

CHAPTER 19

Nuclear Chemistry

CHAPTER ANALYSIS

	IIT JEE 2010		IIT JEE 2011		IIT JEE 2012		JEE Advanced 2013		JEE Advanced 2014		JEE Advanced 2015		JEE Advanced 2016		JEE Advanced 2017	
	Paper		Paper		Paper		Paper		Paper		Paper		Paper		Paper	
Topic	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Nature of the Nucleus																
Radioactivity and Theory of Nuclear Disintegration																
Nuclides																
Nucleus Stability																
Modes of Radioactive Decay																
Decay Mechanism																
Energy Changes in Nuclear Reactions																
Radioactive Decay Rate																
Radioactive Equilibrium																
Radioactive Substances																
Radiometric Dating																
Nuclear Reactions	1		1		1			1				1				
Applications of Radioactivity																
Biological Effects of Radiation																

QUESTIONS

1. Decrease in atomic number is observed during

- (A) alpha emission.
- (B) beta emission.
- (C) positron emission.
- (D) electron capture.

(IIT JEE 1998)

2. **Assertion:** Nuclide $^{30}_{13}\text{Al}$ is less stable than $^{40}_{20}\text{Ca}$.

Reason: Nuclides having odd number of protons and Neutrons are generally unstable.

- (A) If both assertion and reason are correct, and reason is the correct explanation of the assertion.

- (B) If both assertion and reason are correct, but reason is **not** the correct explanation of the assertion.
- (C) If assertion is correct but reason is incorrect.
- (D) If assertion is incorrect but reason is correct.

(IIT JEE 1998)

3. The number of neutrons accompanying the formation of $^{139}_{54}\text{Xe}$ and $^{94}_{38}\text{Sr}$ from the absorption of a slow neutron by $^{235}_{92}\text{U}$, followed by nuclear fission is

- (A) 0
- (B) 2
- (C) 1
- (D) 3

(IIT JEE 1999)

4. ^{64}Cu (half-life = 12.8 h) decays by β^- emission (38%), β^+ emission (19%) and electron capture (43%). Write the decay products and calculate partial half-lives for each of the decay processes.

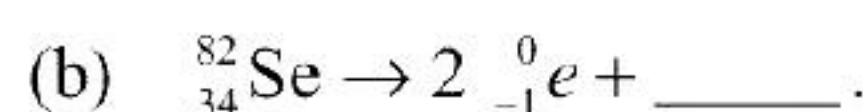
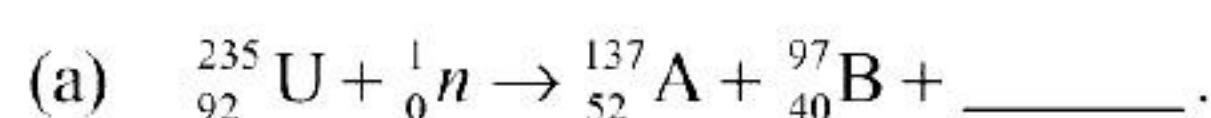
(IIT JEE Main 2002)

5. ^{23}Na is the more stable isotope of Na. Find out the process by which $^{24}_{11}\text{Na}$ can undergo radioactive decay.

- (A) β^- emission (B) α emission
(C) β^+ emission (D) K electron capture

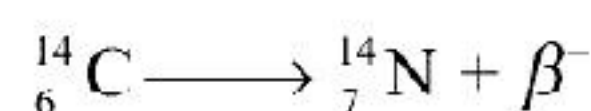
(IIT JEE Screening 2003)

6. Fill in the blanks:



(IIT JEE Main 2005)

Paragraph for Questions 7–9: ^{14}C is absorbed by living organisms during photosynthesis. The ^{14}C content is constant in living organism once the plant or animal dies, the uptake of carbon dioxide by it ceases and the level of ^{14}C in the dead being, falls due to the decay which ^{14}C undergoes



The half-life period of ^{14}C is 5770 years. The decay constant (λ) can be calculated by using the following formula:

$$\lambda = \frac{0.693}{t_{1/2}}$$

The comparison of the β^- activity of the dead matter with that of the carbon still in circulation enables measurement of the period of the isolation of the material from the living cycle. The method however, ceases to be accurate over periods longer than 30,000 years. The proportion of ^{14}C to ^{12}C in living matter is 1 : 10^{12} .

