Nuclear Physics JEE Main PYQ - 2

Total Time: 20 Minute **Total Marks:** 40

Instructions

Instructions

1. Test will auto submit when the Time is up.
2. The Test comprises of multiple choice questions (MCQ) with one or more correct answers.
3. The clock in the top right corner will display the remaining time available for you to complete the examination.

Navigating & Answering a Question

1. The answer will be saved automatically upon clicking on an option amongst the given choices of answer.
2. To deselect your chosen answer, click on the clear response button.
3. The marking scheme will be displayed for each question on the top right corner of the test window.

Nuclear Physics

1. A sample of radioactive material A, that has an activity of $10\ mCi (1\ Ci = 3.7 \times 10^{10}$ decays/s), has twice the number of nuclei as another sample of a different radioactive maternal B which has an activity of $20\,mCi$. The correct choices for hall-lives of A and B would then be respectively : **(+4)**

[9 Jan. 2019 I]

a. 20 days and 5 days

b. 20 days and 10 days

c. 5 days and 10 days

d. 10 days and 40 days

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2. A solution containing active cobalt $^{60}_{27}Co$ having activity of $0.8\,\mu Ci$ and decay constant λ is injected in an animal?s body. If $1\,cm^3$ of blood is drawn from the animal?s body after 10 hrs of injection, the activity found was 300 decays per minute. What is the volume of blood that is flowing in the body ? $(1\,Ci = 3.7 \times 10^{10}$ decays per second and at $t = 10 hrs e^{-\lambda t} = 0.84)$ **(+4)**

[Online•April•15,•2018]

a. 6 liters

b. 7 liters

c. 4 liters

d. 5 liters

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3. An unstable heavy nucleus at rest breaks into two nuclei which move away with velocities in the ratio of $8:27$. The ratio of the radii of the nuclei (assumed to be spherical) is : **(+4)**

[Online April 15, 2018]

a. 8:27

b. 4:09

c. 3:02

d. 2:03

4. Half-lives of two radioactive elements A and B are 20 minutes and 40 minutes, respectively. Initially, the samples have equal number of nuclei. After 80 minutes, the ratio of decayed numbers of A and B nuclei will be : [2016] **(+4)**

a. $1:16$

b. $4:1$

c. $1:4$

d. $5:4$

5. In a radioactive decay chain, the initial nucleus is $^{232}_{90}Th$. At the end there are 6α -particles and 4β-particles which are emitted. If the end nucleus, If $^{A}_{Z}X$, A and Z are given by : [12 Jan. 2019, II] **(+4)**

a. A = 208; Z = 80

b. A = 202; Z = 80

c. A = 200; Z = 81

d. A = 208; Z = 82

6. In a radioactive material, fraction of active material remaining after time t is $9/16$. The fraction that was remaining after $t/2$ is : [Sep.•03,•2020•(I)] **(+4)**

a. $\frac{3}{4}$

b. $\frac{7}{8}$

c. $\frac{4}{5}$

d. $\frac{3}{5}$

7. The mass of proton, neutron and helium nucleus are respectively $10073\,u$, $10087\,u$ and $40015\,u$ The binding energy of helium nucleus is: [1-Feb-2023•Shift•1] **(+4)**

a. $14.2\,MeV$

b. $7.1\,MeV$

c. $56.8\,MeV$

d. $28.4\,MeV$

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8. The ratio of the density of oxygen nucleus $\left({}^{16}_{8}O\right)$ and helium nucleus $\left({}^{4}_{2}He\right)$ is **(+4)**

[25-Jan-2023 Shift 1]

a. $4:1$

b. $1:1$

c. $8:1$

d. $2:1$

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9. Consider the following radioactive decay process ${}^{218}_{84}A \xrightarrow{\alpha} A_1 \xrightarrow{\beta^-} A_2 \xrightarrow{\gamma} A_3 \xrightarrow{\alpha} A_4 \xrightarrow{\beta^+} A_5 \xrightarrow{\gamma} A_6$ The mass number and the atomic number of A_6 are given by: **(+4)**

[24-Jan-2023•Shift•1]

a. 211 and 80

b. 210 and 80

c. 210 and 82

d. 210 and 84

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10. A nucleus disintegrates into two smaller parts, which have their velocities in the ratio $3:2$ The ratio of their nuclear sizes will be $\left(\frac{x}{3}\right)^{\frac{1}{3}}$ The value of ' x ' is:- **(+4)**

[31-Jan-2024•Shift•2]

Answers

1. Answer: a

Explanation:

Activity $A = \lambda N$
For A $\hspace10mm 10 = (2N_0) \lambda_A$
For B $\hspace10mm 20 = N_0 \lambda_B$
$\therefore\ \lambda_B = 4\lambda_A \ \Rightarrow \ (T_{1/2})_A = 4(T_{1/2})_B$

Concepts:

1. Nuclei:

In the year 1911, Rutherford discovered the atomic nucleus along with his associates. It is already known that every atom is manufactured of positive charge and mass in the form of a nucleus that is concentrated at the center of the atom. More than 99.9% of the mass of an atom is located in the nucleus. Additionally, the size of the atom is of the order of 10-10 m and that of the nucleus is of the order of 10-15 m.

