A}{\frac{4}{3}\pi R^3}$$

$$= \frac{A}{\frac{4}{3}\pi(R_0 A^{1/3})^3} = \frac{1}{\frac{4}{3}\pi R_0^3} = constant$$

#421942
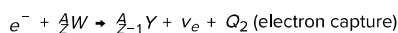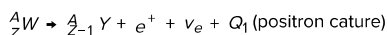
Topic: Binding Energy

For the β^+ (positron) emission from a nucleus, there is another competing process known as electron capture (electron from an inner orbit, say, the K shell, is captured by the nucleus and a neutrino is emitted).

$e^+ + {}^A_Z X \rightarrow {}^A_{Z-1} Y + v$

Show that if β^+ emission is energetically allowed, electron capture is necessarily allowed but not vice versa.

Solution

Consider the competing processes:

${}^A_Z W \rightarrow {}^A_{Z-1} Y + e^+ + v_e + Q_1$ (positron cature)

$e^- + {}^A_Z W \rightarrow {}^A_{Z-1} Y + v_e + Q_2$ (electron capture)

$Q_1 = [m_N({}^A_Z X) - m_N({}^A_{Z-1} Y) - m_e] c^2$

$= [m_N({}^A_Z X) - Zm_e - m({}^A_{Z-1} Y) - (Z-1) m_e - m_e] c^2$

$= [m_N({}^A_Z X) - m_N(A_{Z-1} Y) - 2m_e] c^2$

$Q_2 = [m_N({}^A_Z X) + m_e - m_N({}^A_{Z-1} Y)] c^2 = [m({}^A_Z X) - m({}^A_{Z-1} Y)] c^2$

This means $Q_1 > 0$ implies $Q_2 > 0$, but $Q_2 > 0$ does not necessarily mean $Q_1 > 0$.

#421963

Topic: Nuclear Structure

In a periodic table the average atomic mass of magnesium is given as 24.312 u. The average value is based on their relative natural abundance on earth. The three isotopes ar their masses are ${}^{24}_{12} Mg$ (23.98504u), ${}^{25}_{12} Mg$ (24.98584u) and ${}^{26}_{12} Mg$ (25.98259u). The natural abundance of ${}^{24}_{12} Mg$ is 78.99% by mass. Calculate the abundances of other two isotopes.

Solution

Let, the abundance of ${}_{12}Mg^{25}$ by mass be x%.

Therefore, abundance of ${}_{12}Mg^{26}$ by mass=(100 − 78.99 − x)% = (21.01 − x)%

Now, average atomic mass of Mg is 24.312 = 23.98504 × $\frac{78.99}{100}$ + 24.98584 × $\frac{x}{100}$ + 25.98259 × $\frac{21.01 - x}{100}$

$\Rightarrow$ x = 9.303% for ${}_{12}Mg^{25}$

(21.01 − x)% = 11.71% for ${}_{12}Mg^{26}$

#421972

Topic: Binding Energy

The neutron separation energy is defined as the energy required to remove a neutron from the nucleus. Obtain the neutron separation energies of the nuclei ${}^{41}_{20} Ca$ and ${}^{27}_{13} Al$ from the following data:

$m({}^{40}_{20} Ca) = 39.962591 u$

$m({}^{41}_{20} Ca) = 40.962278 u$

$m({}^{26}_{13} Al) = 25.986895 u$

$m({}^{27}_{13} Al) = 26.981541 u$

Solution

Neutron separation energy S_n of a nucleus $_Z^A X$ is,

$S_n = [m_N(_Z^{A-1} X) + m_n - m_N(_Z^A X)] c^2$

From given data, $S_n(_{20}^{41} Ca) = 8.36 \, MeV$, $S_n = (_{13}^{27} Al) \, 13.06 \, MeV$.

#421980

Topic: First Order Radioactive Decay

A source contains two phosphorous radio nuclides $_{15}^{32} P (T_{1/2} = 14.3 d)$ and $_{15}^{33} P (T_{1/2} = 25.3 d)$. Initially, 10% of the decays come from $_{15}^{32} P$. How long one must wait until 90% to c

so?

Solution

Suppose initially there was 9x gram of P_2 and x gram of P_1.

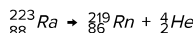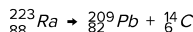After t days, there was y gram of P_2 and 9y gram of P_1.

Therefore $y = 9x e^{-t/14.4}$

and $9y = x e^{-t/25.3}$

$\implies t = 208.5 days$

#421994

Topic: Change in Nucleus due to Radioactive decay

Under certain circumstances, a nucleus can decay by emitting a particle more massive than an α-particle. Consider the following decay processes:

$_{88}^{223} Ra \rightarrow _{82}^{209} Pb + _6^{14} C$

$_{88}^{223} Ra \rightarrow _{86}^{219} Rn + _2^4 He$

Calculate the Q-values for these decays and determine that both are energetically allowed.