7. Which of the following option is correct?

- (A) In living organisms, circulation of ^{14}C from the atmosphere is high, so the carbon content is constant in organism.
(B) Carbon dating can be used to find out the age of earth crust and rocks.
(C) Radioactive absorption due to cosmic radiation is equal to the rate of radioactive decay; hence the carbon content remains constant in living organism.
(D) Carbon dating cannot be used to determine concentration of ^{14}C in dead beings.

(IIT JEE 2006)

8. What should be the age of fossil for the meaningful determination of its age?

- (A) 6 years.
(B) 6000 years.
(C) 60,000 years.
(D) It can be used to calculate any age.

(IIT JEE 2006)

9. A nuclear explosion has taken place leading to increase in the concentration of ^{14}C in nearby areas. ^{14}C concentration is C_1 in nearby areas and C_2 in areas far away. If the age of the fossil is determined to be T_1 and T_2 at the places, respectively, then

- (A) the age of the fossil will increase at the place where explosion has taken place and $T_1 - T_2 = \frac{1}{\lambda} \ln \frac{C_1}{C_2}$.
(B) the age of the fossil will decrease at the place where explosion has taken place and $T_1 - T_2 = \frac{1}{\lambda} \ln \frac{C_1}{C_2}$.
(C) the age of fossil will be determined to be the same.
(D) $\frac{T_1}{T_2} = \frac{C_1}{C_2}$.

(IIT JEE 2006)

10. A positron is emitted from $^{23}_{11}\text{Na}$. The ratio of the atomic mass and atomic number of the resulting nuclide is

- (A) 22/10 (B) 22/11
(C) 23/10 (D) 23/12

(IIT JEE 2007 Paper-2)

11. **Statement 1:** The plot of atomic number (y-axis) versus number of neutrons (x-axis) for stable nuclei shows a curvature towards x-axis from the line of 45° slope as the atomic number is increased

and

Statement 2: Proton–proton electrostatic repulsions begin to overcome attractive forces involving protons and neutrons in heavier nuclides.

- (A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is **not** a correct explanation for Statement-1.
(C) Statement-1 is True, Statement-2 is False.
(D) Statement-1 is False, Statement-2 is True.

(IIT JEE 2008 Paper-1)

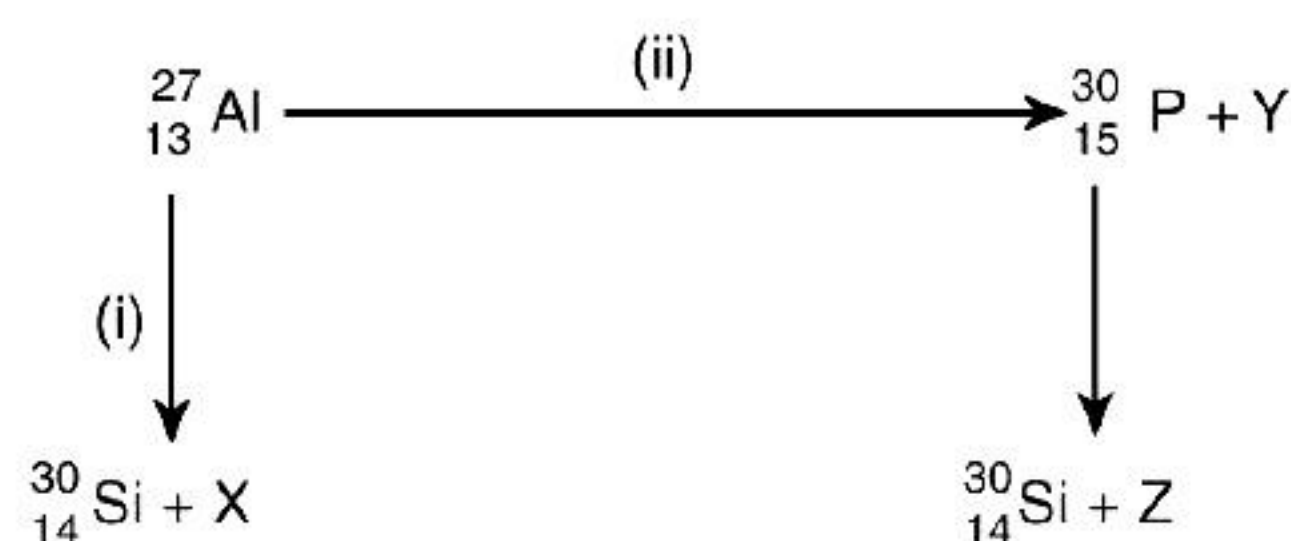
12. The total number of α and β particles emitted in the nuclear reaction $^{238}_{92}\text{U} \rightarrow {}^{214}_{82}\text{Pb}$ is _____.