Read More: Nuclei

Following are the terms related to nucleus:

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2. Answer: d

Explanation:

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

It is given that activity $= 0.8\mu Ci$. Therefore, $\lambda N_0 = 0.8\mu Ci$.
Given: If $1\,cm^3$ of blood is drawn from the animal's body after 10 hours of injection then activity was 300 decays per minute.
Let V be the volume of blood flowing, then activity reduces as $\frac{1}{V}$. Thus,
$\frac{1}{V} \times \lambda N_0 e^{-\lambda} = \frac{300}{60}$
Put $\lambda N_0 = 0.8\mu Ci, e^{-\lambda t} = 0.84, Ci = 3.7 \times 10^{10}$ in above equation, we obtain
$\frac{1}{V} \times 0.8 \times 10^{-6} \times 3.7 \times 10^{10} \times 0.84 = \frac{300}{60}$
$\Rightarrow \frac{1}{V} \times 24.86 = 5$
$\Rightarrow V = \frac{24.86}{5} = 4.97 \sim 5$
Therefore, volume of blood flowing $= 5$ litres

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3. Answer: c

Explanation:

The two nuclei have velocity in ratio $8:27$. By conservation of momentum, we have
$m_1 v_1 = m_2 v_2$
$\Rightarrow \frac{v_1}{v_2} = \frac{m_2}{m_1}$

$\Rightarrow \frac{m_2}{m_1} = \frac{8}{27}$
Now, since $m = \rho\frac{4}{3}\pi r^3$
Therefore $\frac{m_2}{m_1} = \frac{\rho\frac{4}{3}\pi r_2^3}{\rho\frac{4}{3}\pi r_1^3}$
$\Rightarrow \frac{m_2}{m_1} = \left(\frac{r_2}{r_1}\right)^3$
$\Rightarrow \left(\frac{r_2}{r_1}\right)^3 = \frac{8}{27}$
$\Rightarrow \frac{r_2}{r_1} = \frac{2}{3}$
Thus, ratio of radii of nuclei $r_1 : r_2 = 3 : 2$.

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4. Answer: d

Explanation:

80 minutes $= 4$ half-lives of $A = 2$ half-lives of B
Let the initial number of nuclei in each sample be N
N_A after 80 minutes $= \frac{N}{2^4}$
$\Rightarrow$ Number of A nuclides decayed $= \frac{15}{16}N$
N_B after 80 minutes $= \frac{N}{2^2}$

$\Rightarrow$ Number of B nuclides decayed $= \frac{3}{4}N$
Required ratio $= \frac{15/16}{3/4} = \frac{5}{4}$

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5. **Answer: d**

Explanation:

The correct answer is (D) : A = 208; Z = 82
When one α-particle is emitted, then the mass number (A) of daughter nuclei decreases by 4 and the atomic number decreases by 2.
$^{232}_{90}Th \rightarrow ^{208}_{78}Y + 6(^{4}_{2}He)$
When one β-particle is emitted, then the mass number (A) of daughter nuclei increases by 1 and the atomic number remains the same.
$^{208}_{78}Y \rightarrow ^{208}_{82}X + 4\beta$
Therefore, for the end nucleus, A = 208 : Z = 82

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6. Answer: a

Explanation:

First order decay

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

Given $N(t)/N_0 = 9/16 = e^{-\lambda t}$

Now, $N(t/2) = N_0 e^{-\lambda t/2}$

$\frac{N(t/2)}{N_0} = \sqrt{e^{-\lambda t}}$

$= \sqrt{9/16}$

$N(t/2) = 3/4 N_0$

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7. **Answer: d**

Explanation:

B.E. of Helium $= (2m_P + 2m_N - m_{He})c^2 = 28.4MeV$

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8. Answer: b

Explanation:

Nuclear density is independent of mass number As nuclear density $= \frac{Au}{\frac{4}{3}\pi R^3}$

Also, $R = R_0 A^{\frac{1}{3}}$

And $R^3 = R_0^3 A$

$\Rightarrow$ Nuclear density $= \frac{Au}{\frac{4}{3}\pi R_0^3 A}$

Nuclear density $= \frac{3u}{4\pi R_0^3}$

$\Rightarrow$ Nuclear density is independent of A

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Read More: [Nuclei]

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9. Answer: b

Explanation:

The correct answer is (B) : 210 and 80

$${}^{218}_{84}A \xrightarrow{\alpha} {}^{214}_{82}A_1 \xrightarrow{\beta^-} {}^{214}_{83}A_2 \xrightarrow{\gamma} {}^{214}_{83}A_3$$

$$ {}^{214}_{83}A_3 \xrightarrow{\alpha} {}^{210}_{81}A_4 \xrightarrow{\beta^+} {}^{210}_{80}A_5 \xrightarrow{\gamma} {}^{210}_{80}A_6 $$

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10. Answer: 2 - 2

Explanation:

The correct answer is 2.

$$\frac{v_1}{v_2} = \frac{3}{2}$$

$m_1 v_1 = m_2 v_2 \Rightarrow \frac{m_1}{m_2} = \frac{2}{3}$

Since, Nuclear mass density is constant

$\frac{m_1}{\frac{4}{3}\pi r_1^3} = \frac{m_2}{\frac{4}{3}\pi r_2^3}$

$\left(\frac{r_1}{r_2}\right)^3 = \frac{m_1}{m_2}$

$\frac{r_1}{r_2} = \left(\frac{2}{3}\right)^{\frac{1}{3}}$

So, $x = 2$

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