Nuclear Physics JEE Main PYQ - 3

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. Assume that protons and neutrons have equal masses Mass of a mucleon is $16 \times 10^{-27} kg$ and radius of nucleus is $15 \times 10^{-15} A^{1/3} m$ The approximate ratio of the nuclear density and water density is $n \times 10^{13}$ The value of n is ___ [24-Jan-2023 Shift 1] **(+4)**

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2. The energy released per fission of nucleus of ${}^{240}X$ is $200\,MeV$ The energy released if all the atoms in $120\,g$ of pure ${}^{240}X$ undergo fission is ___ $\times 10^{25} MeV$. (Given $N_A = 6 \times 10^{23}$) [27-Jan-2024 Shift 1] **(+4)**

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3. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R **(+4)**

Assertion (A): The nuclear density of nuclides ${}^{10}_{5}B, {}^{6}_{3}Li, {}^{56}_{26}Fe, {}^{20}_{10}Ne$ and ${}^{209}_{83}Bi$ can be arranged as $\rho^N_{Bi} > \rho^N_{Fe} > \rho^N_{Ne} > \rho^N_{B} > \rho^N_{Li}$.

Reason R: The radius R of nucleus is related to its mass number A as $R = R_0 A^{1/3}$, where R_0 is a constant.

In the light of the above statements, choose the correct answer from the options given below

[29-Jan-2024 Shift 2]

a. Both A and R are true and R is the correct explanation of A

b. A is false but R is true

c. Both A and R are true but R is NOT the correct explanation of A

d. A is true but R is false

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4. For the given radioactive decay ${}^{298}_{94}X \rightarrow {}^{294}_{92}X + {}^{4}_{2}$▯ $+ Q$ - value, binding energy per nucleon of X, Y and a are a, b and c. The Q - value is equal to **(+4)**

[10-Apr-2023 shift 1]

a. 294b + 4c - 298a

b. 92b + 2c - 94a

c. 92b + 2c - 94a

d. 92b + 2c + 94a

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5. If half life of a radio-active nuclide A is equal to average life of another radio-active nuclide B. Find the ratio of decay constant of A to that of B. (+4)

[Online•April•19,•2014]

a. In 2:1

b. 1: In 2

c. 2: In 2

d. In 2:2

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6. 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

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7. 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. $5 : 4$

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8. 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 : (+4)

[12 Jan. 2019, II]

a. A = 208; Z = 80

b. A = 202; Z = 80

c. A = 200; Z = 81

d. A = 208; Z = 82

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9. In a radioactive material, fraction of active material remaining after time t is $9/16$. The fraction that was remaining after $t/2$ is : **(+4)**

[Sep.•03,•2020•(I)]

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

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

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

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

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10. The mass of proton, neutron and helium nucleus are respectively $10073\,u$, $10087\,u$ and $40015\,u$ The binding energy of helium nucleus is: **(+4)**

[1-Feb-2023•Shift•1]

a. $14.2\,MeV$

b. $7.1\,MeV$

c. $56.8\,MeV$

d. $28.4\,MeV$

Answers

1. **Answer: 11 - 11**

Explanation:

The correct answer is 11.

$$\text{density of nuclei } = \frac{\text{mass of nuclei}}{\text{volume of nuclei}}$$

$$\rho = \frac{1.6\times10^{-27}A}{\frac{4}{3}\pi(1.5\times10^{-15})^3A}$$

$$= \frac{1.6\times10^{-27}}{14.14\times10^{-45}} = 0.113 \times 10^{18}$$

$$\rho_w = 10^3$$

$$\text{Hence } \frac{\rho}{\rho_w} = 11.31 \times 10^{13}$$

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:

1. Atomic Number
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2. Answer: 6 - 6

Explanation:

The correct answer is 6.

No. of mole $= \frac{120}{240} = \frac{1}{2}$

No. of molecules $-\frac{1}{2} \times N_A$

Energy released $= \frac{1}{2} \times 6 \times 10^{23} \times 200$

$= 6 \times 10^{25} MeV$

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3. Answer: b

Explanation:

The correct answer is (B): A is false but R is true

Assertion A states that the nuclear densities follow the order: ρ Bi > ρ Fe > ρ Ne > ρ B > ρ Li.

Reason R states that the radius of a nucleus is related to its mass number A as R = $R_0 A^{\frac{1}{3}}$, where R_0 is a constant.
These two statements do not have a direct connection. The arrangement of nuclear densities does not directly relate to the formula for nuclear radius.
Nuclear density is independent of A.

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4. Answer: a

Explanation:

The correct option is (A): 294b + 4c - 298a

Q-value = $(B.E)_{product}$-$(B.E)_{reaction}$

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5. Answer: a

Explanation:

The correct option is (A): In 2:1

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6. Answer: c

Explanation:

The two nuclei have velocity in ratio $8:27$. By conservation of momentum, we have

$m_1v_1 = m_2v_2$

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

$\Rightarrow \frac{m_2}{m_1} = \frac{8}{27}$

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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7. **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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---

8. **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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9. Answer: a

Explanation:

First order decay

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

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

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

$$\frac{N(t/2)}{N_0} = \sqrt{e^{-\lambda t}}$$
$$= \sqrt{9/16}$$
$$N(t/2) = 3/4N_0$$

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---

10. Answer: d

Explanation:

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

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