(IIT JEE 2009 Paper-2)

13. The number of neutrons emitted when $^{235}_{92}\text{U}$ undergoes controlled nuclear fission to $^{142}_{54}\text{Xe}$ and $^{90}_{38}\text{Se}$ is _____.

(IIT JEE 2010 Paper-1)

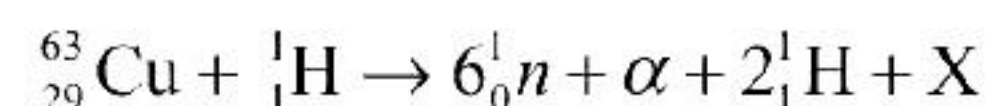
14. Bombardment of aluminium by α -particle leads to its artificial disintegration in two ways: (i) and (ii) as shown. Products X, Y and Z, respectively, are



- (A) proton, neutron, positron.
 (B) neutron, positron, proton.
 (C) proton, positron, neutron.
 (D) positron, proton, neutron, neutron.

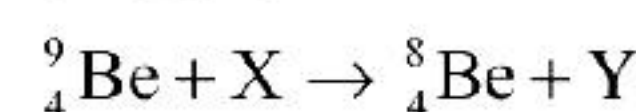
(IIT JEE 2011 Paper-1)

15. The periodic table consists of 18 groups. An isotope of copper, on bombardment with protons, undergoes a nuclear reaction yielding element X as shown below. To which group, element X belongs in the periodic table?



(IIT JEE 2012 Paper-1)

16. In the nuclear transmutation



(X, Y) is (are)

- (A) (γ, n) (B) (p, D)
 (C) (n, D) (D) (γ, p)

(JEE Advanced 2013 Paper-2)

17. A closed vessel with rigid walls contains 1 mol of $^{238}_{92}\text{U}$ and 1 mol of air at 298 K. Considering complete decay of $^{238}_{92}\text{U}$ to $^{206}_{82}\text{Pb}$, the ratio of the final pressure to the initial pressure of the system at 298 K is _____.

(JEE Advanced 2015 Paper-2)

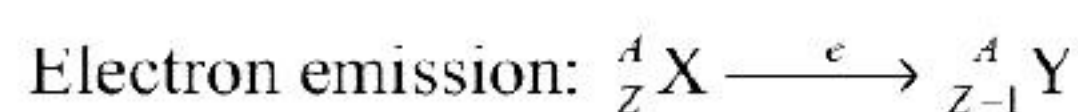
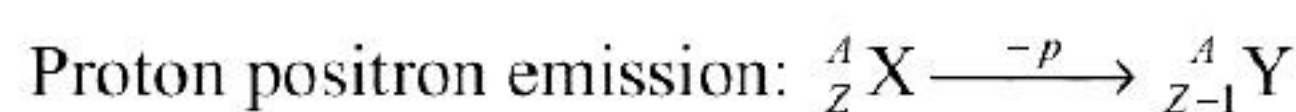
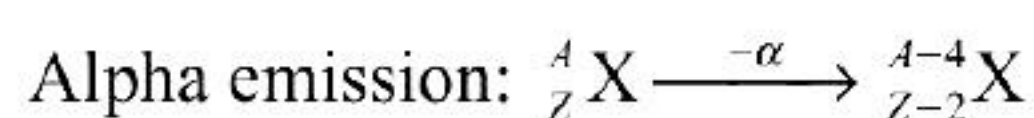
ANSWER KEY

1. (A), (C), (D) 2. (C) 3. (D) 5. (A)
 6. (a) $^{235}_{92}\text{U} + ^1_0\text{n} \rightarrow ^{137}_{52}\text{A} + ^{97}_{40}\text{B} + 2^1_0\text{n}$ (b) $^{82}_{34}\text{Se} \rightarrow 2^0_{-1}\text{e} + ^{82}_{36}\text{Kr}$ 7. (C) 8. (C) 9. (A) 10. (C)
 11. (A) 12. 8 13. 3 14. (A) 15. 8 16. (A), (B) 17. 9