Solution

For $_6^{14} C$ emmision,

$Q = [m_N(_{88}^{223} Ra) - m_N(_{82}^{209} Pb) - m_N(_6^{14} C)] c^2$

$= [m(_{88}^{223} Ra) - m(_{82}^{209} Pb) - m(_6^{14} C)] c^2 = 31.85 \, MeV$

For $_2^4 He$ emission, $Q = [m(_{88}^{223} Ra) - m(_{82}^{209} Pb) - m(_2^4 C)] c^2 = 5.98 \, MeV$

#422014

Topic: Binding Energy

Consider the fission of $_{92}^{238} U$ by fast neutrons. In one fission event, no neutrons are emitted and the final end products, after the beta decay of the primary fragments, are $_{58}^{140} Ce$ and $_{44}^{99} Ru$. Calculate Q for this fission process. The relevant atomic and particle masses are:
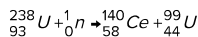
$m(_{92}^{238} U) = 238.05079 u$

$m(_{58}^{140} Ce) = 139.90543 \, u$

$m(_{44}^{99} U) = 98.90594 u$.

Solution

The reaction for the fission of $_{93}^{238} U$ by fast neutrons is as shown

$_{93}^{238} U + _0^1 n \rightarrow _{58}^{140} Ce + _{44}^{99} U$

$Q = [m(_{92}^{238} U) + m_N - m(_{58}^{140} Ce) - m(_{44}^{99} Ru)] \times 931.5 \, MeV$

$Q = [238.05079 + 1.00893 - 139.90543 - 98.90594] \times 931.5 \, MeV$

$Q = 0.24835 \times 931.5 \, MeV$

$Q = 231.1 \, MeV$

#422102

Topic: Nuclear Fusion

Calculate and compare the energy released by (a) Fusion of 1.0 kg of hydrogen deep within Sun (b) The fission of 1.0 kg of $^{235} U$ in a fission reactor

Solution

A.

Amount of hydrogen, $m = 1 kg = 1000 g$

1 mole, i.e.e , 1 g of hydrogen ($_1^1H$) contains 6.023×10^{23} atoms. Therefore 1000 g of hydrogen contains $6.023 \times 10^{23} \times 1000$ atoms.

Within the Sun, four $_1^1H$ nuclei combine and form one $_2^4He$ nucleus. In this process $26 MeV$ of energy is released. Hence the energy released from fusion of $1 kg \, _1^1H$ is

$E_1 = \dfrac{6.023 \times 10^{23} 26 \times 10^3}{4} = 39.149 \times 10^{26} MeV$

B:

Amount of $_{92}^{235}U = 1$ kg = 1000 g

One mole i.e. 235 g of $_{92}^{235}U$ contains 6.023×10^{23} atoms. Therefore 1000 g of $_{92}^{235}U$ contains $\dfrac{6.023 \times 10^{23} \times 1000}{235}$ atoms.

It is known that the amount of energy released in the fission of one atom of $_{92}^{235}$ is $200 MeV$

Hence, energy released from the fission of 1 kg of $_{92}^{235}$ is

$E_2 = \dfrac{6.023 \times 10^{23} \times 1000 \times 200}{235} = 5.106 \times 10^{26} MeV$

$\dfrac{E_1}{E_2} = 7.67 \approx 8$

Therefore, the energy released in the fusion of 1 kg of hydrogen is nearly 8 times the energy released in the fission of one kg of uranium.

#422109
Topic: Binding Energy

Suppose India had a target of producing by 2020 AD, 200,000 MW of electric power, ten percent of which was to be obtained from nuclear power plants. Suppose we are give

that, on an average, the efficiency of utilization (i.e. conversion to electric energy) of thermal energy produced in a reactor was 25%. How much amount of fissionable uranium

would our country need per year by 2020? Take the heat energy per fission of ^{235}U to be about 200 MeV.

Solution

The amount of electric power to be generated, $P = 2 \times 10^5$ MW

10% of this power has to be obtained from nuclear power plants.

Amount of nuclear power:

$P_1 = \dfrac{10}{100} \times 2 \times 10^5$

$= 2 \times 10^{10} \times 3600 \times 24 \times 365 \times J/ \, year$

Heat energy released per fission of a Uranium nucleus, $E = 200 MeV$

Efficiency of reactor $= 25\%$

Hence, the amount of energy converted into electrical energy per fission is calculated as:

$\dfrac{25}{100} \times 200 = 50 MeV = 8 \times 10^{-12} J$

Number of atoms required for fission per year: $\dfrac{2 \times 10^{10} \times 3600 \times 24 \times 365}{8 \times 10^{-12}}$

1 mole, i.e. 235 g of Uranium contains 6.023×10^{23} atoms

Mass of 6.023×10^{23} atoms of Uranium is $= 235 \, g$

Mass of 78840×10^{24} atoms of Uranium $= 3.076 \times 10^4 \, kg$