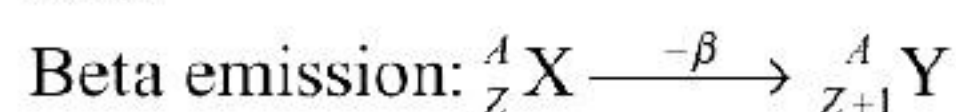
ANSWERS WITH EXPLANATIONS

1. **Topic: Radioactivity and Theory of Nuclear Disintegration**

Decrease in atomic number is observed during:



In beta emission there is increase of atomic number by one.



Answer (A), (C), (D)

2. **Topic: Nucleus Stability**

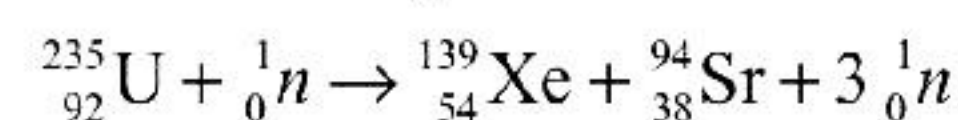
Assertion statement is correct that Nuclide $^{30}_{13}\text{Al}$ is less stable than $^{40}_{20}\text{Ca}$.

Reason statement is incorrect – Nuclides having odd number of protons and neutrons are stable.

Answer (C)

3. **Topic: Nuclear Reactions**

The balanced reaction is given as follows

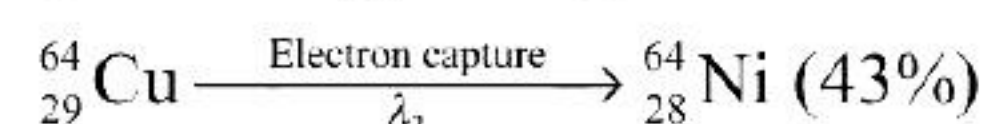


Hence, 3 neutrons are formed.

Answer (D)

4. **Topic: Radioactive Decay Rate**

The three processes of parallel decay of ^{64}Cu are represented as follows:



where λ is the decay constant and

$$\lambda_{\text{net}} = \lambda_1 + \lambda_2 + \lambda_3$$

We know that $t_{1/2} = \frac{\ln 2}{\lambda}$ and given that $t_{1/2}$ for Cu is 12.8 h, so

$$\lambda_{\text{net}} = \frac{\ln 2}{t_{1/2}} = \frac{0.693}{12.8}$$

The decay constants for fractional disintegration in parallel decay processes can be expressed as

$$\lambda_1 = [\text{fractional yield of } {}^{64}_{30}\text{Zn}] \times \lambda_{\text{net}} = 0.38 \times \frac{0.693}{12.8}$$

$$(t_{1/2})_1 = \frac{\ln 2}{\lambda_1} = \frac{0.693 \times 12.8}{0.38 \times 0.693} = \frac{12.8}{0.38} = 33.68 \text{ h}$$

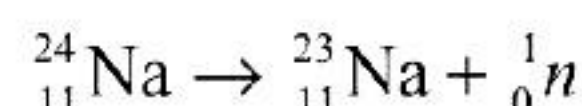
Similarly,

$$(t_{1/2})_2 = \frac{\ln 2}{\lambda_2} = \frac{0.693 \times 12.8}{0.19 \times 0.693} = \frac{12.8}{0.19} = 67.36 \text{ h}$$

$$(t_{1/2})_3 = \frac{\ln 2}{\lambda_3} = \frac{0.693 \times 12.8}{0.43 \times 0.693} = \frac{12.8}{0.43} = 29.76 \text{ h}$$

5. Topic: Modes of Radioactive Decay

${}^{24}_{11}\text{Na}$ has higher neutron/proton ratio (n/p) than the stable isotope ${}^{23}_{11}\text{Na}$. The most likely mode of decay for the neutron-rich nucleus is one that converts a neutron into a proton.



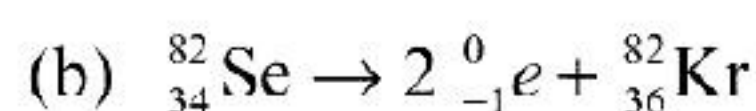
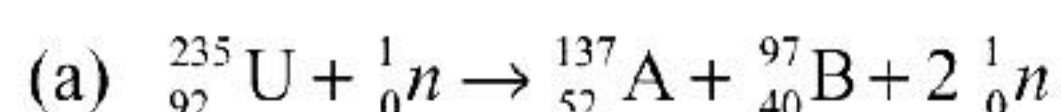
A neutron can decay to form a proton by emitting an electron.



Thus, the given nucleus decays by electron (β^-) emission.

Answer (A)

6. Topic: Nuclear Reactions



7. Topic: Radioactive Decay Rate

Concept based.

Answer (C)

8. Topic: Radioactive Decay Rate

The method of radioactive carbon dating ceases to be accurate over periods longer than 30,000 years.

Answer (C)

9. Topic: Radioactive Decay Rate

Radioactive decay of all elements follows first-order kinetics. So, in accordance with first-order kinetics, the decay constant is

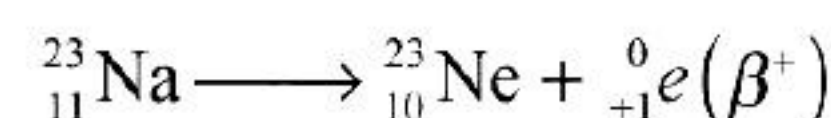
$$\lambda = \frac{1}{T_1 - T_2} \ln \frac{C_1}{C_2} \Rightarrow T_1 - T_2 = \frac{1}{\lambda} \ln \frac{C_1}{C_2}$$

The rate of decay is proportional to the concentration, it would be faster near the explosion as concentration of ${}^{14}\text{C}$ is more. Hence, the age of fossil will increase.

Answer (A)

10. Topic: Modes of Radioactive Decay

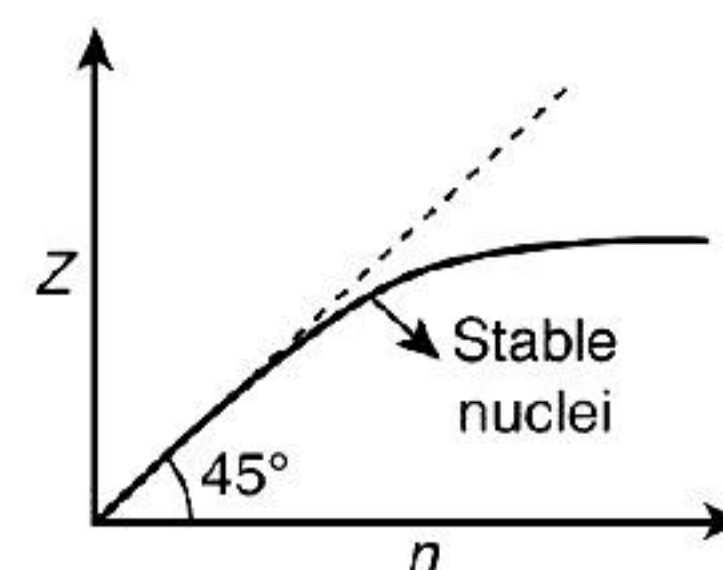
On positron emission from nucleus, proton converts into neutron therefore atomic number decreases by one but atomic mass remains constant.



Answer (C)

11. Topic: Nature of the Nucleus

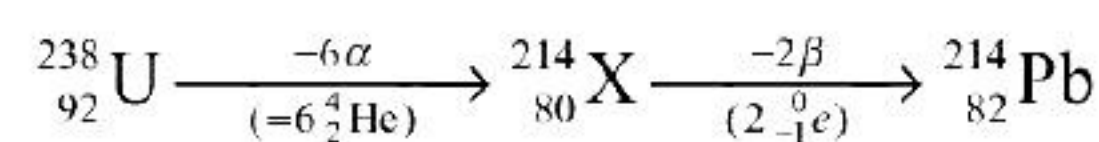
In the plot for number of atomic number (Z) versus number of neutrons (n), for heavier nuclides (i.e. for increasing value of n), proton-proton electrostatic repulsions begin to overcome attractive forces involving protons and neutrons. Hence, the plot shows a curvature towards the x -axis.



Answer (A)

12. Topic: Nuclear Reactions

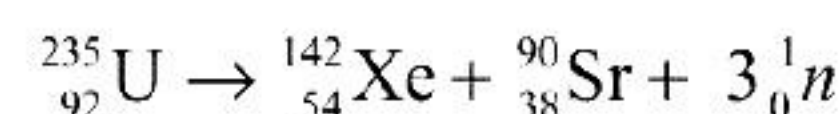
From the following reaction, we have that 6α and 2β particles are emitted which means a total of 8 particles are emitted.



Answer (8)

13. Topic: Nuclear Reactions

The nuclear fission reaction is

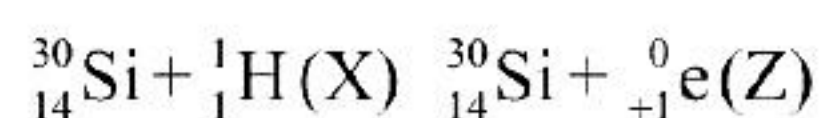
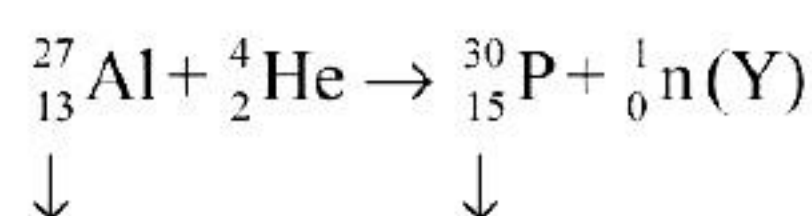


Thus, three neutrons are emitted in the reaction.

Answer (3)

14. Topic: Nuclear Reactions

In order to find X, Y, Z, we need to equate atomic number as well as mass number on both the sides.

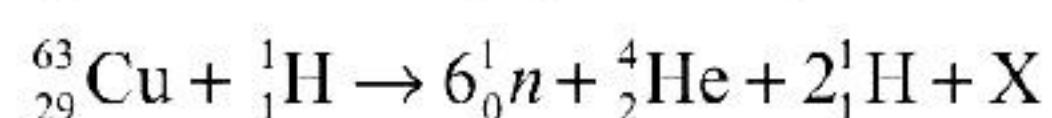


Thus **X** is a proton ${}_1^1\text{H}$; **Y** is a neutron ${}_0^1\text{n}$ and **Z** is a positron ${}_{+1}^0\text{e}$.

Answer (A)

15. Topic: Nuclear Reactions

Considering the reaction (replace α -particle by ${}_2^4\text{He}$)



Equating mass numbers on both the sides, we get

$$63 + 1 = 1 \times 6 + 4 \times 1 + 1 \times 2 + \text{X} = 64 - 12 = 52$$

Equating atomic numbers on both the sides, we get

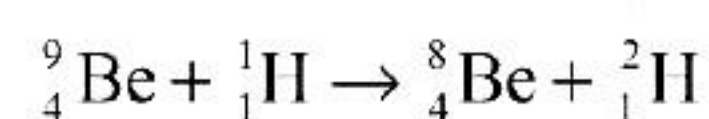
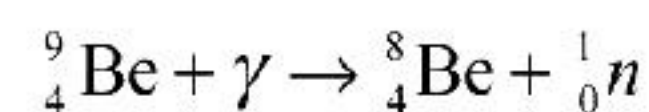
$$29 + 1 = 6 \times 0 + 2 + 2 \times 1 + \text{Y} \Rightarrow \text{Y} = 30 - 4 = 26$$

So, the element is ${}_{26}^{52}\text{Fe}$ and iron is a d -block element, which belongs to Group 8 of the periodic table.

Answer (8)

16. Topic: Nuclear Reactions

The reactions involved are



Answer (A), (B)

17. Topic: Nuclear Reactions

Let us consider

1 mol of air = X atm

During the reaction of ${}_{92}^{238}\text{U} \rightarrow {}_{82}^{206}\text{Pb}$, 8α -particles are released, that is, 8 mol of He particles are released during the reaction. Therefore, 9 mol of gas are present in the vessel.

Thus, total pressure is $X \times 9 = 9$ atm, that is, 9 times the original pressure.

Answer (9)